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Land Use Systems in Grassland Dominated Regions

Edited by

A. Lüscher
B. Jeangros
W. Kessler
O. Huguenin
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D. Suter

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Proceedings of the 20th General Meeting
of the European Grassland Federation
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Foreword

"Land Use Systems in Grassland Dominated Regions" was the stimulating theme of the 20th General Meeting of the European Grassland Federation. This topic was not solely tailored to Switzerland and the other countries in the Alpine zone, but also to all other European regions dominated by grassland. In such regions, grasslands are fundamental for agricultural production and landscape value, including the conservation of natural resources. Changes or losses of the basic functions of grassland can have dramatic impacts on regional developments in grassland areas. In adapting these functions, grassland farming faces tremendous challenges caused by economic, political and technical factors.

The emphasis of the conference was on five aspects. The first topic dealt with the difficulty in combining ecological and economic goals on a farm scale and at a regional level under given ecological conditions and agro-environmental policy regimes. The second was dedicated to the fact that grassland meets human needs through the services that it provides to society. This was shown by highlighting the benefits and potential risks of grassland systems. The third aspect concerned the efficient use of plant nutrients in soil-plant-animal systems in order to optimise grass growth and minimise environmental impacts. The fourth session concentrated on the relevance of forage quality for the quality and safety of dairy and meat products, and the last session was dedicated to the transfer of knowledge into agricultural practise.

With the support of the Swiss Agency for Development and Cooperation (SDC), Bern, young scientists mainly from Eastern Europe were given the opportunity to attend the conference. Offering additional events, particularly addressing young researchers made best use of the knowledge and experience gathered. Nearly 500 participants from some 40 countries attended the plenary, parallel and poster sessions, as well as master classes and technical excursions. In total they contributed some 440 voluntary and invited papers, and ensured the success of the Meeting.

We thank numerous people for their help that made the organisation of the meeting and the publishing of this book possible: the members of the Organising and Scientific Committees, the external reviewers and all the anglicisers. The invaluable help of Neville Millar, Irene Weyermann and Priska Gassmann, in dealing with correspondence from the authors, the correcting, formatting and proof reading of the manuscripts, is gratefully acknowledged. Thanks are also due to the numerous sponsors of the meeting for their financial support. This made it possible to keep the registration fee for the individual participant low.

The 20th General Meeting of the European Grassland Federation organised by the Swiss Grassland Society (AGFF) offered an important platform to all relevant disciplines related to the numerous functions of multifunctional grasslands in grassland dominated regions.

Paul Steffen

President of the European Grassland Federation

Contents

Poster presentations

Theme 4.2: From forage to animal performance 1061

Oral presentations

Poster presentations

Recent and future developments in the Common Agricultural Policy of the European Union

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Agricultural activity has been, is and will be of paramount importance for the Union's identity. In this context, the contribution of grassland, to which this conference is dedicated, to open rural landscapes and to the conservation of natural resources merits a special mention. A sustainable agricultural model requires a policy which is applied throughout the European territory and is economically and socially sustainable and environmentally friendly, market oriented and simpler despite the diversity of Europe's countries and regions. If this European Agricultural Model is to be preserved and prosper it must meet the expectations of society as a whole and must respond to challenges at the international level. There is no preservation without adaptation. Recent and future developments in the Common Agricultural Policy (CAP) have to be assessed against this background.

Apart from the reforms, which are further detailed below, the CAP is faced with an additional challenge, the smooth integration of the agricultural sectors of the New Member States into the CAP mechanisms. Enlargement brings a further 4 million farmers into Europe to join the 7 million who are already there. It is the great success of the enlargement negotiations that after a transitional period foreseeing the phasing in of direct payments, the CAP must be applied in exactly the same way in the whole European Union, there will be no 'two-speed CAP' after 2013.

In line with the above objectives a fundamental reform of the CAP was formally decided in September 2003; it is now in the process of being completed with a second package covering cotton, olive oil and tobacco. This reform, which mainly dealt with the first pillar of the CAP – market policies and direct aids – but which also led to a strengthening of rural development, will be complemented by a further proposal on the future of rural development policy to be adopted in the framework of the new financial perspectives (2007–2013). The Commission Communication 'Building our common Future' of 10 February 2004 on the 2007–2013 financial perspectives proposes the appropriate budgetary means for implementation of these reforms (≈ € 43 Billion/per year at 2004 prices for markets and direct payments, ≈ € 12 Billion/per year at 2004 prices for rural development) and gives some indications of the future orientation of rural development policy.

Key elements of the recent CAP reform which may also be of significance for grassland are the following:

- Introduction of a single farm payment scheme based on historical records and which is independent (i.e., 'decoupled') of production, with limited 'coupled' elements to ensure that agricultural production is not abandoned in certain areas;
- Possibility of regionalisation of the single farm payment scheme in order to allow a flexible response to specific situations;
- Respect for environmental, food safety, animal and plant health and animal welfare standards and the requirement to keep all farmland in good agricultural and environmental condition ('Cross-compliance') by linking the single farm payment scheme to the respect of these rules;

- Further strengthening of rural development policy through the introduction of new eligible measures to promote the environment, quality and animal welfare and the transfer of funds from the market sector to rural development policy through reductions in direct aid payments to bigger farms ('Modulation').

As regards future reforms, concrete proposals regarding the 'new' rural development policy after 2007 will be adopted by the Commission by mid 2004. However, already at this stage it can be assumed that implementation will be considerably simplified by the introduction of a single funding, programming, financial management and control system. Within the financial framework outlined above the Rural Development Policy after 2006 will be focussing on three main objectives:

- Increasing the competitiveness of the agricultural sector through support for restructuring (for instance investment aids for young farmers, information and promotion measures);
- Enhancing the environment and countryside through support for land management, including co-financing of rural development actions related to Natura 2000 nature protection sites (for instance agri-environment, forestry and Less Favoured Areas measures);
- Enhancing the quality of life in rural areas and promoting diversification of economic activities through measures targeting the farm sector and other rural actors (for instance village restoration).

In conclusion, thanks to these reforms farmers in the enlarged Europe have a clear planning framework for their business decisions until 2013, both from a financial point of view and as regards the content of policies to be pursued. Furthermore, reforming the CAP has enabled the European Union to prove its commitment to the reform of world agricultural trade, and to the creation of a freer, and fairer trade system between Europe and, in particular, the developing countries.

Keywords: Common Agricultural Policy, markets and direct payments, rural development policy, reforms

Swiss agricultural policy and its focus on grassland

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Abstract

In Switzerland, over 70 % of farmland is used as meadows and pastures. This explains why grassland-based dairy and cattle farming is such an important part of Swiss agriculture. Agricultural policy is therefore essentially orientated towards these sectors, and fosters the efficient use of grassland. Agricultural policy in general, is based on a constitutional mandate, laying down the principles of a multifunctional agricultural sector. Reforms over the last 12 years have led to a considerable shift from internationally criticized market support to direct payments not linked to production. Policy instruments in all categories (direct payments, market support, structural improvements, research and extension) are geared towards the optimal production, use and storage of roughage in the different production zones. Special mention must be made of the instruments in the direct payment category, which include direct payments for the husbandry of roughage consuming livestock and payments for animals grazing on alpine pastures in the summer. For all direct payments strict cross-compliance conditions apply. The whole range of well-balanced instruments ensures the relative competitiveness of roughage against concentrated feed. The fostering of grassland agriculture can also be advocated on the grounds of the three dimensions of sustainability. In economic terms, fresh grass is a relatively inexpensive animal feed. Ecologically, meadows and pastures offer the best protection from erosion and leaching. Furthermore, grassland-based agriculture is a mode of production that comes close to the ideal of a closed production cycle. In the social context, grassland agriculture is the type of farming most suited to the production conditions in the mountains and hills and can therefore contribute to settlement in these regions. Looking ahead, these reasons for supporting grassland agriculture in Switzerland will most probably retain their validity or become even more pertinent. In the context of an increasing world population, and considering that the available agricultural area is limited, there is also a growing ethical justification for using grassland as efficiently as possible. In addition, the price of concentrates can be expected to rise with the increasing demand for animal products in emerging economies. Our grassland-orientated agricultural policy comprises a set of well-balanced instruments targeted at making optimal use of prevailing natural conditions. During negotiations on international trade liberalisation, Switzerland actively defends a degree of national autonomy, which in substance allows the continuation of this policy for a multifunctional agricultural sector.

Keywords: Swiss agriculture, multifunctional agriculture, agricultural policy, policy instruments, grassland-orientated agricultural policy

1 General policy background

Switzerland is a mountainous country. Hills and mountains cover 70 % of its surface area, with the remaining area a central plateau of plains and large lakes. The climate is mainly temperate and moist, with regional extremes varying between Mediterranean and arctic. Accordingly, Swiss agriculture is, to a large extent, grassland-based, with 70 % of the farmland being used as meadows and pastures. Therefore, the main activities are grassland-based dairy and cattle farming.

Swiss agricultural policy is designed to give farmers optimal support in their use and maintenance of our grassland. It is based on a constitutional mandate, defining the principles of a sustainable and multifunctional agricultural sector. According to the constitution, agriculture must contribute to (a) the provision of the population with food, (b) the conservation of natural resources and upkeep of rural landscape as well as (c) the decentralised settlement of the territory.

Even before an overwhelming majority of the Swiss electorate voted in favour of this new constitutional article in 1996, agricultural policy reforms were initiated as a response to increasing international competition and environmental problems. The changes resulted in a dramatic shift away from the internationally criticised market support instruments and towards direct payments not linked to production. In 1990/92, 63 percent of the funds earmarked for agriculture were spent on market support. This dropped to 25 percent in 2001/2003. Over the same time period, the share of direct payments in the budget increased from 29 to 68 percent.

The reform has produced mainly positive results:

- Economic aspects: Despite increasing competition, market shares have been maintained. Average incomes remain considerably lower than those in other economic sectors. However, the most productive 25 % of the farms in the plains and hill regions have an income comparable to that in other sectors.
- Social aspects: Despite the difficult income situation, farmers are, in general, as satisfied with their standard of living and their job as people in other professions. This is probably related to the non-economic, positive aspects of the farming profession. In general, farms are given up when farmers reach retirement age.
- Ecological aspects: Ecological performance has increased considerably. The share of ecological compensation areas has risen from 20,000 ha in 1993 to more than 95,000 ha or 9 % of the utilised agricultural area in 2002. Today, there are almost 6000 organic farms as compared to 1200 in 1993. The number of animals kept in ‘animal-friendly’ stables has more than tripled over the same period, reaching 350,000 livestock units or more than 25 % of all livestock units. Environmental loads have diminished as well. For example, the N-surplus has decreased by 25 % since 1985, and the P-surplus by 55 % since 1990/92.

For details, refer to our annual agricultural reports (*www.blw.admin.ch*).

2 Grassland-orientated elements of Swiss agricultural policy

Policy instruments in all categories, i.e., direct payments, market support, structural improvements, research and extension, support farmers in optimally producing, storing and using roughage in the different production zones.

2.1 Direct payments

There are two distinct categories: general direct payments and ecological direct payments. General direct payments are made to remunerate farmers for the public services they provide, such as the conservation of natural resources and the upkeep of rural landscape. Ecological direct payments are made to compensate farmers for participating in voluntary schemes, for example, organic farming or animal welfare. All direct payments are contingent on the fulfilment of strict cross-compliance conditions such as the setting-aside of 7 % of the land as ecological compensation areas, the observance of nutrient balances, and regular crop rotation or periodical soil analysis.

There are two types of general direct payments available for the whole Swiss agricultural area: (a) general area payments, lower for grassland and higher for arable land and (b) direct payments for the husbandry of roughage consuming livestock. The latter payments are made per livestock unit, with the number of livestock units per hectare eligible for support depending on the production zone (fewer livestock units per eligible hectare in mountain zones). This payment is a key element in the strategy to support the use of grassland. In 2003, 14 percent of general direct payments were available for this instrument.

In the hill and mountain regions, additional animal- and area-based direct payments are made to compensate for the adverse production conditions – the animal-based payments are limited to 20 roughage consuming livestock units per farm and the land-based payments apply to steep terrain. Furthermore, special payments are available for roughage consuming animals, which are taken up to graze mountain pastures in the summer. The aim of these payments is to ensure the cultivation and upkeep of the extensive summering pastures in the Alps, hills and the Jura, which cover approximately 600,000 hectares. These payments are subject to special ecological conditions.

2.2 Market support

In the 'market support' category of instruments, two measures have to be highlighted from a grassland perspective. First of all, payments are made for milk processed into cheese, irrespective of whether this cheese is marketed on the domestic market or abroad. This payment ensures the competitiveness of cheese against fresh milk products, butter and milk powder all of which enjoy high border protection. Indirectly, the payment for milk processed into cheese is a key component of our grassland-orientated policy, as Swiss milk is produced by cows fed mainly on roughage. A second important element of the policy mix is border protection within WTO limits. The level of tariff-rates for concentrated feed determines the level of support for ensuring the relative competitiveness of roughage.

2.3 Structural improvements

Measures in the field of structural improvements also have a grassland dimension. In the mountains and hills, construction and renovation grants are only available for farm buildings used for the stabling of roughage consuming animals.

2.4 Research and extension

Last but not least, agricultural research in Switzerland has a strong grassland focus. For example, amongst other things, Agroscope FAL Reckenholz, the Swiss federal research station for agro-ecology and agriculture conducts research focused on forage production and grassland systems, the aim being to provide a scientific basis for the sustainable management of pastures and meadows and for efficient forage production. Consequently, swards that exhibit both a high yield and a high forage quality are promoted whilst concepts and methods are developed for preserving extensive pastures and hay meadows that are rich in plant and animal biodiversity and add to the beauty of the landscape. A wide range of seed mixtures are under research for temporary leys and for the renovation of permanent grassland. The species composition of the recommended grass-clover mixtures takes into account the different environmental conditions and the various kinds of forage utilisation. Working together with other research stations, milk and meat production methods are developed, which are based on efficient, environmentally sound and animal friendly grassland-ruminant systems. When it comes to transferring this knowledge to the farmers, extension plays a key role.

To sum up, all categories of the policy mix feature elements designed specifically to support the efficient production and use of grassland. These elements are mutually supportive and as a whole ensure the competitiveness of roughage against concentrated feed.

3 Sustainability as the rationale for supporting grassland farming

Let us now look more closely at the rationale for supporting our grassland-based system of agricultural production. What are the advantages of this system? We will try to answer this question from the sustainability perspective and address each of the three dimensions (economic, ecological and social).

3.1 Economic dimension

From the perspective of the individual farm, grass is, economically speaking, an interesting feed. Research contributes to this by making available resistant and high-yielding seeds specifically adapted to the climatic conditions of the various production zones. Studies show that grass is a relatively inexpensive feed when it is used directly from the field (without storage and conservation) (Gazzarin *et al*., 2003).

Grassland is also important from a macroeconomic perspective that goes beyond the scope of agriculture. It contributes to sustaining one of the key features of Swiss landscape, which, in turn, is an essential resource for the tourism industry, especially in the mountain regions. A study shows that when the Swiss spend their holidays in Switzerland, more than one third of their budget (or 2,3 billion Swiss francs) is spent on 'nature-orientated tourism' (Naturnaher Tourismus), i.e., a form of tourism, which, to a considerable extent, is based on landscape shaped by agriculture (Siegrist *et al*., 2002).

3.2 Ecological dimension

In terms of ecology, meadows and pastures offer several main advantages:
First of all, they offer the best protection from leaching. Under grassland, nitrate concentration in groundwater reaches levels of 1.9 mg NO_3-N l^{-1} under arable land, nitrate concentration in groundwater can be as high as 6.5 mg NO_3-N l^{-1} (BUWAL, 1990). On the other hand, grassland is less efficient than arable land when it comes to preventing the surface runoff of nutrients (phosphorus and nitrate) (Braun, 1991).

A second main advantage is the positive effect grassland has on erosion. As long as grassland is not grazed too intensively or subjected to excessive strain by heavy machinery at the wrong time, erosion on grassland remains negligible.

Thirdly, grassland-based cattle farming is a mode of production that comes close to the ideal of a closed production cycle. In many regions of Switzerland, only roughage (as opposed to concentrated feed) can be produced at the same place as where it is consumed. Less energy-intensive concentrated feed has to be produced and transported to the farms, which results in less emissions of greenhouse gases.

On the minus side, it must be mentioned that the consumption of grass by roughage consuming animals leads to relatively high N-losses in the form of ammonia. This problem is being addressed by research and presents a considerable challenge.

3.3 Social dimension

As a rule, remote areas of Switzerland are characterised by difficult topographic and climatic conditions. In these areas, grassland-based agriculture is the only viable mode of production. By providing support, the Confederation helps agriculture to fulfil one of its multifunctional roles, i.e., its contribution towards the settlement of these less favoured regions. In those mountain areas where tourism is of minor importance and which are too far from regional centres to be attractive for commuters, agriculture is still the main source of income.

4 Outlook and conclusions

We are convinced that Swiss agriculture's grassland orientation will remain a good choice in the future:

- Our grassland-based agriculture is the mode of production best suited to the prevailing natural (topographic and climatic) conditions.
- The agricultural area in this world is limited and the world population is on the rise. Although FAO projections up to 2030 suggest that world agricultural production can grow in line with demand, a persistently high share of the world's population will remain undernourished. In developing countries, cereal production is not expected to keep pace with demand. Furthermore, question marks remain with regards to the impact of land degradation on the productivity of existing farmland and the possibilities to increase yields (FAO, 2002). For all these reasons, the use of all agricultural land, including grassland, in an adequate form to produce food, can be defended on precautionary and ethical grounds.
- Diets in developing countries are changing as income increases. The share of staples, such as cereals, roots and tubers, is declining while that of meat, dairy products and oil crops is rising (FAO, 2002). With rising demand for animal products, it can be expected that the price of concentrates will increase, making the use of roughage for feed more attractive economically (OECD, 2002).

On these grounds, we firmly believe in the pertinence of our policy framework, which supports an agricultural system in line with the principles of sustainability. It has been shown that our policy comprises a set of well-balanced instruments targeted at making optimal use of prevailing natural conditions. This, of course, does not mean that our policy mix can remain as it is forever. There are far too many changes taking place in the international and national environment., Allow me for example, to mention the WTO-Doha Round negotiations at the international level and the increasing budgetary constraints at the national level. Whenever one element changes, be it for external or internal reasons, the other instruments must be modified accordingly, to ensure that the system remains in equilibrium. However, irrespective of such changes, our goal is to safeguard the key features of the system, i.e., a relatively small number of policy instruments which are, however, very well differentiated according to the various production conditions of our country. In the negotiations on international trade liberalisation, Switzerland actively defends a degree of national autonomy, which allows the continuation of this policy for a sustainable agricultural sector that can fulfil its multifunctional tasks.

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Multi-functionality of grassland systems in Switzerland

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Abstract

Variations in natural and anthropogenic factors have favoured, in Switzerland, the development of numerous and varied types of grasslands and a high biodiversity. Grassland is used mainly by dairy cows, with milk production contributing by 40-45 % to the gross income of the Swiss agriculture. This paper describes main research results and practical experiences, which have shaped most grassland systems in Switzerland. These systems can be characterized as follows: i) the management intensity is adapted to local conditions to promote a stable botanical composition with 10-30 % legumes (30-50 % in leys), ii) plant nutrients cycles are balanced and farm manure is the main fertiliser, iii) a high proportion of animal production is derived from grass and forage grown on the own farm (concentrates play a minor role). In the future, while milk production will remain the best way to valorise grassland, multifunctionality will continue to be required. The efficiency of the dairy production has to be improved, by reducing labour and capital inputs as well as nitrogen losses. For mountain regions new systems must be developed to maintain there an open and diversified landscape.

Keywords: grassland management, fertilisation, legumes, grass quality, grazing, multi-functionality

1 Swiss grassland systems today

1.1 Natural growth conditions

Switzerland is a small country with a wide range of climatic, topographic and edaphic conditions. In many regions the climate and topography are unsuitable for arable crops and the landscape is dominated by grassland. On the north side of the Alps the catchment effect of the alpine chain ensures a relatively even rainfall distribution throughout the year (windward side). In lowland regions, with mild winter temperatures, the climatic conditions are very favourable for grass growth. Even on permanent grassland, the annual dry matter production can reach 15 t DM ha^{-1} y^{-1}, as in the best grassland regions of north-western Europe.

Table 1. Area covered in 2001 by permanent grassland in Switzerland in comparison to some European countries (FAO, 2004).

Country	Total area (a) (1,000 ha)	Agricultural area (b) (1,000 ha)	Permanent grassland (1,000 ha)	Permanent grassland (% of a)	Permanent grassland (% of b)
Switzerland	4,129	1,580[1]	1,144[1]	28[1]	72[1]
	4,129	1,071[2]	627[2]	15[2]	59[2]
Austria	8,386	3,390	1,920	23	57
France	55,150	29,631	10,046	18	34
Italy	30,134	15,355	4,379	15	29
Germany	35,703	17,033	5,013	14	29
Ireland	7,027	4,399	3,350	48	76
United Kingdom	24,291	16,954	11,251	46	66
Netherlands	4,153	1,931	993	24	51

[1]included productive alpine pastures; [2]without alpine pastures

Nevertheless, the natural conditions are not as favourable in all regions of Switzerland. In the western and southern lowlands insufficient rainfall in summer limits grass growth and arable crops occupy large areas. In the highlands, pastures and meadows dominate, but low temperatures and a difficult topography reduce the potential for grass production. Above 1,400 m, grazing is often the only possible utilisation.

Due to the natural conditions, there is no agricultural alternative to forage production in many regions of Switzerland. Permanent grassland covers about 59 % of the agricultural area, a relatively high proportion compared to other European countries (Table 1). Adding alpine pastures (600,000 ha) and leys (119,000 ha), the surface occupied by agriculturally used grassland covers about one third of the country area.

1.2 Main types of meadows and pastures

Variations in natural and anthropogenic factors have favoured the development of numerous and varied types of grasslands and a high biodiversity. In Switzerland, the management intensity is used as the first criterion to classify meadows and pastures (Table 2). A high utilisation frequency and a high fertilisation rate promote intensive grassland composed of relatively few species (less than 20). In the mild and humid valley regions of central and northern Switzerland, frequent mowing (5 to 6 cuts per year) and a high nutrient supply with liquid manure lead to a high proportion of Italian ryegrass (*Lolium multiflorum*) in the permanent meadows. With a similar management intensity but with grazing as the main utilisation, perennial ryegrass (*Lolium perenne*) replaces Italian ryegrass. When the climate is less favourable, at higher altitudes for example, ryegrasses are often replaced by meadow foxtail (*Alopecurus pratensis*) in meadows and by smooth meadow grass (*Poa pratensis*) in pastures. White clover (*Trifolium repens*) is the main legume in intensive grassland. Fairly intensive grassland is managed at a somewhat lower intensity, with a first cut following the emergence of the grass inflorescences. There are between 20 and 30 species and typical grasses are cocksfoot (*Dactylis glomerata*), meadow foxtail and meadow fescue (*Festuca pratensis*). Legumes may be rare in this type of grassland and forbs can reach 50 % or more, particularly at higher altitudes. Cow parsley (*Anthriscus sylvestris*) and cow parsnip (*Heracleum sphondylium*) are two typical forbs of fairly intensive meadows, when the fertiliser supply is excessive in relation to the cutting frequency.

Low intensive grassland and extensive grassland are used only one to three times per year, the first cut occurring late, during or after the flowering of the main grasses. Such grassland receives only small quantities of solid manure or PK fertilisers or no fertilisers at all (extensive grassland). At this lower management intensity, soil and climate have a greater effect on botanical composition as compared to more intensive grassland. The number of

Table 2. The main types of grassland in Switzerland according to the management intensity.

Management intensity	Utilisation frequency	Stage at the 1st cut[1]	Fertilisation rate	Main grasses
Intensive	high	before heading	high	*Lolium multiflorum*, *Lolium perenne*, *Poa pratensis*, *Alopecurus pratensis*, *Poa trivialis*
Fairly intensive	intermediate	after heading	intermediate	*Dactylis glomerata*, *Alopecurus pratensis*, *Festuca pratensis*, *Poa trivialis*, *Holcus lanatus*
Low intensive	low	flowering	low	*Arrhenatherum elatius*, *Tristetum flavescens*, *Holcus lanatus*, *Cynosurus cristatus*, *Festuca rubra*
Extensive	very low	after flowering	nil	*Bromus erectus*, *Briza media*, *Agrostis capillaris*, *Nardus stricta* and other grass species

[1]phenological development of the main grasses

plant species lies clearly over 30 and the highest floristic diversity (> 50 species), including rare species, is found in unfertilised dry sites (Dipner and Madel-Kubik, 2004). Low intensive grassland and extensive grassland occur on most Swiss farms as they are recognized as ‘Ecological Compensation Areas’ (ECA). Under the Swiss agricultural policy (Bötsch, 2004), ECA must represent at least 7 % of each farm area (this is one of the conditions for getting direct payments). Indeed about 100,000 ha of the Swiss agricultural area (9 %) were used in 2003 as low intensive or extensive grassland (BLW, 2003).

1.3 Production systems based on grassland

Swiss farms are small (< 20 ha) and three quarters of them have livestock. Dairy production dominates in Switzerland (720,000 cows in 2001, mostly dairy cows) and contributes by 40-45 % to the gross income of the Swiss agriculture. Over 50 % of the Swiss dairy farms have less than 20 cows and only 3 % have more than 50 cows (BLW, 2003). Many farms with cattle have also pigs (44 %). On these intensive dairy farms, mainly located in the central and eastern lowland regions, the input of nitrogen (N) and phosphorus (P), via purchased feeds and fertilisers, often exceeded the output via animal products. Since the introduction of an annual budget for N and P in 1993 (see below), this imbalance and consequently the nutrient losses to the environment (responsible for lake pollution) were reduced. However, a mean extra supply of 84 kg N ha^{-1} y^{-1}, via purchased feed for pigs, is still available for these farms, allowing a 17 % higher milk production as compared to farms without pigs (Thomet and Pitt, 1997).

Today 75 % of the milk produced in Switzerland comes from grass grown on the farm (Lehmann, 1998) and only small quantities of concentrates, which are about 3 times more expensive than in neighbouring countries, are used (approximately 500 kg cow^{-1} y^{-1}). This is a distinctive feature compared to most European countries, which produce milk with much more concentrates. In Switzerland 55 % of the milk is produced in regions with silage feeding during the winter (increasing proportion). 45 % of the milk is used for cheese production (with raw milk) and therefore without silage. Organic farms supply an increasing proportion of milk in Switzerland (8 % in 2003).

The costs of dairy production are distinctly higher in Switzerland than in other European countries (Gazzarin, 2002). During the vegetation period, dairy cows were traditionally partly fed indoors with fresh grass, but today full grazing plays an increasing role. On the other hand, systems based on total mixed ration for high performance cows have also gained in importance.

Non-dairy productions are clearly less developed in Switzerland than milk production. Beef production on grassland is still unusual. The number of sheep and horses is slightly increasing, but remains relatively low (in 2001, 420,000 and 50,000 heads respectively). Non-dairy productions are particularly important in the mountain regions where they contribute to the maintenance of an open and diversified landscape.

Over the last decades, many actors (researchers, advisers, teachers, farmers) have worked together to improve the Swiss grassland systems. The Swiss Grassland Society has played a major role in this process and has given recommendations, which are summarized as follows (ADCF, 1991):

i) the intensity of grassland management must be adapted to the local conditions in order to promote a stable botanical composition,

ii) the plant nutrients cycles should be balanced and farm manure should be used as main fertiliser on grassland,

iii) a high proportion of animal production should be derived from grass and forage grown on the own farm.

Research results and practical experiences, which support these recommendations and shape most current grassland systems in Switzerland, are presented in the next section.

2 Some important results of research and development

2.1 Moderate fertilisation rates of meadows and pastures

Numerous experiments have been carried out on different types of grassland to study the long-term effects of fertilisation on the botanical composition, the DM-yield and the forage quality (Thomet *et al.*, 1989; Jeangros, 1993; Jeangros *et al.*, 1994; Jeangros and Scehovic, 1996; Philipp *et al.*, 2004). These experiments showed that excessive N fertilisation can favour undesired forbs, particularly when the climate is unsuitable for grasses as in the highlands (Table 3). Over the long-term this negative evolution of the botanical composition

Table 3. Effect of mineral N fertilisation (150 kg N ha^{-1} y^{-1}; 2 cuts y^{-1}) on the botanical composition of previously low intensive permanent grassland (Thomet *et al.*, 1989).

Site	Altitude (m asl)	Rainfall (mm y^{-1})		Grasses (%)	Forbs (%)	Legumes (%)
Wildhaus (SG)	1,140	1,700	before (1983)	42	48	10
			after (1987)	16	84	+
Klosters (GR)	1,120	1,300	before (1983)	45	51	4
			after (1987)	40	60	+

reduces the sward density, the DM-yield and the forage quality. To promote a stable botanical composition with about 50-70 % grasses, 10-30 % legumes and 10-30 % forbs (the forbs proportion is often higher in the highlands) and to avoid most weed problems, the nutrient supply must be adapted to the local conditions (soil and climate) and to the utilisation frequency. In any case the fertilisation rate must not exceed the plant nutrient uptake. Guide values, indicating the recommended N, P and K (potassium) supply for each type of meadow and pasture, are available (Table 4). In comparison to many European countries, the recommended fertilisers supplies are relatively low in Switzerland, particularly for nitrogen. Intensive grassland producing 12.5 t DM y^{-1} and cut 5 times requires for example only 150 kg N ha^{-1}, included N in manure. The N requirement of temporary grassland dominated by legumes is even lower. These low rates of N fertilisation are compensated by relatively high proportions of N fixing legumes.

Table 4. Plant nutrients requirement of the different types of grassland (Ryser *et al.*, 2001).

Utilisation mode	Management intensity[1]	Nutrients requirement		
		N (kg ha^{-1} utilisation^{-1})	P (kg t^{-1} DM)	K (kg t^{-1} DM)
Cutting	intensive	30	3.5	19.9
	fairly intensive	25	3.1	15.8
	low intensive	15	2.6	12.5
	extensive	0	0	0
Grazing	intensive	20	2.3/1.6[2]	8.8/2.7[2]
	fairly intensive	15	2.1/1.4[2]	6.6/2.0[2]
	low intensive	0	1.7	3.3
	extensive	0	0	0

[1] see table 2; [2] first value for partial grazing/second value for full grazing

Since 1993, these guide values are also used in Swiss agricultural policy. Direct payments are only given to farmers that attain, among numerous requirements, N and P balance for the entire farm. The total N and P requirements of grassland and arable crops are compared to the amount of nutrients available in the farm manure and the purchased fertilisers (Übersax and Schüpbach, 2004). Available nutrients must not exceed requirements by more than 10 %. The new policy has clearly sharpened the farmer's attitude towards an efficient use of farm manure and has decreased the use of mineral fertilisers. Swiss grassland receives on average less than 50 kg mineral N ha^{-1} y^{-1}.

As most grass nutrients absorbed by ruminants are excreted, a large proportion of grassland requirements can be covered with the nutrients contained in manure. In Switzerland manure supplies about three quarters of N and P used to fertilise grassland and arable crops (Jarvis and Menzi, 2004). For a better use of organic fertilisers, guide values indicating the nutrients contained in livestock excreta as well as in slurry and manure were developed (Ryser *et al.*, 2001). Today, an important challenge for grassland fertilisation is to increase the utilisation efficiency of N in manure. Several studies are dealing with the reduction of N losses, particularly of NH_3-losses, agriculture accounting for about 90 % of NH_3-emissions in Switzerland (Jarvis and Menzi, 2004).

2.2 Grass-legume mixtures for leys

In Switzerland, leys occupy 119,000 ha, i.e., 11 % of the agricultural area, and play a major role in crop rotation. In mixed farms, the forage grown on temporary grassland is mainly used for dairy cow's feeding. These leys are usually sown for two or three years and always contain legumes. As compared to pure grass stands grass-legume mixtures present several advantages (Lehmann and Meister, 1985; Charles and Lehmann, 1989; Mosimann, 1993; Mosimann and Charles, 1996). Their fertiliser N requirement is markedly lower due to symbiotic N_2 fixation, which can exceed 200 kg N ha^{-1} y^{-1} in the lowlands (Boller and Nösberger, 1987; Jorgensen and Ledgard, 1997; Boller *et al.*, 2003). The legumes ensure a higher and more stable nutritive value and favour a better forage intake (Lehmann and Schneeberger, 1988). Leys composed of many species belonging to two different plant families enhance the biological diversity on the agricultural area.

The first list of recommended mixtures was published in 1955. Today this list comprises 31 mixtures suited to different leys duration, forage utilisation, climatic conditions and management intensity (Lehmann *et al.*, 2000). White clover, red clover (*T. pratense*) and lucerne (*Medicago sativa*) often represent 30 to 50 % of the forage. The main grasses are ryegrasses, cocksfoot, timothy (*Phleum pratense*), fescues (*F. pratensis*, *F. rubra*) and smooth meadow grass. The composition of each mixture aims to reach an adequate balance between grasses and legumes (Table 5). The seeding rate of each species is based on its specific characteristics, particularly on its competitive ability (Mosimann and Charles, 1996). Moreover, each mixture is tested under practical conditions before being recommended (Kessler and Lehmann, 1998).

Most mixtures were developed for an intensive or a fairly intensive management. Since 1993 grass-legume mixtures are available to create traditional hay meadows adapted to a low intensive or an extensive management. Seeds of indigenous ecotypes are available for about 40 different forbs species and a set of wild flowers can be added to these specific grass-legume mixtures to get a high floristic diversity.

The success of these mixtures relies not only on their specific composition, but also on the use of adapted varieties. The value of available varieties is periodically assessed under Swiss conditions. A list of recommended varieties was published for the first time in 1969 and is updated every two years. Swiss varieties are well represented on the present list (24 % of the varieties; Mosimann *et al.*, 2002).

Table 5. Species composition (kg ha^{-1}) of some recommended grass-legume mixtures (Lehmann *et al.*, 2000).

Mixture number		200	300	323	330	440	450
Duration (years)		2	3	3	3	> 3	> 3
Management intensity[1]		intensive	fairly int.	fairly int.	intensive	intensive	low int.
Red clover	*T. pratense*	15	5	2	2	1	
White clover	*T. repens*				4	3	1
Lucerne	*M. sativa*			15			
Birdsfoot	*L. corniculatus*						2
Italian ryegrass	*L. multiflorum*	20					
Hybrid ryegrass	*L. hybridum*		6				
Perennial ryegrass	*L. perenne*				7	10	
Cocksfoot	*D. glomerata*		6	6	5.5		2
Meadow fescue	*F. pratensis*		10	12	12		10
Timothy	*P. pratense*		3	3	2.5	3	
Smooth meadow grass	*P. pratensis*					10	2
Red fescue	*F. rubra*					5	8
Tall oat grass	*A. elatius*						4
Yellow oat grass	*T. flavescens*						3
Upright brome	*B. erectus*						2
	Total	35	30	38	33	32	34

[1] see table 2.

The development and the marketing of valuable mixtures require a good collaboration between research, advisory offices and commercial firms. In Switzerland, most mixtures bought by farmers have a quality label, which is granted by the Swiss Grassland Society. Introduced in 1975, this quality label certifies that the mixture includes only recommended varieties and that its composition corresponds to a recommended recipe. This label, voluntarily accepted by the commercial firms and recognized by the farmers, contributes in a decisive manner to the success of the Swiss grass-legume mixtures.

2.3 Milk production based on high-quality grass

A cow requires a grass rich in energy to produce more than 6,000 kg milk annually with about 500 kg concentrates. Several studies have been carried out in Switzerland to assess the nutritive value of the main plant species occurring in grassland. Not only grasses, but also legumes and forbs were investigated. The quality of the forage harvested or grazed on grassland with a more or less diversified botanical composition was also analysed (Meister and Lehmann, 1988; Daccord, 1988; Scehovic, 1988; Thomet *et al.*, 1990; Daccord and Arrigo, 1992; Daccord *et al.*, 2002; Jeangros *et al.*, 2002a). These studies highlighted that legumes and some forbs, such as *Taraxacum officinale* and *Heracleum sphondylium*, have a very good nutritive value (low fibre, high protein and mineral contents). Unfortunately some forbs, *Geranium sylvaticum* and *Alchemilla vulgaris* for example, contain a lot of secondary compounds, which inhibit the activity of microbes in the rumen (Scehovic, 1995a, 1995b and 2001). Depending on their proportion in the sward, these forbs can reduce the digestibility and the palatability of the forage.

Nevertheless the age of the plants at the time of cutting or grazing is the main factor influencing their nutritive value. An early utilisation is necessary to obtain a grass suited to the high requirements of dairy cows. This age effect is less pronounced for legumes than for grasses (Figure 1). The presence of the former in the sward increases flexibility in the grass utilisation. Guide values (Daccord *et al.*, 1999), based on sward type (4 main types depending on the proportion of grasses, legumes and forbs), sward age and utilisation mode (fresh, ensiled or dried grass), are used by advisers and farmers to estimate the grass nutritive value.

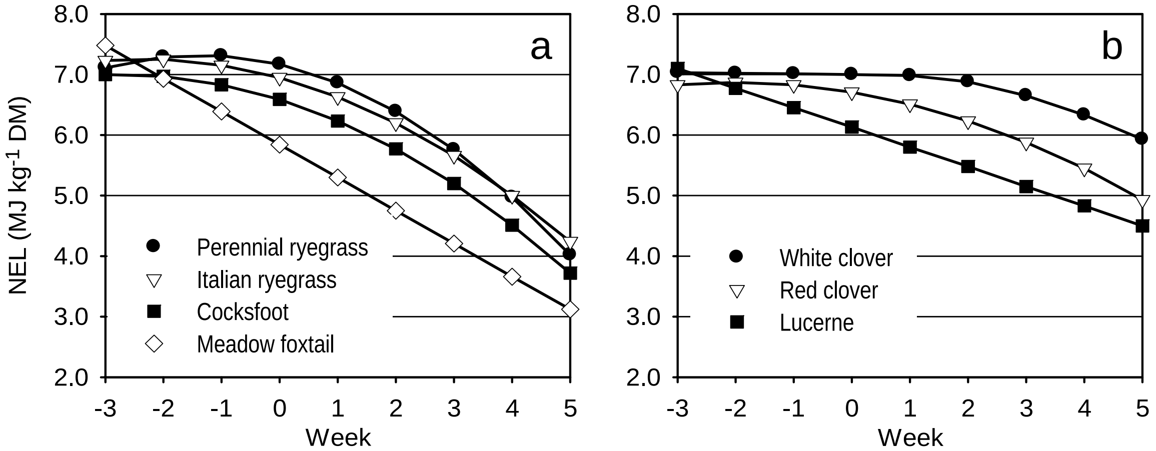

Figure 1. Evolution of the net energy content for milk production (NEL) of some grasses (a) and legumes (b) during the 1st cycle (week 0 = beginning of heading of cocksfoot; Daccord *et al.*, 2002).

In most cases these guide values allow an accurate estimation of the milk production potential of grass, a prerequisite for an optimal use of grass in dairy cow's diet. The potential for milk production of Swiss grassland ranges from 4,000 to 14,000 kg ha^{-1} y^{-1} depending on altitude and grassland type (Kessler and Stutz, 2000).

Table 6. Mean value for some relevant grass, milk and cheese characteristics on four production sites located at different altitudes (modified from Jeangros *et al.*, 2002b).

Production site		L'Etivaz 1 (VD)	L'Etivaz 2 (VD)	Montbovon (FR)	Posieux (FR)
Altitude	(m asl)	1400-1900	1300-2100	900-1250	600-650
Pasture sward					
Floristic diversity[1]	(Shannon index)	4.2	4.5	4.1	2.1
Number of plant families[1]		17	19	18	2
Forbs	(%)	43	43	27	0
Grass					
Crude protein	(g kg^{-1} DM)	152	167	139	206
OMD[2]	(%)	72	74	69	73
IANP[3]	(index)	127	141	93	73
Milk					
Fat	(g kg^{-1})	337		328	332
C18:2 c9t11[4]	(g 100 g^{-1} fat)	2.18		1.50	0.81
Cheese					
α-Pinene	(a.u.)	2,110	1,330	590	n.d.
β-Pinene	(a.u.)	3,280	1,100	194	n.d.
p-Cymene	(a.u.)	170	95	94	n.d.
Limonene	(a.u.)	235	197	84	n.d.

[1]mean value per botanical relevé; [2]digestibility of organic matter; [3]activity of secondary metabolites (Scehovic, 1995a); [4]C18:2 cis 9 trans 11 linoleic acid (CLA); a.u. arbitrary unit; n.d. non detected

For the winter period, which can last up to 7 months in the highlands, important quantities of forage have to be conserved. Barn drying is frequent in Switzerland: 44,800 installations for

79,500 farms (i.e., 56 %) in 1996. As compared to field drying, barn drying ensures a better forage quality, as the grass can be cut earlier and more efficiently (less losses).

About ten years ago a study was initiated in Switzerland to investigate the relationship between the composition of pastures grazed by dairy cows and the milk and cheese characteristics. Four sites located at different altitudes were compared. Milk and cheese produced on highland pastures had a different chemical composition as compared to milk and cheese coming from lowland grass (Table 6). Differences in fatty acids (milk) and terpenoids (cheese) content can be partly explained by differences in the botanical and chemical composition of grass.

2.4 Increasing role of grazing in dairy systems

Recently the costs involved in the Swiss dairy systems have been intensively investigated and the main factors responsible for our high-cost system have been identified: high structural and labour costs (small average farm size), high feeding costs, high level of farm owned mechanisation. Swiss milk producers must drastically reduce their production costs to compete in a new liberalised environment. A comparison of the actual feeding costs on typical Swiss dairy farms confirmed that grazed grass is by far the cheapest feed. Hay and grass silage are 3 times more expensive. The common feature of profitable dairy systems is the use of large amounts of low cost feed. One approach to improve the competitive ability of the dairy production is therefore to promote grazing.

A maximum utilisation of grazed grass can be achieved with a seasonal production system, which synchronises cow's feed requirements with pasture growth. This strategy was implemented and consistently optimised on three experimental (Table 7) and nine pilot farms (Durgiai and Müller, 2004). The aim was to focus more on the achievement of high yields per hectare and high feed conversion efficiency than on high yields per cow. The results are promising. Grazed grass represented more than 60 % of the annual feed consumption by the herd and relatively small quantities of silage, hay and concentrates were necessary. Under favourable growing conditions, an annual yield of 10 to 13 t DM ha^{-1} and a milk output of 11,100 to 14,500 kg ECM ha^{-1} from grassland has been achieved, despite relatively low individual performance (Table 7). The overall feed conversion efficiency, including silage and hay for the winter feeding, was about 1.2 kg ECM kg^{-1} DM. Output of milk has been increased by using high stocking rates to ensure a large proportion of the available grass to be consumed by high merit lactating cows. The performance and feed conversion efficiency of the individual cow decreased but a higher overall efficiency of the system was achieved.

Table 7. High productivity of seasonal dairy production systems based on grazed grass (Thomet and Münger, personal communication).

Experimental site Years	Burgrain (LU) 2002-2003	Waldhof (BE) 2001-2003	Posieux (FR) 2000-2003
Total grass yield (t DM ha^{-1} y^{-1})	13.0	12.2	11.5
Grass silage or hay (t DM ha^{-1} y^{-1})	4.0	3.7	3.5
Overall stocking rate (cows ha^{-1})	2.46	2.32	1.95
Concentrates (kg cow^{-1} y^{-1})	154	371	450
Fodder beet or potatoes (kg DM cow^{-1} y^{-1})	146	94	150
Individual milk yield (kg ECM cow^{-1} y^{-1})	5,835	7,066	6,875
Total milk yield (kg ECM ha^{-1} y^{-1})	14,232	16,393	13,400
Milk yield only from grass (kg ECM ha^{-1} y^{-1})	13,258	14,339	11,130

The genetic merit of cows is increasing in Europe and America, where cows are often individually managed and maize/concentrates diets optimised to reach a high milk output per cow. The resulting larger cows, with a pronounced milk character, may not perform well under a low input grassland system. For this reason, a trial was implemented in 2002 to compare the productivity of large and small cows of Swiss dairy breeds in a seasonal production system based on grazed grass (Steiger Burgos *et al.*, 2004). Early results indicate that the intake capacity of the herd with large cows might be somewhat lower and the productivity per hectare therefore slightly reduced as compared to the herd with small cows.

Other studies compared the continuous and rotational grazing systems under high and regular rainfall (Thomet *et al.*, 2000; Münger and Jans, 2002). Only small differences in productivity in favour of the rotational system were observed. Ten years ago, most dairy farmers practised a rotational system. Today, many farmers have changed to continuous grazing, due to the positive experiences of pioneer farmers with set stocking (less labour, quiet cows and high sward density).

2.5 Grassland as ecological resource

The most valuable landscapes in Switzerland are the result of farming systems based on various types of grassland management (Schüpbach *et al*., 2004). Open and diversified landscapes are particularly important in the mountain regions where tourism represents the main economical activity. As in many other countries, the management of grassland has been intensified in Switzerland over the last 50 years to satisfy the increasing requirements of ruminants, especially of dairy cows. Nevertheless, the intensification was often limited by natural factors and some people soon realised that some of the techniques developed by modern grassland management had a negative impact on environment and landscape. Therefore the area covered by permanent grassland has remained high (Table 1). In this context an extensive research project was initiated twenty years ago to study the ecological and agricultural value of permanent meadows with a diversified flora. This study showed that species-rich meadows (> 40 species) were never fertilised or received only small amounts of fertilisers and were always cut late, allowing many plant species to form seeds. Consequently these meadows produce little hay with a low nutritive value (Jeangros and Schmid, 1991). Such forage cannot therefore be used efficiently in rations for lactating dairy cows.

These results emphasized the dilemma for the management of meadows: milk production based on grass or nature conservation? The concept of the graded management intensity was developed as a solution to integrate both objectives of dairy production and nature conservation (Nösberger *et al.*, 1994). On each farm grassland is managed at different intensities according to the site-specific conditions. Intensive and fairly intensive grassland (Table 2) are necessary to produce grass with a high nutritive value. This type of grassland, which represents a major part of the total grassland area, helps to reduce the purchase of concentrates and therefore the imbalance between nutrients inputs and outputs on the farm level. On low intensive and extensive grassland diversity of flora and fauna is the priority. On dairy farms this type of grassland cannot cover more than 10 to 20 % of the grassland area, otherwise excessive amounts of concentrates would be necessary for the cow's feeding. For the last 10 years, the Swiss society has recognized the benefits for the environment of an extensive grassland management and is ready to support it financially.

The ecological value of extensive and low intensive meadows was investigated in a national survey (Dreier *et al.*, 2002). Only 25 % of the observed meadows revealed a satisfying ecological value and only 7 % had a botanical composition corresponding to the expected vegetation. In hay meadows most plant species come from the previous intensive management. The situation is better for litter meadows, which present higher diversity.

Experiments have been carried out since 1990 to study the effects of reduced management intensity on the plant species diversity of previously intensively managed meadows. A strong reduction of fertiliser applications and of cutting frequency sometimes enhances the floristic diversity (Jeangros and Bertola, 2002), but in many cases the expected botanical changes didn't occur (Koch and Masé, 2001). These results confirm that existing meadows with a high botanical diversity should be preserved. At present many conservation programs exist in Switzerland, for example for meadows located in dry sites (Dipner and Madel-Kubik, 2004).

If some regions are confronted with problems related to an intensive grassland management, some mountain areas in Switzerland are faced with management abandonment due to the decrease of agricultural population and livestock. From 1983/85 to 1993/95, the surface covered by forest increases by 4 % (47,000 ha) on the whole country and by 7 % (38,000 ha) in the Alps (WSL, 2001), mostly to the detriment of grassland. In the future, the emergence of fallow land will be a regional and site-specific problem at high altitudes (Gotsch *et al.*, 2004). The effects of changes in land use practice are currently being investigated in Swiss mountain regions. Changes were recognized, but it is not clear whether man-made biodiversity is really endangered in the Swiss Alps (Peter *et al.*, 2004; Fischer *et al.*, 2004; Körner *et al.*, 2004).

New extensive land use systems are required for mountain regions. Experiments on sustainable grazing systems for mountain pastures showed that an extensive use (low stocking rate, no fertilisation) with crossbred steers is an interesting alternative to abandoning these areas (Troxler and Chassot, 2004). Recent studies in alpine areas grazed by sheep revealed that electric fences allow a better utilisation of the grass in the lower parts of the pasture and a better preservation of species-rich swards located at high altitudes (Troxler *et al.*, 2004).

3 Perspectives and challenges for the future

On the whole, Swiss farmers follow most recommendations of the Swiss Grassland Society. Milk is produced essentially from 'on farm' grown resources, mainly grassland, and only small amounts of concentrates are used. The quality of the products is high and the objectives of nature conservation are taken into account. But some problems can be pointed out. The production costs are high leading to low economical sustainability. The efficiency of the production systems has to be improved, mainly in term of reduced labour and capital inputs (machinery and buildings). The ecological standard for N and P management is quite high, but further efforts are necessary to improve the recycling of manure and to increase the fertilising efficiency of organic N. Moreover, the ecological value of extensified grassland is often not satisfying.

Because grassland systems have to create a rural environment that does much more than just produce food, multi-functionality will continue to be required (Bötsch, 2004). The collaboration between agriculture and nature conservation should be preserved and precise ecological aims have to be set for extensive and low intensive grassland, taking into account all components of the agro-ecosystem. The Swiss government supports this view and the agricultural policy has been recently completed. Subsidies are now available for 'regional ecological networks' with clear ecological aims. On the other hand extensive and low intensive meadows with a diversified flora are now better subsidised. In the future animal welfare has to be better taken into account and a better marketing for grassland products aimed at the urban population will be essential. The quality and specificity ('typicality') of food products based on grassland (milk, cheese and meat) should be better investigated, improved and explained to the consumers, without forgetting non-food grassland products (biodiversity, open landscape, water quality, etc.). Swiss farmers will continue to require financial support and only an informed and convinced urban population will be ready to do so. The challenge is to find a production system compatible with the expectations of the non-agricultural population. In this sense the Swiss grassland system can serve as a pioneer model for other countries, where striving for long-term sustainability is essential.

Grazing will gain in importance in dairy production. An approach taking into account social, ethical and environmental aspects showed that full-time grazing is more sustainable under Swiss conditions than systems with a high proportion of indoor feeding (Gazzarin *et al.*, 2004). For Durgiai and Müller (2004), 'Low Cost' dairy production systems based on grazing can help to reach a good overall level of sustainability. In those systems the challenge will be to optimise the use of the variable amounts of grass grown on pastures throughout the season. Grazing management tools, adapted to Swiss conditions and easily used by the farmers, have to be developed. The question of the optimal characteristics for dairy cows fed on pastures remains open and requires further investigation.

Milk production still appears to be the best way to valorise meadows and pastures. But new alternative systems will be necessary to maintain an open and diversified landscape in the mountain regions. An integrated approach is required to maintain a sustainable grassland management in most Swiss regions. Such an approach offers challenges at the scientific, technical and political level and needs a further strong cooperation between all involved actors (Nösberger, 1994).

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Institutional arrangements for the agri-environment: objectives, local conditions and institutional choices

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Abstract

There has been a significant redirection of the policy objectives set for the agricultural sector, away from production and towards environmental conservation. In this paper, we explain the context for this change of direction and review the ways in which policies and institutions have been and can be developed in order to respond to it. A variety of options is possible and the choice will depend on local conditions. Agri-environmental policies to date have often concentrated on relatively inflexible environmental contracts, but there is scope not only to improve the way in which these contracts are implemented but also to widen the range of approaches that are adopted. We explore the relevance of alternative institutional arrangements, drawing on the experience so far in the United Kingdom and Spain. Finally we speculate on some possible implications for grassland research.

Keywords: environmental goods, agri-environment schemes, organic farming, conservation trusts, UK, Spain

1 Agriculture, the environment and economic development

Economic development tends to alter the values of agricultural products relative to the value attached to the environment. At low levels of development, food consumption represents a major part of total expenditure and agricultural production comprises a major component of the economy. As economic development proceeds and incomes rise, consumers spend a smaller proportion of their income on food. But at the same time the introduction of new technology and the investment of capital into agriculture, in other words the modernisation of agriculture, increases its productive capacity. This increasing food supply, facing a relatively fixed demand tends to cause a downward pressure on agricultural prices. The position might in principle be addressed by shifting resources out of the agricultural sector, but typically resources in agriculture tend to be immobile and so farmers face downward pressure on their incomes.

The changes in agricultural activities have various implications for the environment. The modernisation of agriculture is associated with an increased use of chemical inputs, with mechanisation and an increased scale of operation. Land is ‘improved’ for agriculture, ponds and wetlands drained, pastures fertilised and reseeded, hedges and rough areas are removed to increase the space for commercial operations. Farmers specialise in a smaller number of enterprises and there is a decline in mixed farming. There is a rationalisation in the structure of landholdings, with an increased scale of operation, allowing greater mechanisation and reduced labour costs. These changes can cause chemical pollution of the environment, erosion of soil and damage to soil quality, and loss of valued habitats and landscapes.

But not all areas are suited to agricultural modernisation. Less productive and more remote areas cannot compete at the lower levels of commodity prices. The returns to investments are lower and there is less flexibility for structural change. It is these areas that face the greatest pressures for the withdrawal of resources from agriculture, especially of labour, potentially leading to land abandonment. The environmental impacts here are different, where it is the decline of agriculture that is seen as potentially damaging. Valued habitats and landscape are often maintained by the particular agricultural systems that have been practised in these areas. The decline in production activities can thus lead to a loss of valued habitats, species and landscapes.

These forces are quite fundamental to economic development, but in practice the experience of change in agriculture has been complicated by the operation of agricultural policies. In some cases, the changes, especially the intensification and mechanisation of production have been accelerated by the support given to the farm sector. In the less productive regions, agricultural systems may have been maintained through the provision of agricultural subsidies. Even here there are also concerns that the higher intensity of production is a source of environmental damage, especially with respect to over-grazing. Current pressures to liberalise agricultural markets have the implication of re-emphasising these underlying economic pressures.

At the same time, economic development is associated with an increasing concern for environmental quality. As incomes increase, consumers give a higher priority to environmental and leisure outputs. And, especially in the 'Old World', the countryside is an important provider of environmental quality in the form of countryside goods. However, while farmers receive a direct financial return for their agricultural products through the market, this is not the case for countryside goods and bads. These typically have public good characteristics[1] which means that markets do not work as they do for private goods. We may then expect that there will need to be some government involvement in stimulating an appropriate supply of countryside goods from the agricultural sector.

It can thus be seen that agricultural policies that operate by raising the output price received by farmers will tend to stimulate the provision of agricultural products that in some contexts will tend to deplete the supply of countryside goods. In other contexts, price support may promote the continuation of agricultural systems that support environmental quality[2].

The positions of Spain and the UK are somewhat different in these respects, as illustrated in table 1. Spain retains a higher proportion of the population within its agricultural sector and has a larger proportion of the population living in rural areas[3]. This might suggest that policies in support of agricultural production might gain greater political approval. The table also illustrates some physical differences. The UK has a higher proportion of the land area used for agriculture and a substantially higher proportion of this is under permanent pasture.

[1] Formally, a pure public good has the characteristics that it is 'non-rival' (consumption by one person does not reduce the amount available to another); and 'non-excludable' (once provided for one person it is not possible to exclude others from benefiting from it). In practice, most countryside goods have these characteristics to some degree.
[2] There is a continuing debate as to whether there can be circumstances where it is appropriate to stimulate the provision of countryside goods by means of general support for agricultural product prices (see e.g. Vatn, 2002).
[3] We should note that the definition of 'rural' is itself problematic and so be cautious of international comparisons of this sort.

Table 1. Some comparative statistics for Spain and United Kingdom.

	Spain	UK
Economy		
Percentage employment in agriculture (2002)	5.6	1.9
Percentage of population in rural communities (less than 100 inhabitants / km^2)	24.4	8.7
Gross National Income ($) per capita (2001)	14,300	25,120
Land Use (1999)		
Agricultural area as % land area	50.2	74.9
Arable as % agricultural area	64.3	32.1
Permanent pasture as % agricultural area	35.7	60.6

For Spain: Agricultural Area = Utilised Agricultural Area = Arable land + Permanent pasture
For UK: Permanent pasture = grassland over 5 years old + rough grazings
Sources: World Bank, Food and Agriculture Organisation, Spanish Statistics Institute, Department for Environment, Food and Rural Affairs.

2 The development of agri-environmental policies

The primary approach towards resolving the conflict between agriculture and the environment has been through the development of agri-environmental policy. Such policies act to prohibit or penalise the generation of environmental bads and reward the provision of environmental goods. The balance between these approaches varies between countries, although the emphasis has tended to be on the latter. There is thus a need to determine a reference level of property rights, defining the responsibilities of land holders and the actions that should be supported through positive incentives. The position is illustrated schematically in figure 1.

Countryside goods Landscape Biodiversity Ecosystem functions Community support	**External benefits:**	**Provider gets principle**
	<u>Reference level for environmental quality</u>	
Environmental damage Soil erosion Water pollution Pesticides in the environment Atmospheric emissions	**External costs:**	**Polluter pays principle**

Figure 1. The reference level for property rights.

Environmental policies have been introduced in most economic sectors in the context of the polluter pays principle. But it is often assumed that farmers do not have a general duty to prevent a decline in environmental quality. Rather, society should provide positive incentives to encourage farmers to do more to improve the quality of the environment. This can be regarded as the provider gets principle. This latter approach underpins most schemes implemented under the European Rural Development Regulation.

The general approach adopted to date has emphasised individual environmental contracts between a government agency and an individual landholder[4]. The variety of mechanisms is illustrated in table 2. These vary in terms of the degree to which specific sites are targeted by the policy mechanisms, with environmental specificity decreasing from left to right, and in the way in which contracts with landholders are implemented. At one extreme are sites specifically identified for their nature conservation value, generally through mechanisms outside of agri-environmental policy, such as under the Habitats Directive. They do not always involve environmental contracts with landholders, although management agreements have been used quite extensively in the UK on Sites of Special Scientific Interest. At the other extreme are schemes that offer general support for farming in Less Favoured Areas (LFAs). Such areas have been identified in terms of the degree of natural disadvantage and the maintenance of population has been an important policy objective. However, the protection of the environment, especially against land abandonment is a key purpose. The specific policy approach in LFAs varies between areas, but there is generally a standard payments system that applies to all land. In England, there are additional payments for environmentally sensitive characteristics, such as low stocking intensity or organic farming. In Spain, there are three types of programs according to the specific problems of each area. One of these, where payments are the highest, is linked to specific environmental constraints due to the area's habitat value. But given their general nature, such payments are unlikely to deliver specific environmental improvements in a cost-effective manner.

Between these two extremes, we identify two intermediate approaches, both based on explicit environmental contracts between an individual farmer and a government agency. The majority of agri-environment schemes offer a standard contract on a voluntary basis within a designated area. The areas involved may be large or small. The main limitation of schemes which operate with fixed contracts is the problem of adverse selection (see for instance Moxey *et al*., 1999). The farmers most attracted to enter will be those who are required to make the least change to their systems in order to meet the conditions of the contract. There may well be a proportion of farmers who have to make no changes at all. Thus with a standard level of payment many farmers will receive more than the minimum needed to attract them into the scheme. An alternative approach is to introduce some element of competition. The Countryside Stewardship scheme in England includes an element of competition in that applicants are selected to enter the scheme where they offer the best value for money. Even so, this is not fully competitive to the extent that the contracts include standard payment rates rather than allowing farmers to tender for the lowest payment at which they would be prepared to take on a contract. In practice these contracts require substantial preparation and individual negotiation and are often prepared with professional help. The result is that we can expect the requirements to be effectively tailored to the specific local circumstances, but that the transactions costs of the scheme are likely to be high[5].

[4] The approaches in different EU states are discussed in Buller *et al*., (2000)
[5] See, for instance, Falconer *et al*., (2001).

Table 2. General characteristics of agri-environment schemes for the provision of countryside goods.

	Management contracts in protected area	Agri-environment schemes with competition	Agri-environment schemes with standard contracts	Less Favoured Areas
Examples in UK	Management agreements on Sites of Special Scientific Interests	Countryside Stewardship	Environmentally Sensitive Areas	Hill Farm Allowance
Examples in Spain	no equivalent	no equivalent	Agri-environmental Programs	1. Mountain Areas 2. Depopulating Areas 3. Areas under special difficulties (where practices limited due to habitat value)
Objectives	Conservation of specifically identified sites of significant habitat and species.	Conservation and promotion of landscape and habitat within selected locations.	Conservation of landscape and habitat arising from ‘traditional farming’ in designated areas.	Support for farming in disadvantaged areas
Property rights	Removal of rights to undertake operations likely to damage.	Voluntary participation. Applications accepted on competitive basis.	Voluntary participation, applicants accepted if able to meet conditions.	Eligibility based on location of activity only
Payment	Individually negotiated payments for positive actions.	Standard payment.	Fixed payment for standard contract, based on income foregone.	Standard payment based on location.
Efficiency	Careful site selection. Removal of owner’s property rights reduces scope to ‘extort’ compensation	Competition on benefits provided but fixed payments	Adverse selection – fixed payment open to all attracts lowest opportunity costs	Few conditions beyond maintenance of farming. May be no restrictions on environmental damage
Transactions costs	Detailed site assessment Individually negotiated agreements. High transactions costs	Individually tailored and applications. High transactions costs.	General designation of area. Standard contracts and conditions. Quite high transactions costs.	Low transaction costs

2.1 The limits of environmental contracts

While the development of agri-environment policy represents a significant innovation in policy terms and is as yet relatively underdeveloped, there are a variety of quite fundamental limits of to the general approach. The objectives for environmental improvement are determined by government and may or may not reflect the interests and values of the population. Indeed, the prescriptions established from an EU perspective may not accord with national discourses about the political treatment of the environmental implications of agriculture. Fixed contracts established at a national level may also not fit well with local agricultural circumstances leading to opportunistic behaviour on the part of farmers (that may be tolerated by the authorities who are aware of the problems).

Assuming that the rules impose some cost on farmers, the farmer will always have an incentive to default on aspects of the contract that incur a cost and which may not be readily enforced by the government agency. There are no incentives for producers themselves to seek out methods of reducing costs, especially in individually negotiated contracts.

Characteristic landscapes and conservation values are generally only created at a landscape scale and over significant periods of time. The protection of sites of high nature conservation value often depends upon the land uses in the adjacent wider countryside, by linking existing sites, creating new sites and establishing buffer areas to protect sites from changes in the wider countryside. At the same time, the development of landscape only occurs over significant periods of time and thus relatively long-term agreements are necessary so as to permit the development on new environmental assets. Short term contracts with individual farmers cannot guarantee that the ecological and landscape requirements are met. The tendency by government agencies to modify contract conditions at the end of the contract period creates uncertainty on the part of the farmers who are then reluctant to introduce the longer term changes that may be required to achieve the environmental objectives.

Many landholders are already willing to forego income in order to maintain a certain standard of environmental management and the public is willing to contribute on a voluntary basis. A formalised system of environmental contracts with government fails to take advantage of this goodwill.

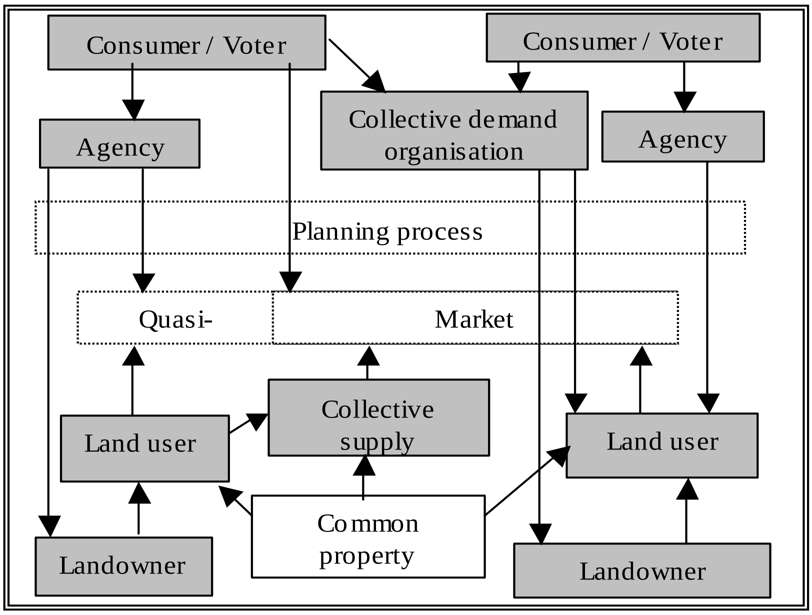

Figure 2. Alternative linkages for the provision of countryside goods.

3 Beyond agri-environmental policies

In practice, what has developed over the past 20 years as ‘agri-environment’ policy represents one amongst a range of possible ways in which the provision of countryside goods might be promoted. The possible range of policy mechanisms is illustrated in figure 2 (reproduced from Hodge, 2001). In the absence of a conventional market, linkages have to be established between the demand for countryside goods and their supply by means of influences over land uses.

Potential institutional arrangements range between simple public provision to near market solutions. They operate both vertically, transmitting incentives from those who value potential alternative outputs (either as voters or consumers) to those allocating resources for their supply (farmers), and horizontally, co-ordinating decisions amongst both demand and supply groups. The potential vertical arrangements may be represented by various models: linked markets, environmental contracts, Conservation, Amenity and Recreation Trusts, dedicated funds and public ownership. Horizontal arrangements imply degrees of co-ordination amongst those demanding or supplying the countryside goods.

What potential is there to introduce alternative approaches? There are some mechanisms that promote the provision of countryside goods through private and market actions. In principle these have the advantage over government provision in that they provide opportunities for beneficiaries to contribute directly towards environmental conservation and in doing so to reveal their preferences for countryside goods. However, in practice, we are unlikely to find a mechanism that does this perfectly. In some contexts, consumers have an opportunity to contribute towards the enhancement of the environment by purchasing particular products. These are generally organic products and what we might generally refer to as niche products. In what follows, we illustrate two examples: organic farming and Conservation Amenity and Recreation Trusts.

3.1 Organic farming

Organic farming is the primary example of a linked market. There is quite strong evidence that organic farming is better in some ways for the environment than is conventional production (Centre for Rural Economics Research, 2002). The extent to which this is fundamental to the characteristics of organic production systems themselves or is due to the regulations governing environmental management in the criteria for certification is uncertain. But when consumers purchase an organic product, they are promoting an agricultural system that is supporting a higher level of environmental conservation than it would be the case if they chose to purchase a conventional product. And because the organic product is likely to have a higher price, there is a sense in which the consumer is making a contribution towards the costs of environmental conservation.

However, there are a number of limitations to this as a mechanism for the provision of countryside goods. Firstly, consumers may purchase organic simply because they feel that the food they buy is safer to eat or of better quality. Thus the premium that they are willing to pay may not bear any relationship to their willingness to pay for a better environmental quality. The consumer may also not have any clear idea of the extent to which organic farming is indeed better for the environment. In fact, research to establish this is complex and there are few easy general answers. Thus consumers cannot be sure what they are achieving through their purchase. They may anyway have doubts about the claims that are made for the product and have difficulty in differentiating between an approved organic standard and advertising claims for conventional products. Finally, economists argue that consumers will ‘free ride’. The environmental benefits provided are essentially public goods; consumers gain no personal benefit from any environmental gain arising from their individual purchase. Thus, they may appreciate that other consumers choose to purchase organic products but not be willing to pay the premium themselves.

This thus suggests that organic farming may be beneficial for the environment, but yet be a relatively weak mechanism for the provision of countryside goods. It is unlikely to offer a ‘market’ for countryside goods. The external benefit associated with organic farming does offer an argument for government support although even in this respect, the question has to be asked as to whether a more targeted scheme rewarding farmers for the provision of specific environmental benefits might be a more efficient approach.

3.2 *Conservation Amenity and Recreation Trusts*

Some organisations acquire land with the specific objective of producing countryside goods for the general public. In this respect, their objectives a often quite close to the objectives of government. We refer to these organisations as Conservation, Amenity and Recreation Trusts (CARTs) (Dwyer and Hodge, 1996). They may have quite specific objectives, such as relating to the conservation of a particular species, to the conservation of the historic environment, or to environmental enhancement more generally.

Some of these organisations have a long history in the UK. The earliest seems to have been the Dartmoor Preservation Association, established in 1883. But the two largest organisations are the National Trust, founded in 1895 and the Royal Society for the Preservation of Birds, founded in 1889. While a significant number have been established subsequently, none have come close to the scale achieved by these long-established organisations. Some figures for the largest organisations are shown in table 3. It is difficult to estimate the proportion of the total land area that is controlled by these organisations given their different spatial coverage and the lack of systematic information. However, landownership by the National Trust represents perhaps 1.5 % of the area within which it operates. Across the UK perhaps 2.5 % of the land area is owned by this sector. But of course, their significance cannot be described simply in terms of the areas involved. Much of the land that they own is of a high landscape and conservation importance and their conservation activities can act as a laboratory and demonstration for the development of new approaches towards environmental restoration and creation.

Table 3. Current membership and landownership amongst the largest CARTs in the UK.

	Membership (1,000s)	Land ownership (1,000 ha)
National Trust	3,000	250
Royal Society for the Protection of Birds	1,022	121
National Trust for Scotland	250	73
Wildlife Trusts	413	81
Woodland Trust	115	19

There is no such history in Spain and, as is the case with other Mediterranean countries, such a movement is only just beginning. Some ecological organisations are acquiring land with particular natural value. The most notable development is the creation in 2003 of a 'Land Stewardship Net' made up of different environmental organisations, as well as some foundations (some linked to banks). While experience varies between regions, these organisation are involved in a variety of activities, not just land acquisition. They offer contracts to private owners to promote better and more informed environmental land management. Most activity has been concentrated in Catalonian and the Balearics, which tend to be more highly developed regions and where amenity activities are linked to tourism.

The achievement of conservation goals can often require detailed information both about the ecology of the habitat being managed and about the agricultural system which is operated within it. In some circumstances, guidelines for management in agri-environment schemes can provide sufficient information for a farmer without a detailed understanding of the ecosystem involved. However, in other circumstances, for instance where habitat is being re-created or where a rare habitat is being protected against external pressures, then a more proactive form of environmental management may be necessary. This would involve a more regular monitoring of the ecosystem and review of the appropriate management responses. This may require a range of skills which are not always available to the particular landholders who happen to be owners of the relevant conservation sites and may be difficult to write into contractual agreements.

CARTs can develop expertise relating to their particular objective, such as the protection of birds, or they may focus their efforts within a particular area. In this way, although they may be relatively small organisations, they can build up a level of expertise within their own particular speciality. But at the same time, their activities are likely to be guided by the institutional and financial environment created by government. This may be done in terms of grants for the purchase of land, contributions towards labour costs and the tax relief generally available to non-profit organisations.

The conservation organisation will have an incentive to seek out least cost ways of generating and protecting the conservation values under its particular circumstances. It will be prepared to trade off costs against conservation gains. Therefore such organisations will tend to act entrepreneurially, seeking new products and new methods of achieving conservation goals. It will respond to changes in relative prices and technology. This suggests that the conservation organisation will require less detailed monitoring by government than a conventional landholder and that in the longer term it would be likely to develop more cost-effective methods of conservation management. Conservation organisations may be able to respond more rapidly to opportunities which arise, such as in purchasing significant conservation sites when they become available on the market.

While such organisations can fill an important role in an overall land conservation strategy in bringing in skills, entrepreneurship and resources, they do not replace the role of government. We may anticipate some growth as economies become more developed but there are limits on their extent. They are always likely to give most attention to the most ‘popular’ environmental initiatives in areas that are appreciated by wealthy tourists or have relatively high per capita GDP.

CARTs can attract resources from membership fees, donations and charges, but the free rider remains a problem and government will still have a role with regard to the provision of the more pure public goods, such as for less spectacular species or landscapes. The model is unlikely to make a major contribution in areas, such as those in Spain where the process of rural depopulation continues and the rural landscape is less attractive. Government will continue to play a major role in such areas.

Table 4. Areas of land under certain forms of conservation management.

	UK		Spain	
	Area	Approx. % of total land area	Area	Approx. % of total land area
Utilised Agricultural Area	15,799	65	26,154	52
Less Favoured Areas	7,110	45	21,188	81[1]
Approvals under EEC Regulation 2078/92 (in 1998)	2,517	10.4[1]	926	1.9[1]
Areas identified under Birds and Habitats Directives	3,943	16.3	19,675	39.4
Organic farming	725	4.2[1]	665	2.3[1]
Conservation Amenity and Recreation Trust ownership	550	2.25		

[1] Percentage of Utilised Agricultural Area

4 Designing institutions for particular circumstances

There is a similar trajectory in the pattern of policy development on Spain and the UK, but the details are different as illustrated in table 4. This reflects both the physical conditions in the two countries, the stage of development and cultural approaches towards rural areas and the countryside. Polices in the UK are much more directed towards the conservation of extensive grassland areas, both in the uplands and lowlands in order to support landscape and wildlife objectives. In Spain, agri-environmental policies are more focussed on arable production activities, reflecting the problems of low profitability and the abandonment of many traditional farming systems that are considered as environmentally friendly. To this extent, Spanish agricultural administrations have been criticised for using agri-environmental payments as another way to subsidise farmers. These differences clearly reflect the different physical environments and the different public preferences for the rural environment. Policies in the UK have been more specifically targeted spatially and based on detailed individual contracts. The reasons for this different approach probably reflects the difference in objectives and perhaps the greater political influence of non-agricultural interests in pressing for more particular influence over the directions of agricultural policy. Finally, we note the greater involvement of the voluntary sector in the UK. Again, this reflects the general public interest in and willingness to pay for landscape and wildlife benefits from rural areas.

5 Some implications for grassland research

Changes in policy objectives inevitably imply a need for a redirection of research. While our emphasis has been on the institutional aspects, there are also implications for the direction of agronomic and ecological research. In the past, the goals for research have been relatively straightforward. An initial concern for maximising production gave way to a greater concern for cost-effective production methods. The aim generally was consistent with one of seeking to increase the farmer's net income. Recognition of the environmental impacts has increased the attention given to understanding the wider environmental impacts of alternative production systems. But we are now facing a more fundamental question as to what rural areas are for. The values generated in rural areas are increasingly related to the countryside goods that they produce. To date the approach towards this has often tended to be backward-looking, to seek to return to traditional agricultural systems, to pre-industrial conditions or even to a 'natural' environment. But this cannot be the way forward in the longer term. The preferences for the alternative outputs have changed, the relative costs of inputs have changed and the wider physical environment has changed. There is thus a need for research both from natural and social science perspectives that identifies the importance of the various outputs such as alternative ecosystem functions, patterns of biodiversity or landscapes that can meet contemporary demands for the rural environment. We then need to design production systems for these countryside goods that are cost-effective, recognising resource costs and taking advantage of new information and technical potential.

In this context, we should also recognise the opportunities arising from institutional developments. The production systems under analysis often represent joint ventures between public and private interests, whether through environmental contracts on private land, public support for initiatives by non-profit organisations or through public ownership. These offer a new variety of experimental contexts and new opportunities for innovation and demonstration. A farming systems approach needs to take advantage of these new institutional contexts.

There is thus a need to recognise the new preferences and objectives for the rural environment that are not identifiable simply in terms of production volume or net farm income. There is a need to develop systems that recognise the resource costs of inputs, take advantage of new techniques and respond to the possibilities and challenges of the new institutional arrangements within which production of food and countryside goods takes place. This will inevitably require a significant element of interdisciplinary co-operation.

6 Conclusions

The change in the general character of the objectives for agriculture, from a priority for production towards an increased concern for environment is consistent with more general trends that occur with economic development. But the ways in which this change is addressed also reflects the political realities of achieving a redirection of policy. Logically we would suggest that the new environmental objectives should be met through an explicitly environmental policy rather than by modifying the existing agricultural policy. In practice we do not start with such a clean sheet and practical policy is an inevitable compromise between what might be 'best' and what is possible. Nevertheless, we can observe the development of an agi-environment policy, even though it only represents between 5-10 % of total agricultural policy expenditure. There is plenty of scope for the further development of this approach.

However, in this paper we have highlighted the wider range of policy options that are available. More attention is needed to determine the ways in which public funds may be allocated between agri-environmental schemes and alternative approaches towards the provision of countryside goods. The 'Land Stewardship Net' in Spain has recently been seeking greater social recognition, as well as legal changes to promote a more favourable financial environment, such as providing tax relief for its conservation activities. More work is required in order to establish the nature and potential for such policies and a clear institutional framework within which such judgements may be made.

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European grassland farms caught between unfriendly markets, perpetually changing agricultural conditions and environmental demands?

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Abstract

Grassland only allows the production of a rather limited number of agricultural products. Compared to arable land it is an inflexible input into agricultural production. In the European Union consumer demand for products, produced predominantly from grassland, is constant or declining. Significant increases in factor productivity in ruminant production, cheaply available substitutes for forage and on the other hand growing attention to protect the grassland environment have caused changes of the economic situation of grassland farmers over the last 20 years. This paper gives a short overview on the structure and development of grassland within the agricultural sector of the European Union. Then the main driving forces of grassland development are analysed and discussed, specifically referring to the farm level: Political conditions of the CAP (first and second pillar), EU market conditions and technological developments. Finally, the economic impact of new policy developments (e.g., decoupling) and technical improvements on farms in grassland regions is discussed and possible development paths are derived.

Keywords: grassland farms, agricultural policy, technical improvements, markets

1 Introduction

In the last decades development of agricultural land use in the European Union was characterised by significant productivity increases through technical improvements, which contributed to surplus production and in a number of cases to negative effects on the environment (Heissenhuber and Hoffmann, 2002). Over the last 20 years traditional use of grasslands to produce fodder for the production of milk, meat and fibre by ruminant animals has become less important in the European Union. Increasing concern about health issues with an associated change in diet by some consumers has led to a drop in demand for ruminant products (Wilkins, 2001). On the other hand a growing attention to protect the environment has had positive impact on the economic situation of grassland farmers, at least in a significant number of cases. Multifunctional grasslands, which meet ecological and recreational demands besides producing forage have received high attention by environmental scientists and environmental pressure groups. Consequently an environmentally sound management of grassland has been supported financially and this has become an income source for numerous grassland farmers.

Topic and approach of this paper deserve a word of caution: The diversity of grassland situations within Europe is immense – and with enlargement it is even increasing further. We attempt to identify some important lines of development and to offer explanations for them. We approach the topic using the framework of farm economists, but we still see the need to use sectoral data. Our ambition is not completeness but to offer some possible explanations for the economic and political influences that also shape the environment of grassland farmers.

2 Development of grassland in the EU

State and development of grassland differs in the member states of the European Union. A high share of grassland can be found in Germany, France, Belgium-Luxemburg and Austria (> 20 % of member states total area). In Southern Europe the share of grassland on the total area is much lower (10-12 %) and marginal in Sweden and Finland (Bruyas, 2002).

Overall grazing livestock makes up two thirds of all European livestock measured in livestock units (Vidal, 2002). While granivore livestock increased between 1980 and 2000 in the EU-9 by 17 %, grazing livestock dropped down by 13 % in the same period (Vidal, 2002). This is consistent with the statement that European agriculture evolved on the most productive agricultural areas while certain disadvantaged regions (mountainous regions and Piedmont areas) and traditional areas for livestock husbandry are abandoned (Caradec *et al.*, 2003). Grassland only increased in a few livestock regions: Ireland, Limousin (France) and Umbrien (Italy). Especially in Western France, Southwest of Netherlands, big parts of Italy, Flandern (Belgium) and Hessen (Germany) a significant drop in grassland area could be recognised.

This overall decline of grassland is partly caused by specific policy measures such as subsidies for aforestration. A change of grassland into arable land could and can still be noticed in France. On the other hand and in terms of direct policy influence on grasslands probably more important are measures that favour grassland use: Measures in favour of 5b regions and elements of the 1992 reform of the CAP as well as of agenda 2000 such as grassland extensification, support of organic farming and premia for suckling cows and ewe premiums limited and in some cases reversed the decline of grassland in disadvantaged regions.

In the year 2000 organic farming area reached 3.20 % of the total Utilised Agricultural Area (UAA) of the EU-15, whereby higher or equal percentages to the EU-average are met in Austria, Italy, Finland, Denmark, Sweden, the United Kingdom and Germany (Duchateau, 2003). In terms of grassland use organic farming is more important than the overall percentage suggests, 4.02 % of European grassland are used by organic farmers (Figure 1). In Sweden 19.54 % of grassland are under organic management while in countries where little organic farming is found, like Greece, this percentage is close to zero. It seems that the organic grassland plays an especially important role in countries and regions where extensive production systems dominate grassland also in conventional farming.

Since the introduction of the milk quota in 1984, technical improvements and changes in intensity of dairy production the number of dairy cows has decreased by 18 % between 1983 and 1990 (Vidal, 2002). Due to increasing productivity and the limited production by the quota, the amount of dairy cows steadily declines by 2 % y^{-1} since 1990. Between 1980 and 2000 three of four dairy farms gave up, which is a clear indication that concentration and specialisation in dairy production continuously takes place. Grasslands not used for dairy production anymore were partly taken up for suckler cows whose number significantly increased (Vidal, 2002).

Reorganisation of European agriculture under constant economic pressure has led to a decrease in number of farms but an increase in farm size over the last 20 years (Vidal, 2000). However, area and herd size in farms with cattle differs widely between the member states. Half of these farms have less than 20 ha and less than 20 livestock units (LU) (Eurostat, 2003). They keep 9 % of whole EU cattle stock. Herd sizes of less than 5 LU can be found in Spain, Italy, Greece and particularly in Portugal, while about 20 % of the herds in Denmark, Benelux and the United Kingdom have more than 100 LU. Very small herds (< 10 dairy cows) can be found in Spain, Italy, Austria and Portugal, but more than 50 dairy cows at farms in Denmark, the Netherlands and the United Kingdom. Overall 60 % of the farms, that keep cattle, are located in disadvantaged regions.

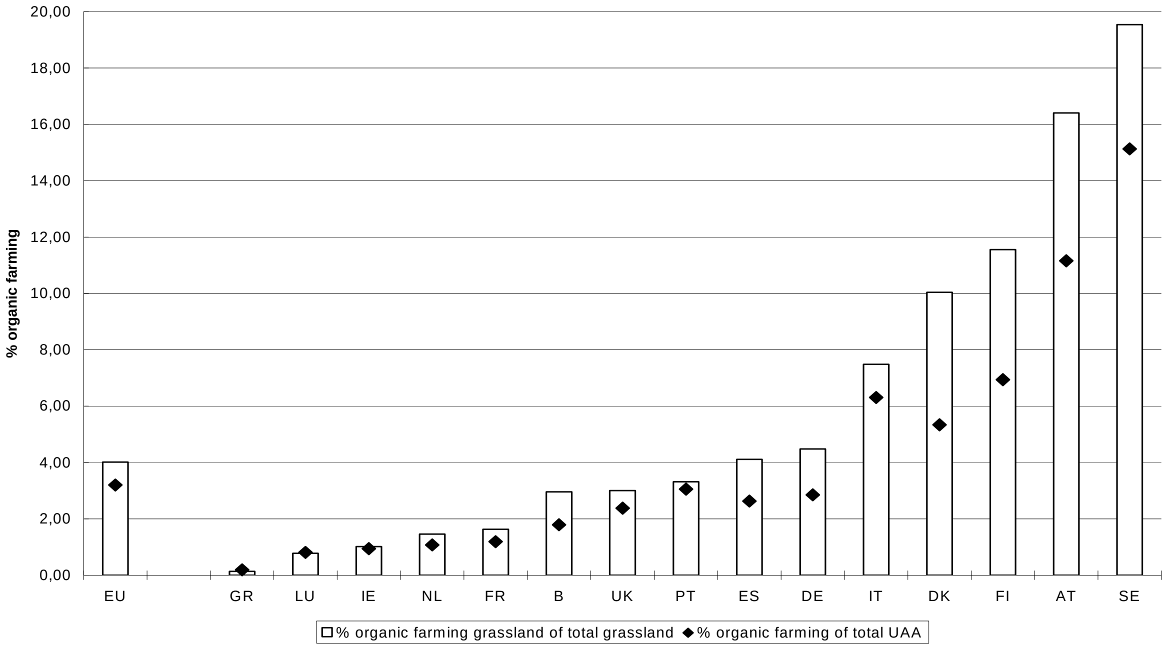

Figure 1. Organic farming grassland in the EU (Bichler, 2003).

The present structure of grassland and ruminant animal production in the EU-15 is shown in table 1. The highest shares on total grassland area of the EU-15 can be found in France, Great Britain, Spain and Germany (> 10 %). All of these member states but Spain keep a high proportion of dairy cows and other cattle. Sheep and / or goats are very common in Great Britain, Spain and Greece. An extraordinary high livestock unit hectare^{-1} grassland exists in Finland (29.2 LU ha^{-1} GL). Also Denmark, Belgium, the Netherlands and Sweden have a comparatively high stocking rate, while the lowest can be found in Austria.

Table 1. Structure of grassland and ruminant animals in the EU-15 in 2000.

	Share on EU-15 in %					
Member State	Grassland	Dairy cows	Other cattle	Sheep	Goats	LU ha^{-1} GL[3]
B	1.1	3.1	3.9	0.2	0.1	4.2
DK	0.4	3.2	2.0	0.1	0	8.2
G[1]	10.8	22.4	16.4	2.3	1.2	2.2
GR	3.8	0.9	0.6	9.8	44.4	1.0
E	15.4	5.6	8.2	25.7	24.3	1.0
F	21.7	20.4	26.2	9.8	9.9	1.5
IRL	7.2	6.1	8.6	5.4	0.1	1.7
I[2]	8.9	10.6	8.6	11.7	11.8	1.3
L	0.1	0.2	0.3	0	0	2.3
NL	1.9	7.5	3.9	1.3	1.6	3.5
A	4.2	3.0	2.5	0.4	0.5	0.8
P	3.0	1.7	1.7	3.8	5.3	1.0
FIN	0.1	1.8	1.1	0.1	0.1	29.2
S	0.8	2.1	2.0	0.5	0	3.4
GB	20.8	11.5	14.0	29.1	0.7	1.3

[1] Livestock Units of goats in Germany are based on own estimation.
[2] Grassland data in Italy are from 1997.
[3] LU = Livestock Unit; GL = grassland
B: Belgium, DK: Denmark, G: Germany, GR: Greece, E: Spain, F: France, IRL: Ireland, I: Italy, L: Luxemburg, NL: The Netherlands, A: Austria, P: Portugal, FIN: Finland, S: Sweden, GB: Great Britain
Source: BMVEL, 2002 (modified).

3 Main driving forces for grassland development at farm level

3.1 Effects of agricultural policy measures on grassland farms

A major change in agricultural policy that influenced grasslands was the introduction of the milk quota in 1984. Later the 1992 reform of the CAP which was continued by the Agenda 2000 reform marked an important change in strategy towards agricultural support. Direct payments to farmers became important, in turn price support lost parts of its significance. To reduce surplus-production cereal and beef intervention prices were decreased towards the world market price level. These changes resulted in cereal prices that had a lower percentage premium above world market prices than was the case for milk and beef. The direct payments were coupled to production: They were (and still are) paid per animal held or produced and per hectare crop produced. Grassland was only indirectly supported by this through the support for animals that lived from grassland. However, no direct payments for the production of grass, hay or silage were part of the main part of the policy. This meant it was always possible to substitute grass by other types of fodder (e.g., cereals or maize) and still receive the support. In some regions the opportunity to receive direct payments for maize silage made beef production on arable land quite profitable and led to a relative disadvantage of beef production from grassland.

Under Agenda 2000 direct payments were raised and a further reduction of intervention prices took place. The increased direct payments per head of cattle could compensate reduced beef prices while income of dairy and arable farms decreases. For example scenario calculations of Vogel (2002) on the effects of the final stage of Agenda 2000 at farms in Northeast Germany resulted in a reduction of gross margin at dairy farms by 7-17 % compared to the situation in 1996. In contrast, gross margin of extensive grassland farms with suckling cows increased due to higher per capita payments, provided that subsidies for agri-environmental measures are unchanged. Kleinhanss *et al*., (1999), who in contrast to Vogel calculated with a full shift of intervention price reduction on market prices, also predicted income losses in dairy production.

The main focus of the 1992 reform was on the reduction of production surpluses. The introduction of agri-environmental measures that meant payments to farmers in exchange for more environmentally sound farming practices was a novel approach which gradually gained importance. The EU regulation 2078/92 which evolved into the ‘second pillar’ of the CAP (besides market support and direct payments which form the ‘first pillar’) focused on environmentally friendly farming practices and the protection of natural habitats, through subsidies for extensification of land use and organic farming. Agenda 2000 pursues the schemes for environmentally friendly farming practices under EU regulation 1257/99 with an enlargement array of measures. A multitude of measures under these agri-environmental programs support specific types of grassland, often in connection with measures geared at increasing biodiversity.

The latest reform decided upon in 2003 under the misleading heading of ‘midterm review of Agenda 2000’, marked another dramatic shift in the development of agricultural policy and will have far reaching impact, also on grasslands. This will be discussed later in the paper.

3.2 EU-market conditions

The degrees of self-sufficiency for milk products in the EU-15 range between 87 % (Netherlands) and 122 % (Belgium / Luxemburg) (BMVEL, 2003) (Table 2). The average degree of self-sufficiency for butter in the EU-15 is 98 %.

The high supply with beef and veal of most of the member states faces a decreasing per capita consumption (Table 3). Only in Denmark, Spain and Portugal demand increased. Total meat consumption in the EU-15 did not change considerably because the demand on poultry increased significantly. The BSE scandal in 2000 and the outbreak of the foot-and-mooth disease in England caused a temporary collapse on demand for red meat. Today, demand for consumption of beef has nearly regained its original level, but has left behind an increased consumers concern on health, food quality and animal welfare which does not necessarily translate in the willingness to pay higher prices for quality production.

Table 2. Degree of self-sufficiency for ruminant products in the EU-15 (in %).

Member State	Beef / veal[1]	Sheep / goat[1]	Total meat[1]	Milk products[2]	Butter[2]	Skimmed milk powder[2]
B/L	138	19	93	122	126	189
DK	119	29	118	101	129	140
G	166	49	88	114	87	203
E	125	108	123	95	30	--
GR	24	85	89	94	107	30
F	120	55	106	103	86	101
IRL	918	289	100	97	931	527
I	69	49	91	88	71	--
NL	113	96	84	87	135	39
A	152	80	100	106	93	132
P	60	69	106	102	132	92
FIN	97	50	70	100	239	100
S	76	44	74	100	113	105
GB	69	79	81	97	75	57
EU-15	112	79	95	100	98	99

[1] in 2001
[2] in 2000
Source: LLM, 2002; BMVEL, 2002

Table 3. *Per capita* consumption of meat (kg y^{-1}) and variation to 1988 (%) in the EU-12.

Per capita consumption[1]	B/L	DK	G[2]	GR	E	F	IRL	I	NL	P	GB	EU
Beef / veal	19.3	26.0	15.1	19.2	16.3	26.9	17.2	25.5	18.8	16.8	17.2	19.9
Variation to 1988	*-12*	*53*	*-36*	*1*	*42*	*-11*	*-9*	*-4*	*-3*	*26*	*-20*	*-12*
Sheep / goat	1.7	1.3	1.1	13.8	5.9	4.9	8.9	1.6	1.4	3.6	6.5	3.7
Variation to 1988	*-6*	*63*	*22*	*-1*	*2*	*4*	*37*	*0*	*100*	*16*	*-4*	*-3*
Pork	44.6	65.8	56.9	32.3	66.1	36.7	41.7	36.1	41.6	44.5	23.3	43.4
Variation to 1988	*-5*	*0*	*-9*	*50*	*48*	*-3*	*18*	*21*	*-11*	*83*	*-6*	*9*
Poultry	21.0	18.1	15.3	18.5	27.0	24.3	30.9	18.3	20.3	30.6	28.7	21.5
Variation to 1988	*28*	*55*	*37*	*19*	*23*	*25*	*50*	*-4*	*22*	*80*	*49*	*22*
Total meat	96.4	117.8	94.1	90.8	127.6	107.6	109.7	91.1	83.8	105.7	80.5	96.8
Variation to 1988	*-4*	*13*	*-10*	*19*	*37*	*-2*	*19*	*6*	*-4*	*62*	*5*	*4*

[1] 1999
[2] 1988 without East Germany
Source: BMVEL, 1994; 2002

Milk producer prices in real terms increased slightly in the years immediately following the introduction of the quota and dropped since (European Commission 2000), whereas cereal prices dramatically declined in this period (BMVEL, 1990; 2002). Decreasing cereal prices made cereals more profitable for feed use. Although total livestock declined, cereal production for feed use increased (European Commission, 2003).

3.3 Technical improvements

Grassland farms are affected by technical and genetic improvements, especially in dairy production, and, therefore, changed feeding requirements. During the last decades intensity in dairy farming increased, although milk prices had a downward tendency (Hoffmann and Heissenhuber, 2002). Within dairy production a high economic pressure to increase milk output per cow exists due to high labour and capital input. The amount of labour needed per cow is largely independent from the amount of milk produced per cow, which makes it interesting from a farmers point of view to increase milk yield per cow by intensive feeding and breeding through selection on high milk production (Dillon and Maher, 2003). Moreover, reduction in costs and a higher labour efficiency play an important role. Variable costs mainly depend on fodder costs and restocking, working hours on labour input for milking (Doluschitz, 2002). Through technical improvements in housing and milking systems labour input kg^{-1} milk for animal care and forage farming was reduced by 90 % in the last decades (Figure 2). Especially in dairy production the costs of production decline with enlargement of herd. Therefore smaller farms with missing possibilities for growth, due to e.g., lack of capital or land, can hardly use these labour saving technologies.

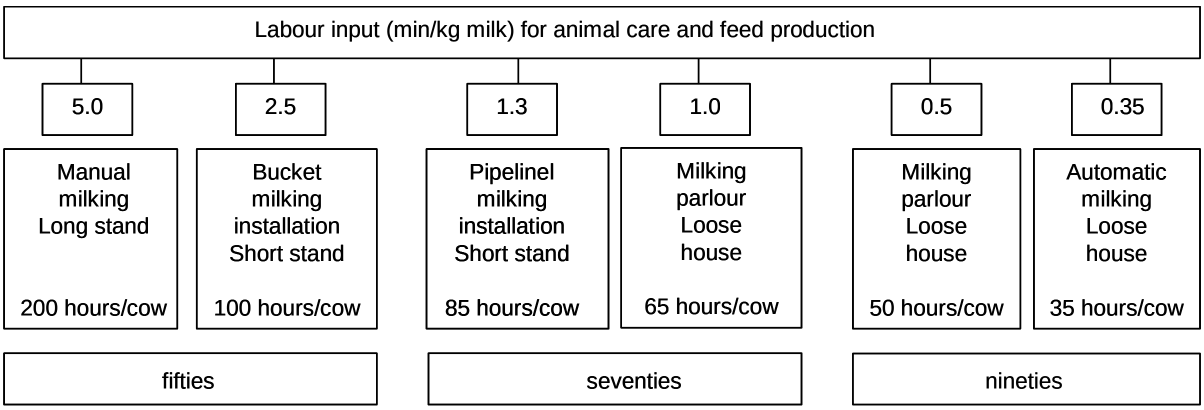

Figure 2. Effects of technical improvements in dairy farming (Heissenhuber 2001, modified).

Through genetic improvements the production capacity of livestock increases. In order to make use of this good forage quality and an optimal composition of concentrates and different forage components, which meet the physiological demands, are required. High milk output per cow faces the constraint that the capacity for feed intake is limited and, therefore, requirements on digestibility increased. The higher the milk yield the less these demands can be met by a feed ration which is based on a single forage component (Mährlein, 2003). Although grazing has a high potential to produce high forage quantity and quality to comparatively low costs (Figure 3), full-time grazing decreased in many European countries, due to the fact that a highly productive sward needs intensive maintenance efforts, depends on weather conditions, shows a decreasing energy content during grazing season and makes high demands on grazing management with increasing herd size. Grass silage is also characterised by the potential to produce high forage quality. Furthermore, it causes lower costs and is less dependent on weather conditions than hay production.

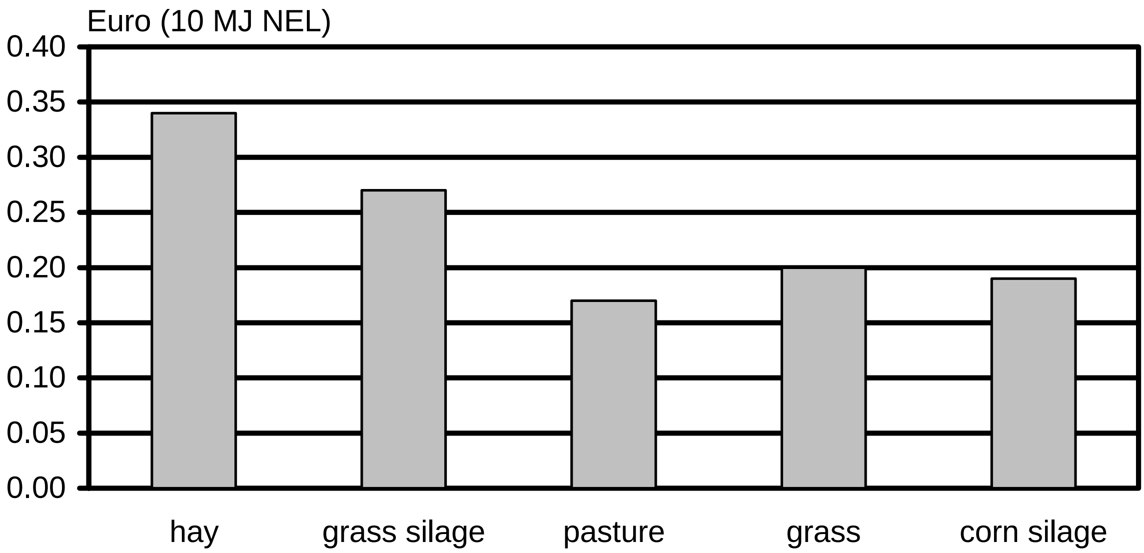

Figure 3. Nutrient costs of different forage without premium (full costs) (Hoffmann and Heissenhuber, 2002, modified).

In comparison to forage from grassland corn silage achieves the highest energy yield ha^{-1} due to its particularly high energy value and high yield. Moreover the lower costs, as a result of lower labour input and the possibility to be subsidised by direct payments, the constant feed quality (harvesting at a certain date) and the high tastiness have increased the input of crop silage in intensive dairy and meat production (Mährlein, 2003). Hoffmann and Heissenhuber (2002) calculated, that the production costs of extensive dairy farms (low-cost feeding strategy: seasonal calving, long grazing period, rotational grazing) are 0.05-0.07 € kg^{-1} milk higher than production costs of intensive dairy farms (permanent housing, input of crop silage). Therefore, farms in absolute grassland regions have competitive disadvantages. E.g., in Ireland, where dairy and cattle farming due to the natural conditions is mainly based on grassland, the strategy is to export their products as extensively and environmentally friendly produced food (Teagasc, 2003).

3.4 Economic effects of potential future policy developments and technical improvements on grassland farms

The Mid Term Review of Agenda 2000, decided on, in 2003 ('Luxemburg compromise'), brings about a reorientation of common agricultural policy in the EU. Main elements are:

– decoupling of direct payments from production,
– linkage of direct payments to environmental standards (Cross-compliance),
– shifting of money from direct payments to rural development (Modulation),
– further cut of market interventions,
– strengthened rural development policy.

The reform introduces a single decoupled payment scheme which comes in two variations. In any case the amount paid is not dependent on any specific production. One possibility is that a Member State introduces the payment based on the volume of a producer's existing direct payments, determined by a historical reference situation for that farm. Member states can also opt for a system where an average payment is paid for each eligible hectare (including grassland) of land in a regional approach. At first sight the regional approach favours grassland, because in the past on average much less premiums have been paid to grassland farmers than to arable farmers. But it has to be understood that while the grassland farmers would in general profit from the regional approach, the grassland use would not necessarily. As the payment is decoupled there are no specific requirements associated with this payment which go beyond the general requirements of cross compliance.

As a result of the political compromise not all payments have to be fully decoupled, but there are some exemptions where partial decoupling is allowed: In several sectors partial decoupling is possible, if the Member State wishes. This applies among others for beef, sheep and goats. Premium for suckling cows can stay fully coupled. Member states which chose to fully decouple immediately will have higher incomes for their farmers, however, the negative impact on production quantities and especially on productive grassland use might be substantial.

The cross compliance provisions refer among many other issues specifically to grassland: 'Since permanent pasture has a positive environmental effect, it is appropriate to adopt measures to encourage the maintenance of existing permanent pasture to avoid a massive conversion into arable land' (EC regulation 1782/2003). Later on it is stated: 'Member states shall ensure that land which was under permanent pasture at the date provided for the area aid application for 2003 is maintained under permanent pasture. However, a Member State may, in duly justified circumstances, derogate from (this requirement), provided that it takes action to prevent any significant decrease in its total permanent pasture area'. It is the made clear that aforestration is under defined circumstances allowed on pastures. However, this implies not only a political recognition of the importance of permanent pasture but could be also interpreted in a way that the politicians expect severe problems for grassland use as a result of the overall reform.

Market intervention will become less important as a part of the reform. The intervention price for butter will be reduced by 25 % over four years and for skimmed milk powder by 15 % over three years. Experts estimate that this will lead to a 15 % reduction of the milk price, others even foresee a drop by 20 %. For compensation a new premium for milk producers will be introduced in 2004 which, however, will not be sufficient to make up for the loss. In addition milk quota will lose in value.

While the rural development programs under the Luxemburg compromise offer in principle increased possibilities for agri-environmental programs, the need for co-financing of these programs by the regions brings about some doubts whether actually the amount of money spend will as much increase as is expected by the architects of the reform. These programs pose a key chance for grasslands. However, much will depend on the regional implementation of these programs.

Introduction of a fully decoupled income payment per farm will have strong effects on farms with beef and sheep production, especially those situated in less favoured areas. Due to decoupling, production of fattening bulls and suckling cows which is at present subsidised by high direct payments will be reduced. Decoupled payments will be paid even if, as a worst case, all cattle are abandoned. Farms with a gross margin of fattening bulls or suckling cow production that is minor the payments per head of cattle and therefore, unprofitable without subsidies, will reduce number of livestock as long as they achieve positive gross margins without premiums. Offermann *et al*. (2003) calculated in a scenario of full decoupling until 2010 for German grassland farms a decrease of finishing bulls by 27.2 % and of suckling cows by 16.4 %, compared to Agenda 2000 (extrapolated until 2010) as reference (Table 4). This results in a drop in beef production by 13.4 %, although beef prices should increase, according to their calculations. Reduction of bulls and suckling cows will lead to a decreasing demand in forage. Furthermore, omission of premium for crop silage production will strengthen competitiveness of grassland and other forage. This will cause a slight extension of grassland use, whereby intensity of grassland use will decrease due to decreasing demand in forage (Offermann *et al*., 2003). Nevertheless, the favourable development of beef prices has to be questioned, if important beef producing member states of the EU (e.g., France) decide to retain payments per head of cattle (partial decoupling). This would slow down reduction of beef production and, therefore, a minor increase in beef prices is to be expected. Moreover, grassland farms in those member states would have a more profitable position, if further reforms of the CAP revert to direct income payments for production.

The amount of dairy production will be maintained and available quota used, also if prices fall by 20 % (Offermann *et al*., 2003). Due to the reduction of the milk price gross margin of dairy production will decrease, because the newly introduced milk quota payment does not sufficiently compensate income losses. This will mainly affect the income of big grassland farms with dairy production, like in East Germany or the UK, especially those that employ hired labour will react quickly. The degree of income losses at grassland farms also strongly depends on the development of beef prices. Increasing beef prices as a consequence of decreasing production mitigate income losses of grassland farms. Therefore, smaller German grassland farms with up to 35 cows, which hold more than half of finishing bulls, have significant lower income losses and increasing incomes, respectively, than bigger specialised dairy farms (Offermann *et al*., 2003).

The area payment for less favoured areas did not show a significant effect on the production of suckling cows. To what extent agri-environmental schemes can stabilise extensive suckling cow production has not been investigated so far. But it can be expected that agri-environmental measures for grassland, which are today already highly linked with suckling cow production will play a major role in future adaptation strategies. Particularly as rural development measures are strengthened by the reform. The budgets of Community support for agri-environmental measures are increased by the funds from modulation and new elements of support like food quality measures, aids for meeting standards and animal welfare measures are introduced. However, the cross-compliance regulation could endanger the current grassland payments in the agri-environmental schemes. If the restrictions of the current grassland schemes are already covered by cross compliance, the former schemes might have to be abolished (Miller, 2003).

However, economic reasoning advises to decouple payments from production as far as possible (Wissenschaftlicher Beirat, 2003). Full decoupling is expected to reduce administrative burdens and to give full freedom to decide on production priorities by technical and business considerations (Häring *et al.*, 2004). The market, not state planning, determines the allocation of resources, which should lead to a more efficient situation. Partial decoupling, especially in beef production, would slow down these economically preferable structural changes and alleviate the reduction of beef production. For this reason some member states have already decided to go this route.

4 Discussion and conclusions

Farm economists tend to look at farms as systems that combine certain inputs (land, labour and capital) in order to produce a number of outputs. Land as an input has some special characteristics which are closely connected to the fact that it is a natural resource: It is immobile, its productivity can only be changed in a limited range and total supply is limited. Because agricultural production is not only producing private goods, but is also affecting public goods like biodiversity and landscape a multitude of legal restrictions apply to land use which tend to limit further a flexible use of the land. In contrast to arable land grassland only allows to produce a rather limited number of agricultural products, which means it is an input even less flexible than arable land.

The increasing economic pressure under which grassland farmers have come has much to do with the lack of alternatives in production. At the same time demand for the products produced from grassland has decreased and even within dairy and beef production other foodstuff than grass has gained in importance. Decreasing cereal prices made it profitable from the viewpoint of many farmers to substitute grass by cereals, especially as this allows higher milk yield per cow, which tends to lower production cost kg^{-1} milk. Technical progress in milk production happened, but it was actually to the disfavour of grassland.

In general agricultural policy has favoured arable land more than grassland over the last decades. However, milk prices and beef prices though depressed from the viewpoint of many farmers are still farther from world market prices than are cereal prices. The Luxemburg compromise is about to change this, which will be a further blow to grassland use. On the other hand agricultural policy recognises the importance of grassland and the public goods it provides especially in terms of biodiversity and landscape, and more recently also with respect to flood protection and erosion control. The programs that resulted from these insights have in some regions been quite successful, but have not reversed the total trend of problematic profitability of grassland use. In the overall picture government by buying public goods has not been a full substitute for the decreased demand for the private goods produced from grassland.

A combination that still has some potential seems to be the combination of such agri-environmental programs with an attempt to market the products at a higher price. The most prominent example of this is organic farming. However, also here potential is limited, as a further increase of organic farming on grassland might lead to an even more skewed distribution of organic products produced and might result in difficulties to market all of these products at premium prices.

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Competitive ‘low cost’ dairy cattle production in Switzerland

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Abstract

Most regions of Switzerland are dominated by grassland. Milk production costs are high, because farms have small structures and the general cost level is high. The central question for Swiss dairy farmers is how to reduce the costs to reach competitiveness under future conditions. In the project OptiMilch of the Swiss College of Agriculture (SCA) nine farms are improving their ‘low cost’ strategy. The goal is integrated sustainability (economic, ecological, social) over the next ten years. For each farm, an individual strategic and operational planning as well as a controlling concept based on the balanced scorecard approach was worked out. The implementation of the production systems has been successful and the farmer families fully identify themselves with the strategy. The targets set indicate that the economic sustainability of milk production and total family income can be improved, ecologic sustainability can be achieved and social sustainability does not suffer from the better economic sustainability.

Keywords: competitiveness, dairy farms, milk production costs, ‘low cost’, balanced scorecard

Introduction

In the project OptiMilch (2000-2003) of the Swiss College of Agriculture (SCA) the world-wide successful milk production strategies ‘low cost’ and ‘high input’ are adapted and optimised under Swiss lowland conditions. Nine pilot farms are improving their Low Cost-strategy (reduction of costs and labour by reducing external inputs, forage conservation and farm infrastructure and optimising the management). In this contribution the first experiences with the ‘low cost’ strategy and the prospects of the pilot farms with the strategy in the following years are summarized. The goal is integrated sustainability (economic, ecological, social) over the next ten years.

Materials and methods

From 2000 to 2003 nine typical Swiss dairy farms started implementing the ‘low cost’ strategy. As shown in table 1 the starting point of the experimental farms was not too different from normal Swiss dairy farms. In the first three years the technical consequences of implementing the new strategy were measurable, but not yet the economic ones. Based on the first experiences and technical successes, the further development of the family farms must be estimated with economic, ecological and social sustainability indicators. For each farm an individual, strategic and operational planning as well as a balanced scorecard based controlling concept were developed. Thus, it was possible to show the start position, the actual state and the target position of each pilot farm.

Results and discussion

So far, the implementation of the production systems has been successful on all the pilot farms and farmer families fully identify themselves with the new strategy. All ‘low cost’ farms are practising seasonal calving in spring and the average weight of the cows is no longer increasing.

The structural data of the average target position for the 'low cost' Pilot farms is given in table 1. The area should increase, but this will be difficult due to the general scarcity of land and the direct payment rules. The number of cows is expected to double and within the cattle business the farms are expected to increasingly specialise on dairy production only. Due to the requirement of land, crop production will decline but other income sources like pig production or second jobs will be kept up.

Table 1. Comparison of the structural data of Swiss Plain farms in 2000 (FAT, 2001) and the Low Cost-pilot-farms in the real position 2000 and in the target position 2010.

	Swiss Dairy farms	*Low Cost Pilot Farms*	
Group	*PLAIN 2000*	*REALITY 2000*	*TARGET 2010*
Number of farms	*249*	*9*	*9*
area used for agriculture (ha)	17.4	23.1	28.9
area used for cattle (ha)	-	18.4	24.7
grassland (ha)	15.1	16.5	23.0
livestock units, cattle equivalent	28.2	40.5	59.1
livestock units per ha	1.62	1.75	2.05
Number of cows	20.7	23.8	45.3
Number of cattle units	27.1	30.1	46.9
Cows / cattle units (%)	76%	79%	97%
Milk yield per cow (kg)	6500	5881	5967
Produced milk (kg)	135000	140017	270441
Number of man-hours (total)	4704	5736	5518
Number of man-hours (cattle)	-	3524	3635
Number of family-hours	3696	3503	3224

Figure 1 shows a set of relevant indicators (axes) for full scale sustainability and the development of the total sustainability index (surface enclosed by the line connecting the indicators). The axes do not indicate an absolute level, but rather a development between a initial situation (equal to 100 percent) and the target situation.

The axes 1 to 4 are indicators for the economic sustainability of the milk production. The outside costs per kilogram of milk (axe 1) will be reduced strongly, and the labour productivity will be increased (axe 3). The result will be a much higher income per hour of family work (axe 2). The area productivity will improve from 8000 to 11000 kg milk per hectare (axe 4).

The economic sustainability of the family farm will also be improved: The agricultural income (axe 5 in figure 1) as well as the equity capital formation (axe 6) which are the main ratios of the profit and loss statement, will be better in 2010 than in 2000, in spite of lower product prices and higher private consumptions (axe 7). The latter is mainly due to the fact that most of the farms will then have children in education. The operational cash flow, the difference between deposits and payouts of the farm activities, will also increase (axe 8).

The ecologic sustainability is shown by the indicators 9 to 11. The average ecological status (conventional, integrated, organic; axe 9) will only improve marginally, because the number of organic farms is only expected to increase from one to two farms by 2010. There will be two instead of one biological farm today. Integrated production is a mandatory condition to receive direct payments in Switzerland and these are absolutely necessary to survive. With the expected increase in the proportion of grassland, the soil protection index (axe 10) will remain constant. Only the present overcapacity of the slurry storage capacity (axe 11) will be reduced due to the increasing stock size (Table 1).

The social sustainability is not expected to suffer because of trade-offs with the improved economic sustainability. Family work hours (axe 12) can be reduced slightly, the average state of indebtedness (axe 13), often a very stressing factor, is not worse in spite of large investments in two farms. The number of holiday weeks will increase (axe 14) as well as the days of further education (axe 15). These improvements on most of the nine pilot farms can at least partly be considered to be a result of the individual operational planning performed in the framework of the project.

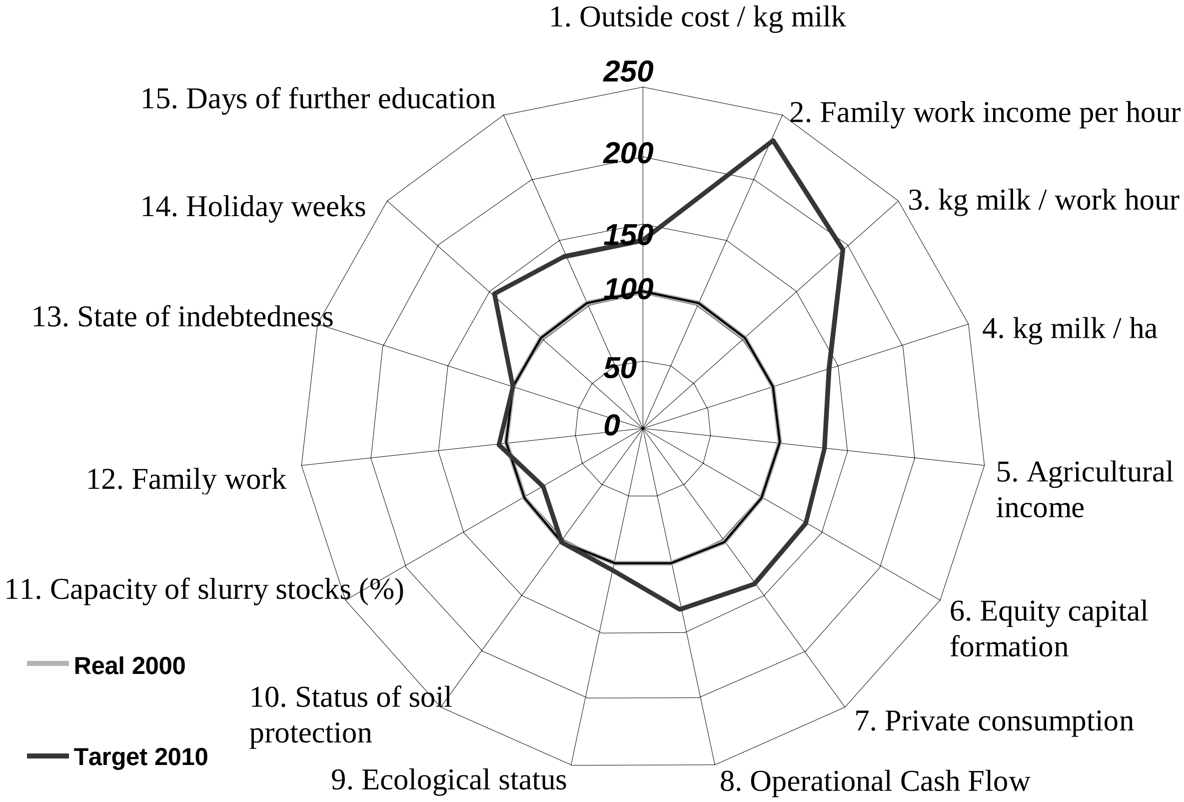

Figure 1. Development in the integrated sustainability of the ‘low cost’ Pilot farms between 2000 (reality) and 2010 (target). Not weighted average over nine pilot farms.

Conclusions

The ‘low cost’ dairy production strategy is possible in the Swiss plain region and can help to reach a good overall level of sustainability. There are two conditions to meet this target: 1) the optimised and individually adapted implementation of a farm-specific ‘low cost’ production strategy and 2) the realization of economies of scale by increasing the milk quantities with low investments. Taking into account the rather long-term planning horizon, it can be expected that only about one quarter to one third of the Swiss dairy farms in the lowlands fulfil the conditions to establish such a system. More Swiss dairy farmers will choose the High Input strategy. They will be forced to increase their milk quantities much more and faster than ‘low cost’ dairy farms. From the viewpoint of macroeconomic sustainability (velocity of change of the structures), it would be advisable for all farms that fulfil the necessary conditions to adopt a ‘low cost’ milk production strategy.

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Efficient and effective policies to prevent fallow land at high altitudes in Swiss mountain regions

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Abstract

Fallow land in the Swiss mountains may generate negative external effects such as landslides and avalanches or hinder the provision of public goods, e.g., biodiversity. Therefore, in mountainous regions, direct payments linked to land use play a key role in Swiss agricultural policy. We present a regionalised spatial land use optimisation model for this particular zone. With the help of this model, we investigate the structural and economic effects of agricultural policies that aim to ensure cultivation at high altitudes. The results show that in future, the emergence of fallow land will be a regional and site-specific problem, the extent of which will furthermore depend on the structural development of the agricultural sector. Hence, in order to be ecologically effective and economically efficient, direct payments which are related to land-use and specifically designed to prevent the emergence of fallow land at high altitudes must be allocated on a regional and site-specific basis.

Keywords: land use, fallow land, agricultural policy, direct payments, linear programming model

Introduction

Agricultural land use offers obvious examples of spatial environmental externalities. Soil erosion and loss of biodiversity are manifestations of the negative effects of inadequate land exploitation. On the other hand, appropriate land use prevents the emergence of these negative externalities. These types of spatial externalities are particularly pronounced in mountain regions. Therefore, agricultural direct payments linked to land use play a key role in the prevention of these negative externalities and the provision of public goods in the Swiss mountain area. In view of the substantial, publicly financed support, it is legitimate to analyse whether existing policy objectives are achieved effectively and efficiently with the current policy. For this purpose, a regionalised spatial land use optimisation model has been developed (Flury, 2002). It allows the analysis of site-specific policy measures on a regional level. In this paper we analyse the regional importance of fallow land at high altitudes and the structural and economic effects of its prevention as one positive externality of grassland cultivation.

The model and the scenarios

The model is a comparative-static linear programming model, the object of which is to maximise the sectoral revenue of agriculture in the overall model region which is sub-divided into 40 sub-regions. This is achieved by means of optimal allocation of production factors among farm types in the different sub-regions, giving due consideration to the restrictions of each level of aggregation (farm, sub-region, overall model region). The model includes various farm types cultivating grassland for different types of cattle and sheep as well as both full-time and part-time farms. The land can be used at two different levels of intensity. Spatial data from different geographic information systems and public statistical databases on a per hectare grid is integrated for six levels of altitude and four categories of slope. Input requirements are functions of land use activity and topographic situation.

The analysis of policy alternatives compares a reference solution for the year 2000 and a projection solution for the year 2010. The future scenario reflects an integration of Switzerland into the EU. Agricultural price support is eliminated and factor costs are adjusted to the lower EU level.
Within the context of the future scenario, the average annual decline in the number of farms and labour is a decisive characteristic. Farm growth allows the use of economies of size and results in lower cost and higher farm income. Since the future speed of structural change is uncertain, results are presented for two different assumptions: 2.5 % decline in the number of farms corresponds roughly to the empirical development observed in Switzerland over the last ten years; 5 % represents approximately the rate observed when no restrictions are placed on the decrease in the number of farms in the model.

Results and discussion

The assurance of land use at high altitudes is of particular relevance for the conservation of biodiversity and the prevention of negative externalities such as landslides (see, e.g., Niemeyer *et al*., 2001; Mössmer, 1985). Therefore, in the following we use a model to investigate the future development of fallow land over 1500 metres above sea level (asl). There are roughly 260,000 ha of agricultural land in the overall model area and approximately 31,000 ha are located at or above this altitude (see table 1, first column). Two thirds are located between 1500-1800 m asl and one third is even higher. About two thirds of this land is in the Canton of Grisons, approximately one sixth in the Canton of Valais. The remaining sixth is located in the other five model regions.
There is virtually no fallow land in the reference situation. Under the assumptions of the future scenario, 1800 ha lay fallow between 1500-1800 m and a further 1700 ha above 1800 m asl when a 2.5 % annual decline in the number of farms is assumed. Considerably more land (3800 and 5500 ha, respectively) lays fallow at 5 % annual decline in the number of farms. In addition, it can be seen that the largest amount of fallow land exists in the two regions where the greatest acreage of land is available at high altitudes. Fallow land emerges because farmers take the cost of their own labour into account in their long-term planning: potential earnings of farm labour outside the agricultural sector (the so-called opportunity costs of labour) are considered when labour allocation decisions are made. These additional costs provide a general explanation for the emergence of fallow land in the long range. Higher labour costs make it unprofitable to cultivate remote areas (with higher transportation costs that are duly considered in the model) and land at higher altitudes with an adverse benefit-cost ratio due to lower yields. Differences in farm size and activities represent yet another reason for the regional variation of fallow land.
The fallow land share is negligible (less than 1-2 %) in the overall model area (260,000 ha). Disaggregated to the regional level and different altitudes, however, the situation must be interpreted differently: up to 60 % of the available land lay fallow at the highest altitude in the Canton of Valais. Such important shares may seriously affect the provision of public goods and cause considerable negative externalities at a regional and local level.
Enforced cultivation of fallow land would lead to a decline in the revenue of the agricultural sector. This loss in income can be measured by the so-called shadow price (last column of table 1). A shadow price is a price that emerges as a solution to an optimisation problem. It is an implicit or 'planning' price that a good, or in that case a productive input will take if resources are allocated optimally. In table 1 it corresponds to the increase in revenue that would arise without enforced overall cultivation of fallow land. Or, given that the amounts indicated were granted, overall cultivation of fallow land would be carried out without any loss in revenue to the agricultural sector. The most pronounced variation in shadow prices can be observed between the various regions. The required payments are over eight times higher

in Valais than in Grisons. If uniform payments were granted, as it is the case under the present system, these payments would have to be fixed at the highest regional shadow price in order to ensure cultivation of the overall fallow area. Under these circumstances, the payments granted in most regions would be far too high and this would result in economic rents. This is inefficient from an economic point of view. If payments were granted that were lower than the maximum shadow price (e.g., average values applied to the overall region) land in regions with above-average shadow prices would not be cultivated. This is both ineffective and inefficient. On the one hand, the ecological objective is not fully achieved and on the other hand, excessively high payments are granted to regions with shadow prices below-average to ensure the cultivation of their land. Shadow prices vary considerably between levels of altitude and farm size growth rates. Higher payments are necessary at higher altitudes and when structural change advances more rapidly because a greater area of land lays fallow when more members of the labour force are encouraged to leave the agricultural sector. This, in turn, necessitates higher payments for the prevention of fallow land.

Table 1. Farmland available in the reference solution, fallow land at 2.5 % and 5 % average annual decrease in the number of farms in the overall model region and in the two cantons of Grisons and Valais at different altitudes and shadow prices for land use.

			Average annual rate in decline in farm number					
			2.5 %			5 %		
Region	m asl altitude	Hectares of farmland available	Hectares of fallow	% fallow of farmland	CHF shadow price	Hectares of fallow	% fallow of farmland	CHF shadow price
Overall	1500-1800	20601	1812	9	67	3766	18	110
Overall	>1800	10471	1664	16	81	5521	53	126
Grisons	1500-1800	11937	532	5	37	884	7	46
Grisons	>1800	8325	1087	13	59	4566	55	109
Valais	1500-1800	3776	985	26	218	2204	58	305
Valais	>1800	1111	393	35	284	666	60	354

Conclusions

In the future, the emergence of fallow land will be a regional and site-specific problem the extent of which will, in addition, depend on the structural development of the agricultural sector. Large shares of fallow land at high altitudes in certain regions may be gravely detrimental to the provision of public goods such as biodiversity and cause considerable negative externalities. The payments necessary for the prevention of fallow land vary considerably from one region to another and are also governed by the level of altitude involved. Hence, regional, site-specific direct payments for the prevention of fallow land at high altitudes are both ecologically more effective and economically more efficient.

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Multifunctionality and agricultural subsidies in the mountainous grassland of Austria

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Abstract

Field-level analyses in two Austrian case study areas recorded firstly, the number of ecological and other services individual parcels of grassland were required to fulfil and secondly, the degree to which the number of such services corresponded with the level of related public subsidies. There was no relationship between the level of farm-based flat rate subsidies and the number of different non-agricultural functions served by grassland fields. However, there was a correlation between field-based subsidies and the use of grassland for disaster protection (against avalanches and landslides), for recreation, hunting and nature conservation, as well as for secondary infrastructure requirements (e.g., buffer zones for power lines). The subsidies paid are at their highest (about 450 € ha^{-1}) in association with fields serving three different non-agricultural uses.

Keywords: multifunctionality, grassland, subsidies

Introduction

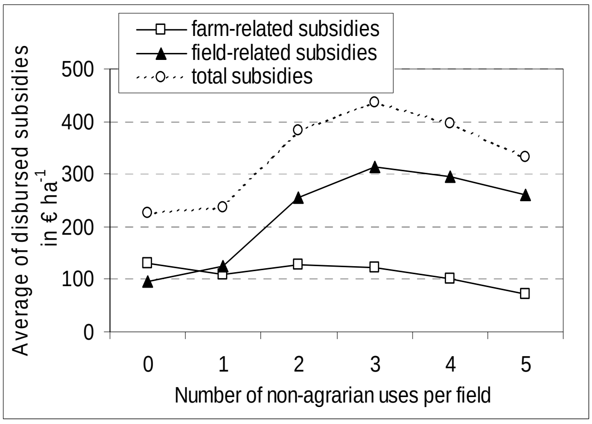
One of the reasons used to justify subsidies to grassland enterprises is the external benefits created by pastures and meadows (e.g., Lankoski and Ollikainen, 2003; Doussan *et al*., 2000), especially given the growing demand for these benefits. In addition to fodder production, the demands placed on grassland include such uses as nature conservation, water management, recreation, tourism and hunting. This raises the issue of how much correlation there is between the diversity of non-agricultural demands placed on grassland and the level of subsidy payments received (particularly those given within the context of ÖPUL, the Austrian agri-environmental program). An understanding of the interdependence of grassland multifunctionality and public payments to grassland enterprises is likely to offer insights into how public funds could be used more effectively.

Materials and methods

The study is based on the assumption that grassland multifunctionality is expressed as a series of different single uses/demands overlying each other on the same area of land. The nature and number of such uses on 599 specific parcels of grassland were surveyed in 2000 and 2001 in two mountainous case study areas (the cadastral mountain communities Artolz and Münichreith in Waldviertel/Lower Austria and St. Johann in Tyrol). Two survey methods were used: standardised interviews with 52 grassland farmers and systematic analyses of designated land use plans. Information on area-based ÖPUL payments was gathered from official records, particularly from the so-called 'Mehrfachanträgen', and covered the following individual subsidy measures: 'basic subsidy', 'organic farming', 'reduction of yield-increasing inputs on grassland', 'renunciation of yield-increasing inputs on grassland', 'keeping the cultural landscape open', 'maintenance of meadow orchards', 'renunciation of the use of silage', 'maintenance of ecologically valuable areas' and the regional project 'Ecopoints Lower Austria'. The efficient allocation of disbursed monies should result in a correlation between the amount of direct or indirect area-related payments and the number of non-agricultural uses. This hypothesis was examined using chi square tests and Spearman correlations (non-parametric tests had to be used because the variables were not distributed normally).

Results

All the surveyed grassland fields received payments through ÖPUL. The pastures and meadows surveyed fulfilled an average of two non-agricultural uses, but 42 fields (7 %) served only agricultural functions, while 49 fields (8 %) had four additional uses. One field served five non-agricultural functions (Figure 1). The farm-based subsidies ranged between 130 € ha^{-1} (agricultural use only) and 73 € ha^{-1} (fivefold non-agricultural use), with about 100 € ha^{-1} for four non-agricultural uses. The highest amount of farm-related subsidies (approx. 130 € ha^{-1}) were paid in association with pastures and meadows featuring two non-agricultural uses (Figure 2). Field-based ÖPUL-payments ranged between 95 € ha^{-1} (no additional demands) and 295 € ha^{-1} (four non-agricultural demands), with 260 € ha^{-1} paid where there were five non-agricultural uses. Grassland fields fulfilling three non-agricultural uses received the largest field-based subsidies (315 € ha^{-1}). Total ÖPUL payments reflected in particular the field-related payments: farms got 225 € ha^{-1} for areas used solely for agriculture, the highest amount (about 435 € ha^{-1}) for three non-agricultural uses, 400 € ha^{-1} for the fulfilment of four non-agricultural demands and 330 € ha^{-1} for addressing five such demands.



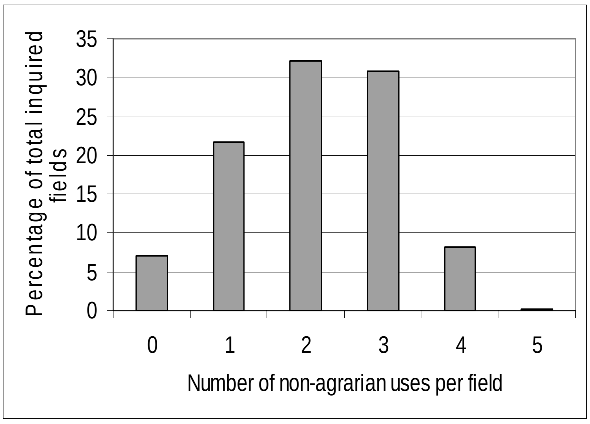


Figure 1. Frequency of total non-agricultural uses per field (left) and amount of subsidies per total non-agrarian use (right).

Chi square tests identified no relationships between disbursed subsidies and military or water management uses. Relationships were examined in more detail using Spearman correlation coefficients (Table 1). There were very weak relationships between recreational use of grassland fields and both farm- and field-based payments. Field-based subsidies showed very weak correlations with the use of grassland as disaster protection areas, for secondary infrastructural requirements, and for hunting, and in relation to the total number of non-agricultural uses. These correlations impacted on the interactions between the total amount of subsidy and individual non-agricultural uses of grassland. Field-based payments compensated in particular for use for nature conservation, as the weak – but highly significant – correlations demonstrated. However, the reverse is the case for farm-based payments. Further analyses of correlations between individual ÖPUL-measures and nature conservation use showed that the 'Ecopoints Lower Austria' measure in particular influences this result (r = -0.246), because it mainly supports regions featuring few landscape elements and which are outside designated nature conservation areas.

Table 1. Correlations between non-agricultural uses of grassland and related farm-based, field-based and total subsidies.

Non-agrarian using forms	Farm-related subsidies		Field-related subsidies		Total disbursed subsidies	
	Coefficient of correlation by Spearman	Level of significance	Coefficient of correlation by Spearman	Level of significance	Coefficient of correlation by Spearman	Level of significance
Military use	-0.075	n.s.	0.01	n.s.	-0.041	n.s.
Use as danger zones and safety areas	0.053	n.s.	0.139	**	0.136	**
Recreational use	0.107	**	0.11	**	0.131	**
Use by nature conservation	-0.341	**	0.384	**	0.301	**
Secondary spatial use	0.039	n.s.	0.131	**	0.115	**
Hunting use	0.053	n.s.	0.189	**	0.169	**
Use by water management	-0.049	n.s.	0.03	n.s.	0.009	n.s.
Sum of non-agrarian using forms	-0.034	n.s.	0.384	**	0.341	**

n.s.: not significant *significant on the level of 0,05 **significant on the level of 0,01

Discussion and conclusions

Total subsidies per hectare increased with the number of simultaneous uses cited by the farmers up to and including three non-agricultural uses, but declined with any additional uses. It may be that grassland fields supporting as many as four or five additional non-agricultural uses have such intensive demands placed on them that the manager is no longer able to incorporate these parcels of land in appropriate ÖPUL measures. Alternatively, it is possible that ÖPUL only supports some of the social demands placed on grassland (such as for nature conservation), as a result of which other non-agricultural uses (like water management or hunting) remain uncompensated (see Wytrzens and Neuwirth, 2003). There are two possible explanations as to why higher farm-based subsidies correlated with a lower likelihood of the grassland being within a nature conservation area or involved in contracted nature conservation. It may be that areas outside official nature conservation areas get higher levels of subsidy to try and guarantee continuous nature conservation outside of these declared conservation areas. Or alternatively, ÖPUL measures – and the Ecopoints Lower Austria measure in particular – are not sufficiently oriented to nature conservation needs. The partial deficits in the public compensation of multifunctionality in grassland areas demonstrate that the efficiency of allocation of public resources for these purposes can be improved. In addition, the analysis of the designated land use plans for these areas (when compared with the farm survey results) showed that there were also deficits in the formal record of this multifunctionality, indicating improvements in this recording are required (in particular with regard to nature conservation).

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The optimum land-use plane for the Commune of Gjinar-Elbasan

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Abstract

The aim of the study was to prepare the scenario of the optimum land-use plane for the commune of Gjinary, Elbasan's district, discovering a development optimum which consider the ecological and social potentials, respecting traditions and improving them, to found the commune which to fulfil the needs itself, therefore to fight the poverty and emigration of peoples. Questioners of the people, the studies of ecological and social potentials and, making the actual and improved energetically balance between production and needs of people and livestock implemented the necessary figures.
Data processing carried out by the Excel and Arkinfo/Arkview programmed which, making the stratification analyse of maps, prepared the Optimum Land-use Plane Scenarios respecting the priority mission solutions, sustainable development and erosion control.

Keywords: scenario, sustainable, erosion control, pasture, energy

Introduction

The social transformations happened; increasing and emigration of population, in the new factitious conditions want and give the other solution possibilities to have more rational land-use and profits for rural population.

Methods

The traditions, economical activities and desires of inhabitants of Commune Gjinar-Elbasn to develop by means of questionnaires (a handred questionnaires) were known; all figures on relieve, clime, soil, erosion (situation and potential), vegetation, population, livestock husbandry, productivity of crops, livestock, pastures and forests by means of field expeditions and from some carried out studies for all 140 plots (area of each one plot was to 50 hectares) were collected; the needs calculations of population for energy and food and, livestock husbandry for fodder after composed matters (carbohydrate, proteins, fatty substances) were carried out also, costs and incomes were calculated; the productive ecological potential and development priorities were identified and, all collected figures by means of the Excel and Arkinfo/Arkview programmes were processed which, making the stratification analyse of maps, the Optimum Land-use Plane Scenarios respecting the priority mission solutions, sustainable development and erosion control, were prepared (Karadumi *et al*., 2003).

Results and discussion

As the activity areas of the country people traditionally and for the future, agriculture, livestock husbandry and too little forestry will be remained. Amongst the crops wheat, corn, horts etc. also in the farming, the chicken, sheep, cattle, horses, pigs, etc. and goats were traditionally and will be remain the main activities.
In this commune there were active populations and therefore, there is the large human potential for their future development.

Improving the made products amount and energy indicators in line of the full food regulation, Commune of Gjinary-Elbasan could maintain with food and energy, the population of 6,564 people or to 64.2 % of its increasing to compeer with actual population.

The full of livestock husbandry needs that be managed in Gjinary Commune is the lowest, 70 % of the energy needs and 65 % of protein needs only; these reflect to lowest production rate especially to cows with to 900 litres y^{-1}, raising more extensively and unprofitable.

In conditions of limited fodder base must increase the first forage culture area, to increase their rates for each unit of area and also, to reduce more the number of small livestock heads, also and, cows number to reduce to 2 heads for each one hectare.

After the climatically, topographical and land indexes as: temperatures, precipitations etc. elevation, slope, expositions etc., depth, stones, erosion, pH etc. the land area must use more for forestry and fruit-tree cultures and, less for agriculture and pastures also, the machineries to use for their cultivation will be too much difficulty or specially (Karadumi *et al*., 2003).

Conclusions

The proposed variant of optimum land use plane more adapted is given in table 1 and in the figure 1 (Karadumi *et al*., 2003). All changes, in conditions of erosion risk, want the indispensable measures to control the erosion.

Table 1. Actual and optimum land use plane scenarios.

	Actual situation		Proposals	
	ha	%	ha	%
Arable lands	1,656.10	22.89	1,656.10	22.89
Fruit-tree	78.30	1.08	519.00	7.17
Olive-tree	-	-	207.00	2.86
Vineyards	-	-	530.50	7.33
Forest	3,662.38	50.62	1,743.52	24.09
Natural Pastures	721.35	9.97	721.35	9.97
Meadow	-	-	741.00	10.24
Unproductive	115.63	1.60	115.63	1.60
Settlements	40.04	0.55	40.04	0.55
Sport area	0.77	0.01	0.77	0.01
Bare terrenes	354.23	4.90	354.23	4.90
Eroded terrenes	606.51	8.38	-	-
Reforestation, grasses cover	-	-	606.51	8.38

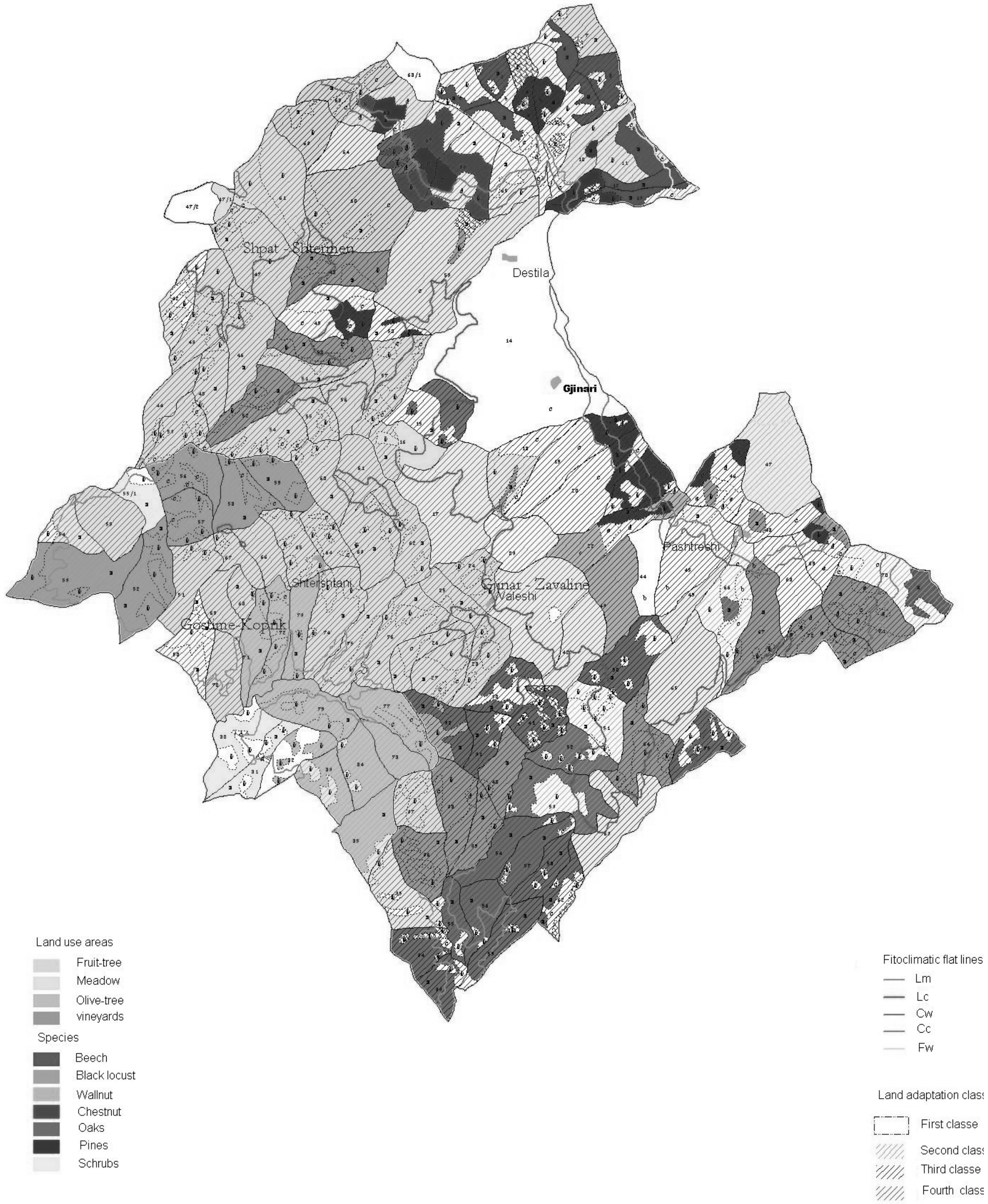

Figure 1. Optimum Land Use Plane Scenario.

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Grassland conservation projects: methodology of assessment, achievements and obstacles

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Abstract

Less favoured grassland areas such as upland meadows or those alongside rivers are often botanically diverse. Conservationists argue for management practices which support this diversity. This is often contradictory to the management plans of farmers who, to improve the quality of their grass crop, use these grasslands intensively and therefore typical species become endangered.
To balance the ecological, economic and social demands on such grasslands, agri-environmental schemes and other governmental programmes were introduced.
Using case studies of three projects in Saxony and a survey of grassland conservation projects in Western Europe, the approaches and contents of schemes and projects were examined and obstacles to participation in schemes and key factors of success were identified.
The methodology for the assessment included organisational analysis and network analysis. Whilst network analysis is already extensively used in environmental politics, its use in combination with organisational theories is a relatively new approach.
The factors of success of grassland conservation projects included the clear formulation of aims, the composition of stakeholder groups, communication channels, structure of organisations, adequate and stable finances and the quality of monitoring. The obstacles identified were competing schemes within projects and stakeholders not being very informed about schemes which promote diversity.

Keywords: conservation, factors of success, grassland, network analysis

Introduction

Upland meadows or grasslands alongside rivers are often botanically diverse. Farmers tend to either intensify the use of these grasslands to improve the grass crop or stop production on these least favoured grassland areas. Both strategies lead to a decrease in grassland species, and can even result in loss of grassland and therefore a loss of landscape features. Consequently, programmes which reward management practices which support diversity have been argued for. However, the measures, although often economically profitable, have not been implemented to a satisfactory degree in practice. Even projects which are specifically designed to encourage farmers to implement measures often do not make the anticipated impact. The reasons for this and the key factors of successful projects were investigated using three case studies in Saxony and a survey of projects across Western Europe.

Materials and methods

The methodology of the assessment for the three case studies included both organisational and network analyses, a comprehensive literature search and interviews with stakeholders.

The analyses provided a comprehensive assessment of the projects and an understanding of how and to what degree programmes had been implemented.
Organisational analysis assesses the efficiency of an enterprise and places an emphasis on the structures of projects and their implementation. To use this method effectively, it is important to decide beforehand which level of the organisation is to be assessed: the individual parts of the organisation, the organisation as a whole or its impact on the outside world.
Network analysis is used to study networks, which are based on political, economic and social relationships between stakeholders (Kriz *et al*., 1994).
The case studies were on species conservation projects on upland meadows and riverside grassland in the plains of the river Mulde and the development of a landscape plan for a biosphere reservation in the east of Saxony, an area with a unique combination of heaths, ponds, forests and intensively used agricultural areas.
Additionally, a survey of grassland conservation projects across Western Europe was carried out in order to put the detailed findings of the case studies into a wider perspective. Twenty reference projects were selected from one hundred projects on the basis of their success. These projects integrated agricultural practices and nature conservation by using available funding schemes and recommending implementation options to farmers.

Results

In the case studies in Saxony, a cultural landscape programme based on EC Reg. 1257/1999, which included several measures (see table 1), had been suggested for use in these projects. The review of this programme (RL-Nr.: 73/2000) showed that a number of measures for maintaining extensive grasslands are funded to about the same degree, although they entail different costs. For example, the extensive use of meadows which restricts cutting, by delaying the first cut until after the 16th of June and prohibits the use of agrochemicals, is promoted by a yearly payment of 102 € ha^{-1}. The same amount is received by farmers when the land is extensively grazed, i.e., grazing with a limited stocking rate and the prohibition of using agro-chemicals. For farms with cattle and sheep production, grazing is usually more cost effective than cutting. Therefore for economic reasons, grazing options, although less suitable especially for the conservation of upland meadows in Saxony, are more competitive and are preferred to cutting options. Also, as programmes are very diverse, there was often a lack of awareness of measures offered even amongst those stakeholders who, because of their professional background, should be fully informed.

Table 1. Funding of grassland conservation measures in Saxony.

Measure	Explanation/Remarks	Funding in € ha^{-1}
Extensive use of meadow	Mowing after June 15th, no agro chemicals	102
Extensive grazing	Grazing, no agro chemicals	102
Conservation grazing	Conservation grazing management according to agreement with nature conservation office	360
Conservation mowing	Conservation mowing management according to agreement with nature conservation office	
	- mesotrophic meadow (typical hay meadow)	360
	- wet meadow	410
	- upland meadow	450
Sheep	Extensive grazing with sheep	410

Source: Regulation of the Saxon Ministry for Environment and Agriculture to promote environmental friendly agriculture, RL-Nr.: 73/2000.

The findings of the case studies showed that it was difficult for project stakeholders to choose measures with the purpose of protecting certain plant communities and to convince farmers to employ them.

In general, the analyses of the case studies and the reference projects in Europe showed that there are specific factors of projects which are of major importance to the successful integration of nature conservation and agriculture. The factors are:

1. Aims: a clear formulation of the aim of the project and the breaking down of the overall aim into smaller targets which serve as stepping stones, help to achieve success. Even if only some aims are reached, the projects can be classified as having been successful, and the reasons for not achieving other aims can be investigated and adaptations can be made.
2. Stakeholders: the integration of all relevant stakeholders, especially the regional opinion leaders in the decision making process of whether and how a project should be carried out supports the success of a project. Early integration promotes the reduction of prejudice, supports the identification of realistic aims and can avoid conflicts and resistance.
3. Project organisation: a clear structure of projects with a clear allocation of tasks is a basis for a fruitful cooperation of the integrated stakeholders and allows conflicts to be addressed and makes projects more transparent. The organisation should include the position of a project/programme leader or a representative who serves as the public contact person.
4. Communication: good and functioning communication is vital for project implementation. Over time specific communication channels will develop in projects and determine how successful the transfer of information and the integration of the stakeholders will be. Therefore communication channels should be regularly monitored.
5. Finances: sufficient and committed financial support to allow for the proper planning and implementation of projects provides the stakeholders with security and keeps motivation high. Also, a target oriented selection of measures to compensate farmers for management practices, which go beyond good agricultural practice is, crucial.
6. Monitoring: projects and programmes should undergo high quality periodical monitoring. This allows results to be recognised, strategies to be adapted and even possibly a decision to be made to end a project. Effective monitoring can form the basis of documentation and helps to communicate results to the public, which is important for local/regional backing and support.

Conclusions

Organisational analysis and network analysis are very useful tools for investigating projects to maintain and enhance biodiversity on grasslands. These methods allow for the identification of key factors which determine the outcome of projects.

The analyses showed that in projects which aim to integrate nature conservation and agriculture the key factors are often not considered enough, which is seen as one reason why many of these projects do not give the anticipated results. The available range of, sometimes competing, financial measures and the lack of information about them amongst the stakeholders present additional obstacles for the success of such projects.

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Comparing contributions of agriculture to environmental functions in a grassland area: method and results

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Abstract

Preserving the environmental functions of agriculture in a grassland area needs an original approach on the farm users and uses. Because the environmental functions depend on characteristics at a larger scale than field or whole farm, they must be studied on a continuous farming area, often run by several and different farms. The approach of such farmland area users and functions is rare and complex: preliminary methodological setting up is necessary to tackle the farming activity at this scale and as regards these functions. Our aim was to apply this double approach – definition of a methodological frame, then analysis of the farms and functions – on a continuous farming area of 350 ha run by 36 land-users in a grassland region. It emerges that there was a variety of contributions to environmental functions within one farm, as well as among various farms. These varieties arise from the heterogeneous quality of the used environments and of the various adaptations of the practices to these environments. This study provides approaches to define and to target means of action for grassland areas with strong environmental importance.

Keywords: multifunctionality of agriculture, territory, cattle farm, landscape

Introduction

For a few years, the attention of the land managers and scientists has been increasing towards the environmental functions of agriculture, and more globally towards its multifunctionality. The diagnoses made on the environmental functions for grasslands are often positive, because farming intensification is globally less developed than in crop areas with less risk of pollution, erosion and loss of biodiversity (Parris, 2002). Some authors highlight the heterogeneity and complexity of the environmental effects in and between livestock areas and farms (Chatellier and Vérité, 2003). In this context, it is necessary to analyse the achievement conditions of the environmental functions in a grassland area, for instance diversity, characteristics, determining factors. Our work addresses these issues at two levels: 1) elaboration of a characterization method of the achievement conditions of the environmental functions at the grassland area scale, 2) analysis of these conditions, of their diversity and determining factors for an area.

Materials and methods

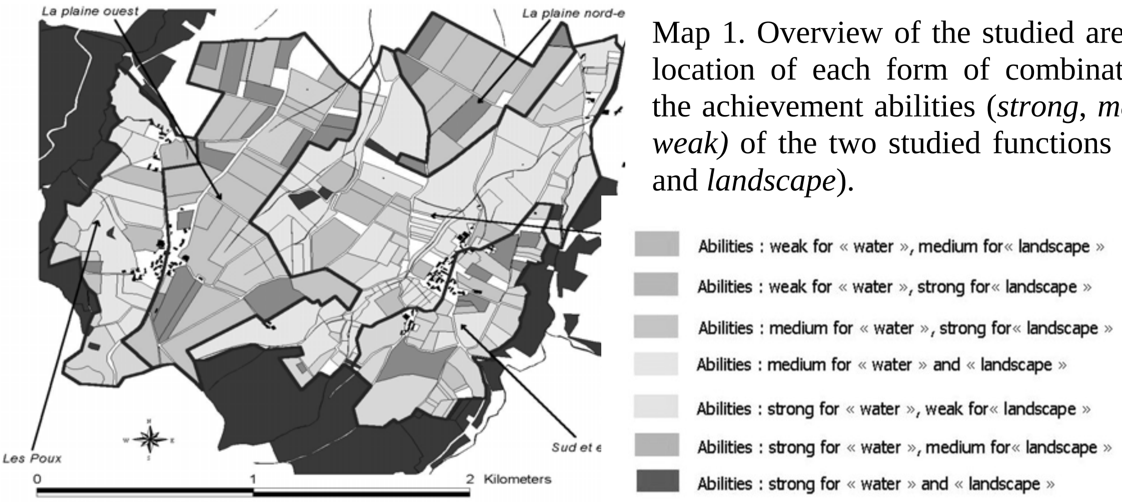
The functions of agriculture present specificities because of interactions between farming practices and the environment: spatio-temporal variability, constraints limiting the technical options for the farmer. Consequently, the characterization of the environmental functions requires methodological adjustments integrating the following points: 1) the environmental expectations towards agriculture take a variety of forms expressed at a global level but also at a local level, and focus on a large diversity of 'support-objects' (Beuret and Trehet, 2001); 2) the achievement of each function depends on the adequation practices-environment within territory entities appropriate for each function, and sometimes common to other functions

(Martin *et al*., 1998). In this context, it led us first to define and to use several terms for studying the achievement conditions of the environmental functions in a farmland area. For instance, the *function* is what should be achieved by a *farming entity* in order to satisfy a *user*'s *expectation.* The *entity* undergoes modifications because of interactions between farm practices and the environment (example: a hedge, a parcel). The *expectation* towards this entity is expressed in the speech of the person bearing this expectation or in regulation texts. The *user* of the farmland area has the prospect of an economic, recreational, or patrimony benefit for him without necessarily undertaking agricultural practices there (example: a botanist, an indoor livestock farmer). The support-entity of a function can be characterized by an *achievement level of the function* which depends on the satisfaction level of the user's expectation. This achievement level can be evaluated indirectly by observations on the support-entity compared to known characteristics on favourable conditions for the achievement of the function: this evaluation succeeds at an achievement ability rather than a real achievement level. *Combinations of achievement abilities of the functions* characterizes common or aggregated support-entities (parcels, sets of parcels, line of hedges). In a second stage of work, the elaborated terms and method were used on 350 farmland hectares in one piece including 215 ha of permanent grasslands. This area forms a large sloping terrace demarcated by a stream and the forest, and has 36 farming users. The diversity of the environments, users and uses motivated the choice of this area. The safeguarding of surface water quality and of landscape diversity were the two environmental functions studied, in a first stage, on the basis of surveys with local leaders and of national regulations. For each of the 239 farming parcels, the conditions of the environment (e.g., closeness to a stream, visibility from the surrounding ridges), of the practices (e.g., assessments of nitrogen and phosphorus, number of pesticide treatments, presence of bushes and hedges) and the more or less favourable satisfaction of these two conditions for the achievement of the two environmental functions, were defined from bibliographic references, maps and discussion with farmers. So for each parcel and each environmental function studied, was attributed one of three achievement abilities: '*weak ability*' when environment and practices are unfavourable to the achievement, '*strong*' when environment and practices are favourable, and '*medium*' in the other cases. Comparison of the achievement abilities and conditions of environmental functions in the studied area reveals important points and opens prospects of analysis and directions to develop the multifunctionality of grassland areas.

Results and discussion

Several facts seem to us particularly significant for the diversity of the contribution of agriculture to the environmental functions of grassland areas.

The combinations of achievement abilities of the two functions are very variable within the studied area. The map underneath illustrates this diversity: each level of grey tint corresponds to one of the 9 possible observable combinations [('*strong*' or '*medium*' or '*weak*' / '*water*') X ('*strong*' or '*medium*' or '*weak*' / '*landscape*')]. In spite of this diversity, homogeneous spatial entities appear on the map (surrounded by a bold stroke) with 29 to 49 farm's parcels in one piece that is 47 to 94 ha altogether. They do not generally include more than 3 of the 7 combinations of achievement abilities actually observed. They indicate a relative spatial organization of the achievement abilities of the environmental functions over the area. These homogeneous entities have been compared from their achievement abilities of the functions and from their grassland nature. For example, the West entity has the most grassland-like nature (71 % of its surface in permanent grasslands). *Les Poux* is similar to its East neighbour – *Plaine Ouest* -, in terms of achievement abilities of the 'water' function (60 % of the surface with a '*medium*' level, 25 % '*strong*', and 15 % '*weak*'), whereas this latest entity has a less grassland nature (38 % of permanent grasslands). Concerning the '*landscape*' function, the achievement abilities are steadily higher on this spatial entity (100 % of the surface with a '*strong*' level on *Plaine Ouest*, 100 % '*medium*' at *Les Poux*). These differences are partly explained by the environment: the 'landscape' environmental conditions are everywhere more favourable on *Plaine Ouest* than on *Les Poux*. The relationship is less direct for the '*water*' function ; when the unfavourable environment is a large part of the surface (61 % at *Les Poux*, 34 % at *Plaine Ouest*), the favourable practices cover a large part of the surface (71 % at *Les Poux*, 49 % at *Plaine Ouest)*, which eventually allows compensations between practices and environments ending in homogenizing the levels of achievement abilities of this function. These compensations more particularly concern the grassland portion of the area. We are not in a position to attribute a general nature to these conclusions based on a small area. Nevertheless we deduct from this study that: 1) a better contribution of farming to the environmental functions is not limited to actions on 'sensitive' areas or on 'aggressive' practices, the two approaches being necessary, 2) the study of the synergisms and antagonisms between practices and environments should be deepened for each function, more particularly in the grassland sectors where they seem frequent.



Map 1. Overview of the studied area with location of each form of combination of the achievement abilities (*strong*, *medium*, *weak)* of the two studied functions (*water* and *landscape*).

Conclusions

This work emphasizes the role of the spatial distribution of the parcels, and of the practices and uses of the whole farm parcels, for the achievement of environmental functions by farming. This spatial organization reflects on the productive functions of the farms, more particularly in stock breeding. We conclude that it is a key issue for understanding and for carrying out actions on the multifunctionality of agriculture.

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Forage production and economic analysis of the main types of farms in a Mediterranean agroforestry system

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Abstract

A large area of public land in Mediterranean agroforestry systems carries tenants livestock in numbers that exceed the carrying capacity of the pastureland. Consequently, the pastures are impoverished, shrub and tree regeneration damaged, and hence, farmers are obliged to feed the animals with additional forage or fodder in *extensive* systems throughout the year, including the grazing season. There is a need for range management plans which include an analysis of: (a) the potential carrying capacity of the pastureland in an ecologically viable condition and providing adequate nutrients for the animal's health and compatibility with other land uses (an essential aspect in Mediterranean agroforestry systems), (b) a complete livestock inventory (current pastureland carrying capacity) and (c) an economic analysis of the main types of farms. This paper shows a complete methodology for such range management plans for Mediterranean agroforestry systems and the results of its application in a Spanish region with a significant livestock tradition.

Keywords: agroforestry, pastureland carrying capacity, livestock, Mediterranean grassland.

Introduction

The studied area is located in the 'Sistema Central', one of the main mountainous regions of the Castilian Meseta, to the east of Avila Province, bordering Madrid Province. It takes up about 7,500 ha of the 'Las Navas del Marqués' township. The property, known as the 'Monte de Las Navas', is owned by the Monte Las Navas S.A., a society with over 75 % investment by the municipal government, and it is exploited by 77 farms in collective systems and 29 farms in individual systems (Table 1). In addition to public property, the studied area includes some private meadows (95.33 ha cultivated for hay) that are exploited in individual systems.

Table 1. Tenants livestock types in the 'Monte de Las Navas' property (3,640 ha grazed area).

Types[0]	Farm Systems	Sources			Products	NºFarms	Total numb.
		collective pastures	hay meadows	imported (% UF)			
Beef cattle	extensive	x	x	68.9	weaned calves	18	1,605
	extensive+fatstock	x	x	49.9	calves	19	2,141
	fatstock	-	x	100.0	calves	12	756
Dairy cattle	semi-intensive+fatstock	x	x	98.0	milk+calves	5	289
	semi-intensive	x	x	77.7	milk	11	289
	semi-intensive (fenced)	x	x	98.0	milk	12	1,154
	intensive	-	x	100.0	milk	17	840
Sheep	extensive	x	x	28.0	lambs	4	1,370
Goats	extensive	x	-	61.0	milk	8	2,631

[0]Breeds: limousine x avileña-negra ibérica (beef cattle), frisona (dairy cattle), manchega x merina (sheep), serrana (goats).

Today, the dairy cattle production systems need to import more than 77 % of the energy (UF). Setting aside dairy intensive systems that do not use the collective pastures (cowshed-cattle), the dairy semi-intensive systems only use a little area close to the milking plant (fenced or not) as it is necessary to gather cattle twice a day for milking. So today all the dairy cattle production systems are in fact intensive. Beef cattle and goats production systems (excluding fatstock) import more than 50 % of the energy (UF), so they should more accurately be called semi-intensive systems.

Materials and methods

A pastureland management plan must include three different types of inventory: a pastures inventory, a farms inventory and an infrastructures inventory. The pastures inventory was prepared based on an earlier classification of vegetation types, which was derived by digitising from the screen on digital orthophoto images (spatial resolution of 0.5 m/pixel), along with attribute data from a national vegetation database and fieldwork. We next built a grid with 375 inventory plots (1 plot/10 ha) located in the centres of the digitised polygons. These plots were surveyed by means of a Leica GS530 GPS. At each plot a botanical inventory was made, recording the taxonomical and syntaxonomical checklist (Rivas-Martínez, 2001). An abundance index was calculated for each taxon using a 'point quadrat' method. The forage production results (Table 2) were derived from this analysis and confirmed with bibliographical sources (San Miguel, 2000).

Table 2. Pasture syntaxa, productivity and occupied area at 'Monte de Las Navas' property.

Alliance	Syndynamic (order)	P(UF)[2]	A(ha)[3]
Tuberarion guttatae	*Poetalia bulbosae*	1082	2347
Molineriellion laevis	*Poetalia bulbosae*	472	269
Periballio-Trifolion subterranei	*Arrhenatheretalia/ Plantaginetalia majoris*	2453	797
Campanulo herminii-Nardion strictae	*Arrhenatheretalia/ Plantaginetalia majoris*	2214	170
Cynosurion cristati	*Plantaginetalia majoris*	4940	57

[2]P(UF)- Forage productivity in UF units /ha [3]A(ha)- Occupied area in ha.

The farms inventory includes field polls used to analyse the ownership, the ground location used by the livestock, the herd-type composition, the feeding, the production, the animal health, the management facilities, the farm implements and the personnel of the main types of farms. The results of the infrastructures inventory consist of several GPS surveyed geodatabases containing information on troughs, mangers, fences, roads, trails, and silos of collective use.

The results of the three inventories are organised in a geographical information system (ArcGIS 8.3) to output three basic geodatabases: (i) the current pastureland carrying capacity (derived from the farms inventory), (ii) the potential pastureland carrying capacity (derived from the pastures inventory and the forage productivity analysis, taking into account the availability and access to pastureland analysis made from the infrastructures inventory results; for example, the watering places buffer analysis) and (iii) the pastureland diagnosis (by the comparison of the two former spatial geodatabases). In this way, all the planned developments for the pastureland can be priced and the forage production increase quantified, so it is possible to compare the residual value of the pasture with the actual exploitation conditions and the potential residual value of the pasture with planned developments.

Results and discussion

The results of the economic analysis are shown in table 3. The high percentage of imported energy (UF) by the *extensive* systems (with low production) limits significantly the profitability of these farms. Only the dairy cattle farms yielded economic benefits without agrarian subsidies. Sheep, goat and beef cattle farms can only be considered as complementary activities, as their profit margins, even with official monetary help, do not allow a family to live on them.

Table 3. Farms economic analysis.

Types	Farm systems	Income[5]	Expenses	Profit margin	Subsidies	P.margin+Subs
Beef cattle	extensive	19,485	28,759	-9,274	16,678	7,404
	extensive+fatstock	27,112	32,836	-5,724	26,418	20,695
	fatstock	69,600	79,009	-9,409	25,230	15,821
Dairy cattle	semi-intensive+fatstock	82,791	61,791	21,000	7,486	28,486
	semi-intensive	67,301	42,036	25,265	2,345	27,610
	semi-intensive (fenced)	86,327	60,668	25,659	2,273	27,932
	intensive	102,376	70,963	31,412	1,452	32,864
Sheep	extensive	7,360	10,610	-3,250	9,680	6,430
Goat	extensive	21,816	24,301	-2,485	8,021	5,536

[5] Amounts in euros (for each farm type)

If we calculate the residual value of the pasture UF in the current exploitation conditions for the extensive beef cattle, we obtain a negative value of -0.08 E/UF, with a complementation medium value around 59 % (7 months of feed from other sources). The revised management plan leads to a residual value of 0.02 E/UF, with a complementation medium value around 36 % (4 months) (Table 4). This residual value of the pasture UF is equal to the current price of the pasture UF based on the estimated forage production and the loan cost. This new situation would be, in this case, economically viable.

Table 4. Residual value of the pasture UF in extensive systems (beef cattle).

Conditions	Production[6] value	Fixed expenses	Ext. Feed expenses	P.Margin	Pasture UF	Value pasture UF	Ext. Feed %
Actual	1,069,826	262,486	1,105,199	-297,860	3,794,202	-0.08	59 % (7 months)
Planned	1,069,826	262,486	688,512	118,828	5,930,261	0.02	36 % (4 months)

[6] Amounts in euros (for global system)

Conclusions

Some likely reasons for the current *wasteful extensive* production systems are a very low pasture rental rate per hectare (eventually balanced with the low production value), and a general lack of control in agroforestry systems on public land. Nowadays this land is being used like an open stable, with stock numbers exceeding the pastureland carrying capacity in areas nearby troughs and mangers, where the shrubs and tree regeneration is seriously damaged, whereas other areas (30 % of the property) have livestock numbers lower than their capacities. The main features of the improvement plan are enlargement of the grazed area and improvement in its' quality and production. The goal of these plans is also to promote extensive systems, reducing the energy imported by them and making them compatible with other land uses (mainly forestry).

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Comparison of farming systems in a north-western alpine region

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Abstract

The Aosta Valley is an alpine region where agriculture is extensive and predominantly based on dairy farming for the production of high quality cheese from milk from a native cow breed, mainly fed on hay during winter and fresh pasture in summer. Therefore, the agricultural area of the region is principally covered by lowland permanent grasslands and native mountain pastures (over 1800 m asl). Various kinds of farming systems can be found in this territory because of different factors such as geographical position, field distribution, weather conditions, regional subsidies etc.
The aim of this paper is to describe and compare the most widespread farming systems in the region. The analysis focuses on agricultural aspects such as farm features, forage systems and animal husbandry, on ecological descriptors such as floristic richness and slurry spraying, and on the economic situations of farms in relation to the regional policy.

Keywords: farming system, natural grassland, species richness, regional policy

Introduction

The Aosta Valley is an alpine region situated in the north-west of Italy. The land is mainly used for grassland to provide forage for dairy production. Livestock rearing is the local agricultural tradition leading to the production of a high quality cheese called 'Fontina' (Protected Designation of Origin product). This cheese comes from a native cow breed (Pezzata Rossa Valdostana) fed on a diet based on natural and locally produced fodder crops. Pezzata Rossa Valdostana is a hardy alpine breed which should be protected because it is one of 11 alpine breeds which have an important and interesting genetic heritage. Moreover, grassland comprises 97.8 % of the current agricultural area (ISTAT, 2000). Therefore animal production is not only fundamental for the regional farming economy, but is also crucial for the preservation of the region from a cultural, recreational and ecological point of view.
Cattle farms are mainly made up of natural grasslands and each of them has a precise role in the farming organization. Different farming practices can be applied with respect to the timing of cutting or grazing, livestock waste management and irrigation, in accordance with the use of the grassland. All these practices can affect biodiversity, landscape and water resources and are influenced by agricultural regional policy.
The aim of this paper is to describe and compare the most widespread farming systems in the region, taking into account these considerations.

Materials and methods

In order to identify different kinds of farming systems, we applied an approach based on 2 concepts: the agricultural function of grasslands (Jeannin *et al*., 1991; Dubeuf, 2001) and farm functioning (Jeannin and Cristofini, 1990; Fleury *et al*., 1995). Farming system analysis consists of studying the functional, temporal and spatial organisation of the farming region.
Eighty-six farms were contacted and given a questionnaire regarding fodder crop management (utilisation, fertilisation, irrigation and production), livestock management (summer and winter diet, calving period, milk production), farm buildings (cattleshed situation) and equipment (mechanisation level).

The meadow typology (Roumet *et al*., 1999) and the environmental value of grasslands (Tarello *et al*., 2000) were used to identify the ecological effects of farming systems and economic results from an impact analysis of agricultural policy on mountain areas were included (Bagnod *et al*., 2001).

Results and discussion

Table 1 illustrates the most widespread farming systems of the region according to agricultural, ecological and economical features.

Table 1. Farming system description.

Characteristics	Farming system		
	traditional	mountain pasture	lowland pasture
Agricultural			
Farmer's goal	winter milk production and forage autonomy	summer milk production for high quality cheese	whole year milk production
Annual Work Unit (AWU)	1.8	2.8	2.5
Number of sub-farm parts	1	2	1
Farm location	hillside or mountainside	winter farm: lowland summer farm: mountain	Lowland
Mean lowland farm surface (ha)	9	13.2	14.5
Number of milking cows (mean)	16	40	25
Number of cuts	2	2	3
Animal management	no summer pasture	grazing cattle on summer mountain pasture	grazing cattle on summer pasture
Hay purchase	0 %	more than 30 %	0 %
Weakness or strength	weakness: low incomes strength: marginal areas utilisation	weakness: 2 parts of the farm to manage and hay purchase strength: mountain utilisation	weakness: high inputs strength: quality forage
Ecological			
Type of meadow	various plants with medium-sized and large leaves	tufts of umbelliferous plants with medium-sized and large leaves	grass tufts with large leaves
Number of species (mean)	34.7	24.8	24.5
Cattle waste management	balanced distribution	risk of excess on winter farm	balanced distribution
Economical			
Gross income (€)	33,000	87,800	82,600
Farm income (€)	19,000	51,600	44,700
Subsidies (€)Annual Work Unit (AWU)	13,700	41,300	41,300
Income per Annual Work Unit (AWU) (€)	10,500	24,800	15,500
Gross income / subsidies	2.4	2.5	2.0
Gross income / agricultural machinery capital	0.8	2.3	1.0

The traditional farming system is based on winter milk production and characterized by all parts of the farm in one location where cattle remain for 270 days. The rest of the year (summer period), the cows are taken to mountain pastures and the farmer only makes hay. These farms are small, extensive (utilising marginal areas) and ecologically interesting (highest floristic richness and reduced problems with cattle slurry). Economically, their subsidies generate an elevated gross income, but farm income is low because of large investment in farm machinery.

The mountain pasture farming system is made up of two parts in separate locations: one is used during winter; the other is located in alpine pastures for summer grazing and better quality milk production. These farms have a large number of cows considering the area, therefore they need external forage input and excessive cattle waste is produced and distributed affecting floristic composition (umbelliferous tufts and low number of species). From an economic point of view, this kind of farm produces higher incomes and it uses subsidies and machinery to the greatest advantage.
The third kind of farming system is carried out in one location, situated in the lowland area where cattle remain during the whole year and provide important dairy production. Lowland pasture farms are medium-sized and characterised by frequent cuts in summertime and proportioned slurry spreading that influences the floristic meadow composition (grass tufts and low floristic richness). These farms need higher inputs (work, energy, machinery) and are economically dependent on public subsidies. Moreover hay production requires intensive use of machines which increase the need for capital.

Conclusions

Subsidies allow favourable incomes to be attained and if they didn't exist, many farms would have to stop their activity. However, as far as the three systems described are concerned, it is possible to highlight that subsidies help mountain pasture and lowland pasture farming systems. If we consider the present regional law for agriculture where mountain pasture subsidies have been increased, many farms which are traditionally managed, risk being damaged by this agricultural regional policy. This possible outcome could affect local land management, because these types of farms are located in marginal areas and if they disappear most of the hillside and mountainside landscapes would not be safeguarded. Moreover, the management practices in traditional farming system favour floristic richness.

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Cost benefit analysis of food processing on organic grassland farms in Slovenia

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Abstract

Grassland represents 93 % of the area on Slovene organic farms. Therefore, livestock production is the prevailing activity on those farms. The consumer interest for organic food products has also been growing lately. The food processing of animal products is thus an additional market opportunity for organic livestock farmers. The processing is related to the relatively high investments (buildings, equipment, legislation issues). Before the actual investment is undertaken the farmer needs information on its financial feasibility. The aim of this study is to analyse the costs and benefits of investment into food processing on a sample organic grassland farm. The investments are evaluated using simulation modelling for the estimation of investment cost and annual investment cash flows. The investment costs and annual cash flows represent input information for the computation of net present value and internal rate of return. Assuming that annual production levels are achieved and that food products are successfully marketed, the investments could be financially feasible.

Keywords: food processing, organic farms, investment analysis

Introduction

The consumer preference for organic food products in the Slovene market is high (Adamič, 2000). Experience has shown that in many cases the crops and milk must be processed in order to be sold successfully. This is why Slovene organic farmers started implementing food processing on their farms. Farms on grassland represent 63.3 % of Slovene organic farms. The average size of Slovene organic farms is 13.4 ha, which is nevertheless larger than the average size of Slovene farms (4.8 ha) but still too small to achieve satisfactory income for the family. This is especially true on full time family farms. This is why it has become a necessity to seek other income sources. Many studies (Turk and Rozman, 2002; Pažek, 2003) have shown that processing of farm products can improve farm income and that processed products give better financial results than when simply selling the raw crop or milk.

The main farming activity on grassland, livestock production, also offers a variety of food processing alternatives. The main processing alternative is, of course, cheese production. Meat processing is another alternative; however, it is interrelated with relatively strict legislation. It should also be mentioned here, that Slovene grassland is usually covered with old fruit trees (old varieties grafted on seedling rootstock). The combination of grassland and extensive orchards represents typical Slovene landscape. These fruit trees enable additional fruit processing alternatives such as: different kinds of cider, different kinds of brandy, juices, apple vinegar and dried fruits.

The implementation of processing on organic farms is interrelated with relatively high investment costs. Since the investment costs represent the main constraint when implementing food processing, cost benefit analysis must be carried out before an individual food processing investment project is undertaken. The cost benefit analysis is a basic tool for selection of the best investment project. In the paper the methodological framework for investment planning and analysis on individual organic farms is presented. The approach used combines computer simulation modelling and cost benefit analysis for evaluation of different investment alternatives.

Materials and methods

The financial cost benefit analysis (CBA) is a basic farm management tool for investment project appraisal. Its main characteristic is its capability to include time value of money that is based upon the assumption that 1 € today is worth more that 1 € tomorrow (inflation). The main indicator of financial cost benefit analysis is net present value (NPV) calculated as the difference between the sum of discounted investment cash flows and investment costs:

$$NPV = -I + \sum_{i=1}^{t} P_i/(1+r)^t$$

Where:
NPV – net present value
I – investment costs
Pi – annual cash flow or cash flow in year i
r – interest rate
t – time period

The NPV must be greater than 0, otherwise the investment project is not financially feasible. Another indicator of investment analysis is internal rate of return (IRR), which equals the highest interest rate at which NPV equals 0. The IRR is of course not the deciding factor whether to undertake the project or not.

In order to conduct the CBA, annual cash flows must be calculated. For derivation of annual cash flow budgets and investment costs of a specific project, the technical parameters of an investment and planned production must be determined. For this purpose the actual on farm data can be used. However, as mentioned earlier, this data is rarely available before the actual project is undertaken and varies from farm to farm since the technological project solution is specific for every single farm. Therefore, estimation of this data must usually be conducted using an appropriate methodological tool. Such a tool should enable project investment planning and analysis using different technical solutions as well as different production levels. As reported by Berg and Kuhlmann (1993) and Turk and Rozman (2002), in such a case simulation modelling can be applied. Using simulation modelling the analyst can obtain information on an observed system as well as system responses at different model input parameters. In this case individual food processing on organic farms represent the observed system. The relationships between system elements (in this case material, home, hired labour) are expressed with a series of technological equations that are used for calculation (estimation) of input usage and outputs produced. In our case the *EKOSIM 1.0* computer simulation model was developed. It enables preparation of enterprise and cash flow budgets for different investment projects on organic farms, and performs a cost benefit analysis on the basis of given project input parameters for every single farm.

Results and discussion

Table 1 shows results of a simulation for a sample organic farm with 12 ha of grassland and 250 fruit trees (70 % apple trees and 30 % pear trees). The farm operator has 65 goats where milk is the main production orientation. The following processing alternatives are possible on this farm: goats cheese production (soft and hard cheese), pear brandy, apple brandy, apple cider, apple vinegar and apple juice.

Table 1. Investment analysis indicators for different investment projects on sample farm.

Product	Production (kg y^{-1} resp. l y^{-1})	Investment cost (€)	NPV = 10 years (€)	Pd – Investment return period (years)	IRR t = Pd (%)
Hard cheese Soft cheese	1217 (40 %) 1268 (60 %)	22269	35090	4	14.05
Pear brandy	396	4520	1310	8	14.90
Apple cider	8750	5668	3974	6	14.25
Apple juice	8750	9329	27372	3	26.05
Apple vinegar	9450	6808	40388	2	53.40

The results show that apple vinegar yields the highest NPV after 10 years, followed by cheese production (assuming that all products are successfully marketed). It should however be stressed out at this point that goat breeding is the primary orientation of this particular farm and that the cheese production would probably be a prioritised alternative. Other investments would depend on the availability of investment funds. However, the investment costs for cheese production are the highest. The investment costs also represent the main constraint when implementing on-farm food processing. The alternative decision for this particular farm (in case of unavailability of investment funds) could be investing into apple vinegar or apple juice production that both result in high annual net returns and short investment return periods. The real value of the *EKOSIM 1.0* model is in its capability to calculate investment costs and to perform financial cost benefit analysis for different food processing technical solutions (for instance: the analysis of how the substitution of one processing machine with a more expensive but more capable and faster machine influences the investment costs and other financial indicators). Also, the model response to different input parameters can be observed. Using such a simulation approach, the best food processing solution can be found.

Large quantities of apple vinegar and juice could cause a real marketing problem. Despite apple cider resulting in substantially lower NPV, the combination of all three products (according to consumer demand) would probably be the best solution for this particular farm.

Conclusions

The case study on a sample farm analysed investments into different food processing branches on sample organic grassland farm. The results show that investment into apple vinegar production could be the most profitable under the assumption that the products are successfully marketed, followed by cheese and apple juice production.

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Importance of grassland in the economy of the Sudeten Region

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Abstract

The role and importance of grassland in the economic development of the Sudeten Region are discussed in this paper. Infomation on the area occupied by grasslands and their productivity is presented. Grassland are a fodder base for ruminants, can produce biomass for renewable energy and play a role in protecting the biodiversity of mountain sites as the so-called ‘lands of ecological use’. Productive grassland, which occupy 104,000 ha in the region and range up to an elevation of 700 m asl, were found to be most important. With appropriate technology their potential productivity is approximately 636,000 t DM of fodder for ruminants, mainly cattle and sheep. However, due to a declining market for animal products, over 30 % of grasslands remain unused and are now being designated for biomass production instead. According to official Polish statistics (Ustawa, 1991) grasslands that play an ecological role occupy only a small area, 1-2 %, in the region.

Keywords: the Sudeten, grasslands, fodder, bio-fuel, lands of ecological use

Introduction

The Sudeten is a land of forest and grassland. In some communes grassland occupies almost 90 % of the cropland. Grassland benefits the local communities by producing fodder for meat and milk production. Meadow plants also provide a supply of roots, nectar, pollen etc. which serve as food for other animals and have long been used for medical and therapeutic purposes. In the XVIII century herbs and medical mixtures from the Sudeten were sold all over Europe. Grasslands play a role in soil forming processes, in crop rotations, in the protection of soil against erosion and in the creation and protection of water resources.

Special attention is now paid to the role of grassland in the appearance of the landscape and in preserving plant and animal species diversity. For this reason the so-called ‘lands of ecological use’ were designated and legally protected in Poland.

Due to a recent low utilisation of grassland in agriculture consequent upon a shrinking market for animal products, the production of biomass on abandoned land is being considered to produce renewable energy in the form of bio-fuels. These would be of interest to the Turów power plant situated in the so-called Black Triangle at the border of the Czech Republic, Poland and Germany. The three major potential uses of grassland are discussed in this paper, i.e., for fodder, biomass production or as lands of ecological use.

Materials and methods

The 300 m asl contour line was taken as the lower borderline of the mountain region of the Sudeten. Areas of productive grassland there were estimated from outlines of the agro-forest and grass-field boundaries. As a result, grasslands of low productivity were excluded from the agricultural use category and grouped under use for other purposes. Arable lands that did not conform to cultivation standards ploughing were classed as forest the productivity of these lands was estimated from our own experimental studies.

Estimates of areas for biomass production for bio-fuels were based on statistical data for abandoned meadows and pastures (Fatyga and Czujowski, 2003) supplemented by data from observations and experiments on the effects of abandonment for 1, 2, 3, 4, 5 or more years on yields

Areas of grassland designated as ‘lands of ecological use’ were calculated by the method of Fatyga *et al.* 2002 based on the Nature Protection Act (Ustawa, 1991). A special programme was designed to select areas that meet the criteria of the Act from a database of natural, topographic and soil conditions.

Results and discussion

Productive grasslands: Fodder for ruminants is the most important output from productive grassland. In addition to producing high quality animal products, management of the grassland protects the landscape and maintains the healthy functioning of soils and grassland ecosystems. The area of grassland that meets the criteria of rational economic use in the Sudeten was verified and estimated at 104,000 ha. Proportions of the elevation classes (important for productive purposes): 300-500 m, 500-700 m and > 700 m asl are given in table 1. In the 300-500 m asl zone there are nearly 64,000 ha of medium quality grassland which can give, with an appropriate fertilisation, from 6 to 8 t DM ha^{-1}. The grassland area in the higher zone decreases to 34,700 ha, with average yields of 4 to 6 t DM ha^{-1} due to less favourable soil and climate. Grasslands situated above 700 m asl have no importance for agricultural production but have a role as lands of ecological use and in diversifying the landscape. Grazing of small herds of cattle and sheep provides fresh animal products in these areas thus increasing the attractiveness of the farms and agro-tourism centres. Yields range from 2-4 t ha^{-1} of poor quality hay. In total, the Sudeten can produce annually 636,000 t DM, a figure on which estimates of numbers of ruminants: cattle, sheep, goats and recently introduced fallow deer and red deer can be made. The size and structure of a herd depend on many factors but mainly on profitability and market for animal products.

Table 1. Grassland area (ha) and yield (t DM ha^{-1}) in the Sudeten region.

Zones	Area (ha)	Mean yield (t DM ha^{-1})	Total yield (t DM ha^{-1})
300-500 m asl	63,934	7.0	447,538
500-700 m asl	34,682	5.0	173,410
> 700 m asl	5,183	3.0	15,549
Total	103,799		636,497

Fallow grasslands and biomass production: Difficulties in selling goods, mostly animal products, is the most important problem in the Sudeten, and this has resulted in an increase of fallow grassland. The total area of fallow land is 29,000 ha, i.e., 30 % of the grassland area and the fallow land is distributed differently in different communes. There is a suggestion to produce biomass from these lands for renewable energy as bio-fuels. This is for consideration only since the basic role of grassland is to produce food. Moreover, to obtain sufficient biomass yield the grassland would require to be fertiliser and cut at least twice a year. According to preliminary studies (Nadolna, 2003), fallowing decreases DM yields to as little as 50 % of normal. Also specialised combustion facilities, harvesting equipment and transport are necessary to utilise the biomass.

Transformation of grasslands to lands of ecological use: As required by Polish law, lands of ecological use are to be established on grassland that deserves protection, i.e., the remainders of ecosystems important for the preservation of unique genetic resources or habitats. The Nature Protection Act (1991) lists also lists areas of unused vegetation, which are registered in the commune statistics as ecological grasslands. This is not totally correct since a

prerequisite for establishing lands of ecological use are criteria other than a lack of agricultural utility. In my opinion, lands in the Sudeten which are unused but overgrown with permanent vegetation and located on organic, calcareous or wet soils should be considered as lands of ecological use.
Studies carried out in one commune demonstrated that the area of grassland which could be regarded as lands of ecological use was small – slightly over 68 ha, i.e., 1 % of the commune area. The greater part of these lands were wetlands.

Conclusions

- Grasslands producing fodder for ruminants (cattle, sheep, goats) are of the greatest economic importance in the Sudeten. Their total area was 104,000 ha and annual production was 636,000 t DM.
- Bio-fuels production from biomass could serve as a temporary alternative but its economic importance is as yet unknown.
- Grasslands on lands of ecological use play only a minor role and occupy small areas estimated at 1-2 % of the total.

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Climate change: reduced rainfall, seasonal re-distribution of herbage and the cost of milk production in Ireland

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Abstract

From the climate changes predicted by the HADCM3 model it has been estimated that grass production in Ireland will be seriously reduced by water deficit by 2050. An assessment, using a farm simulation program of the impacts on management and economics of dairying is presented in this paper. Both an intensive (2.5 cows ha^{-1}, 410 kg N ha^{-1}) and extensive REPS (1.75 cows ha^{-1}, 120 kg N ha^{-1}) system were simulated in three rainfall scenarios, i.e., a 50 % reduction on current rainfall in spring, summer or autumn. In both systems, following a spring or summer rainfall deficit, herbage availability failed to recover to normal levels and heavy supplementation was required continuously from mid-summer until the end of the grazing season in November. Autumn rainfall deficit had a similar impact but later in the season. In all three scenarios there was increased use of meals and silage. Spring or summer rainfall deficit reduced the gross margin per cow by € 100 (from € 1235) and the gross margin per hectare by € 150 (from € 1700) in the REPS system. The margin per cow was reduced by € 175 (from € 1175) and the margin per hectare by € 450 (from € 1650) in the intensive system. The results indicate that climate change may encourage the adoption of environment-friendly systems.

Keywords: climate, herbage, REPS, milk, economics, management

Introduction

Irish agriculture is dominated by systems of livestock production from grazed grass. From the climate changes predicted by the HADCM3 model it has been estimated that grass production in Ireland will be seriously reduced by water deficit by 2050 (Holden and Brereton, 2002). The estimated reduction in rainfall may be as much as 50 % of current rainfall over periods of several weeks. The period of greatest reduction is expected to vary regionally, between early and late summer (Holden and Brereton, 2003). An initial assessment of the secondary impacts of climate change using a farm simulation program (the impacts on management and economics of dairying) is presented in this paper. The two common commercial systems of dairying were simulated; an extensive system conforming to the Rural Environment Protection Scheme of the EU (REPS) and a standard intensive system (INTS).

Materials and methods

The simulation described the management of a herd of spring-calved, Holstein-Friesian cows of medium genetic merit in a rotational 20-paddock grazing system. The time-step of simulation was a half-day. Herbage production was estimated by a grass growth sub-model (Brereton *et al.*, 1996) driven by daily weather data generated by the Simmeteo weather generator (Richardson, 1985) from current climate monthly means. Grass utilisation was controlled by a grazing sub-model (Brereton and McGilloway, 1998). Following normal strategies for provision of winter feed, 45 % and 40 % of the paddocks were closed for the first and second silage cuts during April-May and June-July, respectively, and 500 kg of concentrates were fed in the first 6 weeks post-calving. Following the normal tactical responses to variations in herbage supply, the deficit periods, with supplementation of grazed grass, silage, meals or housing and the surplus periods, with the removal of herbage as baled silage, was determined by mean herbage available in the grazing area. Both the intensive (INTS; 2.5 cows ha^{-1}, 410 kg N ha^{-1}) and extensive (REPS; 1.75 cows ha^{-1}, 120 kg N ha^{-1}) systems were simulated in three rainfall scenarios, i.e., a progressive reduction from 20 % to 50 % of the current rainfall over 3 month periods during March-May, June-August or September-November.

Results and discussion

In both systems, during a spring or summer rainfall deficit, herbage availability was rapidly reduced and supplementation was introduced (Table 1), though the conditions for housing were not met. After the period of rain deficit, herbage availability failed to recover to normal levels and supplementation was required from mid-summer until the end of the grazing season in November. Autumn rainfall deficit had a similar impact but later in the season. In the INTS system, supplementation would have been necessary from mid-May onwards with the spring drought, from early July with the summer drought and from early September with the autumn drought. With the baseline climate this did not arise in the INTS system until after the middle of September. None of the droughts had any great effect on herbage cover at the start of the following year. In the REPS system the effect of spring drought was less severe.

Table 1. The effects of reduced rainfall on costs (€) of purchased feed and on gross margins per animal and per hectare. Negative silage costs represent the sale value of surplus silage. Baseline gross margins are taken from Humphreys, *et al*. (2002). Gross margins for drought affected systems are adjusted by the change in meals and silage costs relative to baseline.

		Per animal				
System	Climate	meals	silage	Meals + silage	gross margin	Relative
REPS	Baseline	60	-48	12	1235	1.00
	Spring drought	78	28	106	1141	0.92
	Summer drought	90	8	98	1149	0.93
	Autumn drought	73	-11	62	1185	0.96
INTS	Baseline	71	24	95	1175	0.95
	Spring drought	84	184	268	1001	0.81
	Summer drought	93	203	296	974	0.79
	Autumn drought	74	156	230	1040	0.84
		Per hectare				
REPS	Baseline	105	-83	21	1700	1.00
	Spring drought	137	49	186	1535	0.90
	Summer drought	157	14	171	1550	0.91
	Autumn drought	128	-19	109	1612	0.95
INTS	Baseline	178	59	236	1650	0.97
	Spring drought	210	461	671	1216	0.71
	Summer drought	231	508	739	1147	0.68
	Autumn drought	185	390	575	1311	0.77

Supplementation was needed for a short period about early June, but herbage cover recovered later. The supply situation became critical again in late September. The effects of summer and autumn drought were the same as in the INTS system. Under baseline climate conditions in the REPS system, supplementation did not arise until early November. In all three scenarios there was an increased use of meals and silage relative to the baseline. Spring or summer rainfall deficit reduced the gross margin per cow by € 100 (from € 1235) and the gross margin per hectare by € 150 (from € 1700) in the REPS. The margin per cow was reduced by € 175 (from € 1175) and the margin per hectare by € 450 (from € 1650) in the intensive system.

Conclusions

The results indicate that climate change may encourage the adoption of the less intensive environment-friendly systems. The criteria used to trigger the housing option were not met in any case and consequently restricted herbage availability persisted in the periods after the rainfall deficit until the end of the season. The results suggest that a period of full housing in mid-season would have allowed herbage availability to recover for a late season of un-supplemented grazing.

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Utilisation of permanent grasslands by cattle farming without market dairy production

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Abstract

Permanent grasslands form a significant part of agriculture in the Czech Republic (CR). During the last ten years, after the decrease of agricultural production and with support for the extension of grasslands, the area of permanent grassland has increased by 138 thousand ha to 950 thousand ha, i.e., 25 % of agricultural land. The proportion of areas classified as LFA (Less Favoured Areas) is 59 % in the CR. Utilisation of permanent grassland by cattle is an environmental measure in mountain and piedmont areas. The number of cows without market dairy production (WMDP) (mainly suckler cows) in the CR has risen from 'zero' to 124 thousand of cows (since 1989); that is 25 % of total number of cows at present. The economy of management of cows WMDP is evaluated, with herd sizes from 10 to 169 cows. The average cost per cow per year was 16,236 CK (cca 485 EUR, 1 EUR = 33.5 CK). The annual subsidy required per cow is 7,000 CK for cows in herds producing calves for fattening and 2,900 CK for cows in herds producing calves for breeding. There is a tendency for costs to decrease with increasing the size of a herd.

Keywords: permanent grassland, suckler cow, economy, cows without market dairy production (WMDP)

Introduction

The first *utilis*ation of beef cattle for maintenance of the landscape and meat production in the CR took place in 1972, with the import of Hereford cattle to the state farms Šumava in West Bohemia. These herds were used to harvest areas inaccessible for mechanization at a height of over 800 m above sea level.

A massive growth in the farming of cows without market dairy production (WMDP) in the CR occurred only after 1990, when more beef cattle of French origin and Aberdeen Angus cattle from overseas were imported. At that time the portion of arable land on the total area of agricultural land (4,288,000 ha) was 75 %. In the course of 13 years the areas of permanent grasslands have risen from 833,000 ha to 940,000 ha. However, there was a tragic decrease of ruminants at that time. The number of cattle in the CR in 1990 reached 3,360,000 head whereas at the present time there are only 1,473,000 head. However, the situation is significantly worse in sheep farming where the number of sheep has dropped to one fifth of the original number (103,000 head). The only positive aspect is the increase in cows WMDP farmed on permanent grasslands from 8,000 head in 1990 to some 124,000 head at present. Unfortunately, the EU's requirements for increase in the area of permanent grasslands by 500,000 ha do not correspond to the allocated quota of less than 93,000 head of subsidized cows WMDP, whereas the CR's requirements were for 230,000 cows. These requirements are connected with the projected increase in average yields of dairy cows and the decrease in their numbers by 15,000 to 30,000 head in order to maintain the current milk production in the CR. The EU countries with comparable area or number of inhabitants have a significantly higher number of subsidized cows on permanent grasslands (Austria – 325,000 head, Denmark – 112,932 head). Even the countries with a much lesser portion of less favoured areas from the

group of accession countries (Poland – 325,581 head, Hungary – 117,000 head) have been granted higher numbers of subsidized cows WMDP.
The stock carried on 100 ha of agricultural land by cattle has dropped from 78.4 head to 35.6 head. It follows that with an average yield of extensively cultivated permanent grasslands of 180-200 q ha^{-1} the production of forage crops would be sufficient for about 0.5 livestock unit. It is evident that with the current area allocated to fodder crop production, aside from less favoured areas for dairy cattle of high production and cattle fattening, there will be a much higher surplus of forage crops from permanent grasslands. The costs of alternative methods of *utilis*ation (pressing, burning of dried mass) are prohibitively high. It is probable that many grasslands will be left without grazing and without maintenance. This will result in the decimation of selected species and a decrease in botanical diversity. Permanent mulching will then considerably reduce ecological stability of these grasslands, with possible pollution of underground waters and the environment by decay products of organic substances. Production of composts could be an alternative, but their subsequent *utilis*ation for manuring in production areas is impossible because of the transport distances from less favoured areas.

Table 1. Development of cattle numbers in the CR.

Index	1998	1999	2000	2001	2002	2003
Dairy cows	598,243	583,301	547,493	529,105	495,962	466,173
Index 1998/2003	100.00	97.50	91.52	88.44	82.91	77.89
Cows WMDP	48,595	58,725	67,294	82,257	100,333	124,149
Index 1998/2003	100.00	120.85	138.48	169.27	206.48	255.48
Cows in all	646,838	642,026	614,787	611,395	596,295	590,322
Index 1998/2003	100.00	99.26	95.05	94.52	92.18	91.26
Cattle in all	1,700,789	1,657,337	1,573,530	1,582,285	1,520,136	1,473,828
Index 1998/2003	100.00	97.45	92.52	93.03	89.38	86.67

Cows without market dairy production – Cows WMDP

Materials and methods

The climate conditions in the CR are significantly different from those of maritime and mountainous areas of Europe. Comparable conditions can be found in the countries of Central Europe (part of Austria, Hungary, Slovakia). The average rainfall in the majority of the CR territory does not exceed 700 mm; the average annual temperatures range between 5 and 7 °C. Most rainfall is in the winter where temperatures are below 10 °C and there is little plant growth. Rainfall during the vegetation period is less than that required for optimal growth of grass and forage crops. As the need of forage production on permanent grasslands has considerably dropped and manuring of these lands limited for more than 10 years, the yields have decreased by 30-50 %. The content of nutrients in the harvested grass has significantly decreased too, with crude protein contents commonly around 100 g kg^{-1} dry matter and reduced contents of potassium and phosphorus. The herd size of cows WMDP ranges from 15 head up to herds numbering some hundreds of cows. The majority of herds are pastured in a system of large fields which comes close to the set stocking system.
Within the economic evaluation, 10 enterprises have been studied with sizes varying from 16 ha and 10 cows up to enterprises with 2,700 ha and 169 cows WMDP and other agricultural enterprises. The remainder calculation method was used for the cost investigation. The aim of the economic investigation was to obtain objective data for the required subsides for suckler cow (WMDP) enterprises.

Results and discussion

The established average cost per cow and year in this system was 16,236 CK (about 485 EUR). This cost per cow is larger by 5,651 CK than that mentioned by Kvapilík (1995), because of changes of input prices during the compared periods. The average number of workers per herd with 57.27 cows was 0.914.

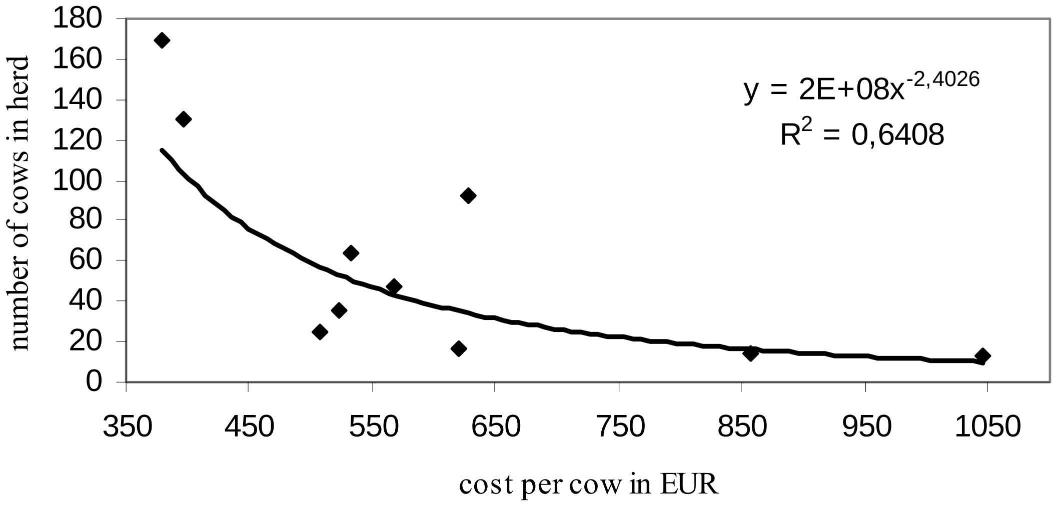

Figure 1. Impact of herd size on cost per cow WMDP.

The profit percentage in commercial farming producing cattle for further fattening was 4.83 % with inclusion of subsidies for cows WMDP of 7,742 CK (231 EUR). The sale of breeding animals considerably improves economic indexes with the profit increased to 30.22 %.

Table 2. Impact of farming system on profitability.

Number of cows per enterprise in head	57.27
Profit per cow with sale of breeding animals in CK / EUR	4,906.42 / 146.46
Profit per cow with sale of fattening animals in CK / EUR	783.64 / 23.37
Cost per cow WMDP in CK / EUR	16,236.23 / 484.66
% of profit with sale of breeding animals	30.22
% of profit with sale of fattening animals	4.83
Subsidy per head in CK / EUR	7,742.66 / 231.12
Profit – subsidy per head in CK / EUR for sale of breeding animals	-2,836.24 / -84.66
Profit – subsidy per head in CK / EUR for sale of fattening animals	-6,959.02 / -207.73

Acknowledgements

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New approaches for preservation and promotion of dry grasslands in the conservation politics of Switzerland

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Abstract

The inventory of the increasingly rare Swiss dry grasslands which are rich in species will soon be completed. For nature and landscape conservation purposes, an area of more than 20,000 ha will be designated as sites of national importance (which is about 1-2 % of the entire agricultural land of Switzerland). These grassland sites are the evidence and the outcome of a traditional, regionally adapted land use of low intensity. They are elements of a traditional agrarian landscape and are hence important for tourism. The remaining relicts are mainly endangered by abandonment.
Up-to-date methods (interpretation of aerial photographs, GPS-calibrated species data sampling) have been adopted for survey and evaluation of the sites of national importance. A specific legal foundation is the basis for both land use subsidies and conservation measures. The national conservation strategy will be attached to the different models for implementing regional conservation. It should provide an incentive. Subsidy contracts will be offered to the farmers to keep them using grasslands with low yield but high bio-diversity. They should be provided with sustainable alternatives to abandonment. In a new approach the conservation strategy aims to create ‘priority zones’ and to strengthen the co-operation with the agrarian bodies. Is it an optimal approach of ours to enlist our partners by means of agreements?

Keywords: bio-diversity, habitat conservation, low intense land use, inventory, dry grasslands, conservation politics

Introduction

According to the Federal Law on the Protection of Nature and Landscape (LPN, article 18a), the Federal Council designates biotopes of national importance. The ruling of conservation measures is regulated by specific Federal Ordinances (for Federal Inventories). There are basically two habitat inventories that affect agricultural grasslands: The Federal Inventory of Fenlands of National Importance (1994) and the Federal Inventory of Dry Grasslands of National Importance, which is in preparation. Each inventory includes a total area of about 20,000 ha which is some 1-2 % of the Swiss agricultural land.
Both inventories aim to conserve and promote the most valuable sites for habitat and species conservation. The current efforts in agricultural legislation to encourage ecological agriculture will be complemented and enforced by specific conservation measures. In doing so new ways are sought in conservation politics concerning the conservation of dry grassland.

What are dry grasslands of national importance?

Eggenberg *et al*. (2001) describe 18 vegetation groups that constitute the inventory content. Because of actual threats meadows and pastures (up to tree line) are primarily included. Sites are accepted if they satisfy a set of requirements including size and quality. Diverse information is collected that is necessary to qualify each site. Data collection and data evaluation is standardised according to Eggenberg *et al*. (2001). The inventory project will establish more than 10,000 site information sets on dry species rich grasslands of Switzerland. These data sets will provide basic information for conservation measures as well as for research. The following data are provided for each site information set and may be of particular relevance for research: a standard test point with full vegetation relevé, vegetation cover with very high resolution of both quality and quantity (although compatible with CORINE biotope types), land use type, and standardised data on zoologically relevant structures. The sites borderlines are fully digitised and can be superposed to any thematic map.

General framework for the political implementation

Several basic assumptions are relevant for the political implementation of the dry grassland inventory:

- Dry grasslands are linked to low intensive and small structured land use.
- Agriculture and forestry are subject to severe pressure for adaption following accelerated structural change. Abandonment of uneconomical areas is the consequence.
- The distribution of dry grasslands (Figure 1) and its endangerment is quite different in the various regions of the country.
- Unlike habitats like raised bogs, dry grasslands can regenerate in the medium term.
- The cantonal conservation bodies are the main agents for the implementation. Many of them have long and profound experience in grassland conservation.
- The current agricultural policy intends to promote an increase in the importance of the ecological aspect, especially on grasslands, through the Federal Ordinance relating to Ecological Subsidies (EOS) and the Federal Ordinance relating to Ecological Quality. Hence this situation is *the* essential precondition for the conservation of dry grasslands.

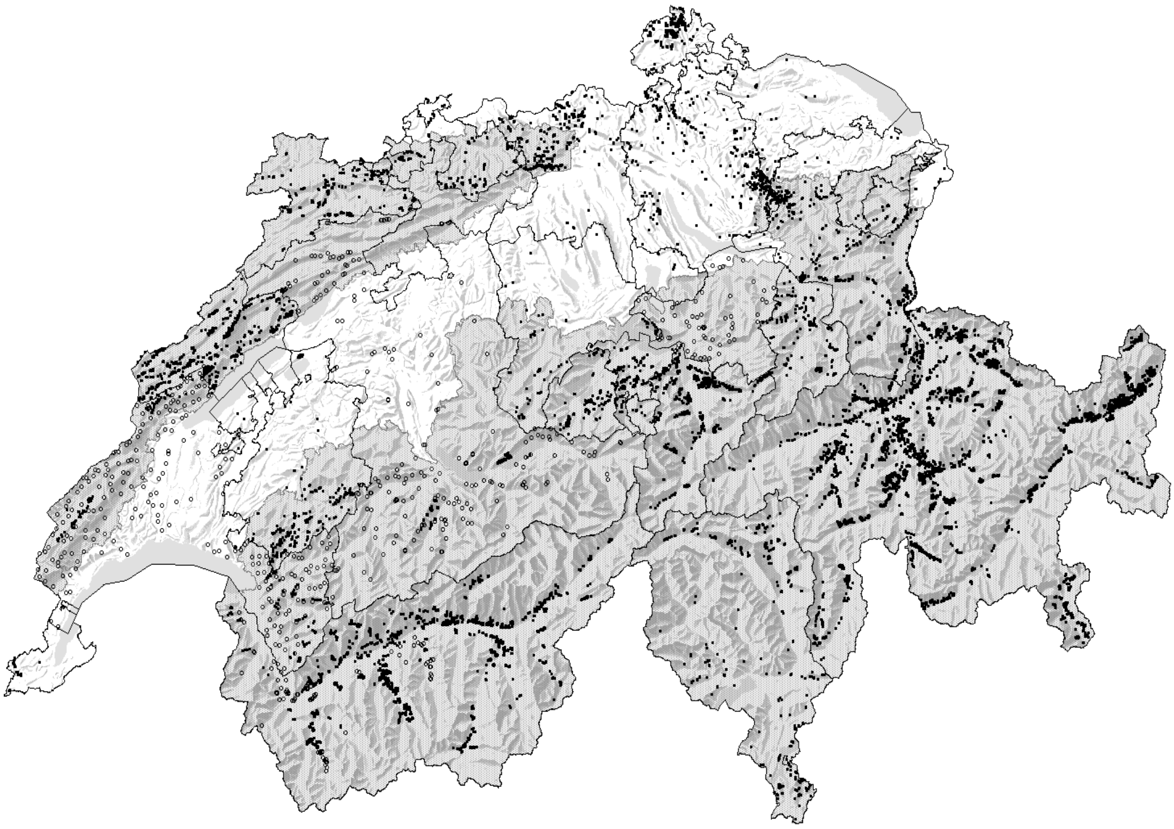

Figure 1. Distribution pattern of dry grasslands in Switzerland (situation 2003). It can easily be seen, that the most valuable sites are concentrated in the mountain area (grey area). This is in contrast to the area of the arable plains where only few relicts are left. Points are dry grasslands already recorded and circlets are areas yet to be processed.

The concrete implementation strategy in dry grassland conservation

The implementation of dry grassland conservation is in co-ordination with agriculture and forestry policy. It is based on the principle of sustainability and is pushing a strategy of incentives, so that conservation and promotion of dry grassland areas should be economically interesting for the farmers.
This means that our dry grassland conservation politics will contribute to the structural improvement of economically marginal areas in the mountains. By means of financial contributions economical value is added to these economically marginal but biologically rich grasslands, with the aim to stop the retreat of agriculture in these mountain areas.
The highest shortfall in terms of bio-diversity is in the Central Plateau. Further loss through intensification of the remaining relict areas has to be stopped. Mandatory regulations are available to achieve this. On the other hand financial incentives can motivate the regeneration of formerly valuable dry grassland areas.
The central instrument of the implementation will be voluntary contracts (between farmer and conservation bodies). These contracts contain agreements on land management, conservation, maintenance measures and the financial compensation for all efforts. With this model, 'bio-diversity as a product' becomes a value that is demanded and compensated by the public. With the contract model an approach is prioritised that is applied in many cantons with great success. Furthermore, management contracts can easily be combined with other instruments of agricultural policy and are well accepted by the farmers.

Beside classical object conservation, a further implementation tool is offered to the cantons: priority zones. The cantons will be enabled to conserve the dry grassland objects in combination with their surrounding biotopes, in order to enhance the flexibility of implementation. In doing so the common principle of 'undiminished conservation' of the single object can be put on one side in favour of the overall biotope combination.
Thus, interplant and regionally adapted solutions that are holistic in their approach are made possible for optimally achieving the conservation targets.
Regional concepts are the base for priority zones whose implementation is ruled by a service agreement. Furthermore, there is a connection between these priority zones and the agricultural legislation: Regional networking projects according to the Federal Ordinance relating to Ecological Quality. Valuable synergies can be created between these two instruments of execution by co-ordinating the targets, especially the definition of target species.

Conclusions

It is the aim of dry grassland conservation policy to conserve the areas primarily by means of supporting traditional land use. The appreciation of this traditional agricultural landscape is a very important factor, both for the farmers and the general public. Specific public relation activities, direct contact to agricultural schools and advisory services are important accompanying activities in the strategy of protecting and promoting dry grassland.

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Evaluation of grants given to maintain semi-natural grasslands in Nord-Trøndelag, Norway

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Abstract

Since 1993, Norwegian governmental subsidies have been applied to preserve valuable semi-natural grasslands in Norway. After 8 years of management and payments, the effects of the subsidies were investigated in the county of Nord-Trøndelag. The intention of the subsidies, to secure both open landscapes and biodiversity, was not obtained due to a general lack of knowledge of ecology and biodiversity at all levels. This clearly demonstrates the importance of knowledge and information exchange between scientists, authorities, politicians and farmers to secure maintenance of the most valuable semi-natural grasslands. In addition, transdisciplinary research and exchange of knowledge between archaeologists, historians and ecologists are necessary to preserve the most valuable cultural landscapes with regard to both biodiversity and cultural monuments.

Keywords: biodiversity, exchange of knowledge, transdisciplinary, management, restoration, subsidies

Introduction

The semi-natural grasslands are characterised by a light-demanding flora. They are often very species-rich (Kull and Zobel, 1991; Herben *et al*., 1993) and often connected to historical and cultural sites. Land-use changes during the last part of the 20th century threaten former widespread traditionally managed, semi-natural grasslands in Europe (Van Dijk, 1991). Overgrowth is the main threat to valuable semi-natural grasslands in Norway, resulting in fragmentation, local plant extinctions and endangered species and landscapes (Eriksson, 1996).

In Norway, governmental subsidies (STILK) have been used to promote landscape management and maintenance of valuable habitats since 1993. The guidelines for these subsidies have changed during this period, from emphasizing an open landscape to focusing on maintenance of biodiversity and cultural monuments. The idea behind the subsidies was to compensate farmers for extra work with landscape management when producing food and fodder. The farmer had to apply for the grant, which was administrated by the Agricultural Department of the County Council (FMLA).

In the county of Nord-Trøndelag, a pilot project was initiated in 2000 to evaluate the effect of these subsidies and assess whether the intention with STILK was obtained (regarding landscape and biodiversity). The Norwegian Crop Research Institute was responsible for the project in cooperation with local authorities and work groups (Sterten, 2001).

Methods

The Agricultural Department of the County Council (FMLA) chose Inderøy and Levanger as representative municipalities for the study. The municipalities then selected 25 representative grasslands for further studies, 20 grasslands which had received STILK in the period of 1993-1999, and 5 nearby grasslands which had not been subsidized.

The grasslands were evaluated in the period of June 20th to July 14th 2000. Each grassland was investigated with regard to the re-growth status (open, early succession, medium succession or late succession phase), all vascular species were recorded and the vegetation was classified according to the abundance of exclusive grassland species, typical grassland species, trivial species, nitrophilous species, re-growth species and forest species. The diversity at species level (number of species) and the general importance of the grassland for biodiversity with regard to occurrence of different types of species (according to the above classification) were recorded. The grazing pressure in each area was estimated (not grazed, partly grazed – some tussocks left, and optimal grazed), as well as the clearing (no clearing, partly clearing or optimal clearing).

In addition the farmers were interviewed to examine their interests and attitudes towards semi-natural grasslands and conservation of biodiversity. They were also questioned about their knowledge of landscape and biodiversity management and their motivation for applying STILK.

Results

In 14 grasslands the biodiversity was low (< 15 species m^{-2}) and dominated by species classified as nitrophilous species, re-growth species and forest species. In 6 grasslands the biodiversity was high (> 20 species m^{-2}) and the vegetation was dominated by exclusive and typical grassland species, but 3 of these areas had not received STILK. The results showed that some grasslands of little importance for biodiversity had received STILK. Other nearby species-rich grasslands had failed to obtain STILK, due to lack of applications, or denied applications. The results of the investigation also showed that some of the subsidized grasslands were small (< 2 ha).

The subsidies had been given for one year only, and the farmers had used the grants for restoration of grasslands, i.e., for clearing of shrubs, bushes and trees, and for fencing. Some of the farmers had too few animals with regard to optimal grazing pressure after restoration. When investigated, 5 of the grasslands were therefore in a late succession phase, 10 of the grasslands were in a medium succession phase. Ten grasslands were still open, but 3 of them had not received STILK.

The interviews showed that most of the farmers regarded the investigated semi-natural grasslands as a possibility to increase their pastures and that this was the reason for their application for the grant. Only half of them regarded biodiversity as a future resource and knew that fertilising decreases the species number in such semi-natural grasslands. However, most of the interviewed farmers expressed a need for better knowledge of how to recognize valuable habitats and how to maintain them.

Discussion

Since the subsidies were given for only one year, it resulted in clearing of the areas in the first year, but shortcomings in further management. Several of the farmers had invested many working hours in the clearing and fencing process, but lack of further management resulted in an even quicker overgrowing than in nearby comparable grasslands that had not been cleared. The intention with the subsidies, to secure open landscapes and biodiversity for the future, was not obtained. This indicates that the subsidies were not sufficiently based on knowledge of grassland dynamics and the need for management after restoration. Due to the problems with overgrowth after clearing the areas, the farmers expressed a need for management advice from the authorities.

The results indicated the authorities' difficulties in identifying the most valuable grasslands with regard to biodiversity. Nice sceneries and open landscapes are easy to recognize, but open landscapes are not necessarily a guarantee for high biodiversity at species level. To identify valuable semi-natural grasslands, knowledge of both plant communities and indicator species is needed because of the complex concept of biodiversity.

The small size of some of the areas is a problem if the biodiversity is to be maintained for the future. To secure long term preservation of biodiversity at landscape, habitat and species levels, larger areas should be subsidized instead of small, isolated grasslands. This will ease the integration of the species level, the level of communities and the level of processes (WallisDeVries *et al*., 2002).

This investigation clearly indicated a need for improved knowledge of biodiversity, restoration and management on all levels. As a result, the Norwegian Crop Research Institute arranged courses for authorities and farmers. The aim was to facilitate knowledge and information exchange to secure the best future management for conservation of valuable grasslands. However, the response of grasslands to restoration and management are still not fully understood and further research is needed.

In addition to biodiversity, cultural and historical sites occurring in connection with the grasslands need proper management. Transdisciplinary research and exchange of knowledge between archaeologists, historians and ecologists may therefore be necessary as well as further information to authorities and farmers. Furthermore, politicians have to be informed about cultural landscape management, so they can regulate the subsidies correctly.

Conclusions

The intention with the subsidies, to secure open landscapes and the maintenance of semi-natural grasslands and biodiversity for the future was not obtained due to a general lack of knowledge of ecology and biodiversity, and due to inadequate guidelines. This clearly demonstrates the importance of cooperation and exchange of knowledge between scientists, authorities, politicians and farmers to secure the maintenance of the most valuable semi-natural grasslands.

Acknowledgements

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Environmentally friendly milk production: a case study

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Abstract

A group of dairy farmers in south-west Scotland is collaborating to produce added-value milk from sustainable wildlife-friendly systems. The milk is branded as 'White & Wild' and offered to consumers in selected supermarkets at a premium of 6 British pence (p) (£ 0.06) per litre. In return, 2 p is donated to the Wildlife Trusts, while 3 p is paid to the milk producers to fund an agreed on-farm biodiversity programme. This involves identifying 10 % of the farm area to go under a range of environmental improvements, such as setting up bird nesting boxes, creating ponds, conserving existing species-rich grasslands and managing field boundaries – all specifically to encourage wildlife diversity. The 'wildlife-friendly' milk has created considerable media interest, the farmer group, currently 50 strong (just over 3 % of the total number of Scottish dairy farmers), is expanding and sale of the milk, currently about 10 % of that produced, is increasing. This paper briefly describes the farmer-supermarket initiative and the environmental management and biodiversity achievements.

Keywords: milk production, environmental management, biodiversity, marketing

Introduction

The south west of Scotland is predominantly a grassland area with a long history of milk production. The development of modern agriculture changed the landscape significantly as farming reacted to the demand for intensive production systems. Examples of these changes are the reduction in hedgerows found within the landscape (a 54 % reduction in the period from the mid 1940's (Loudon and Lyon, 2003)), and the decline in species-rich grassland.
Modern agriculture in Scotland is changing towards de-intensification, and will undoubtedly de-intensify yet more after the mid-term review of the European Union, Common Agricultural Policy (CAP). Increasingly the farmer has to become a steward as well as a food producer and be responsible for the conservation of much of our landscape and its biodiversity (Scottish Executive, 2001). Within these changing times for agriculture and specifically within the dairy sector, the White & Wild pioneering initiative is one alternative route that is attempting to bring production, the market and the environment closer together.

White & Wild

The scheme and brand concept was born from Agritrade Direct Limited, a dairy farmers' buying consortium in north east England with the main aim of reversing the reduction in milk prices (Whitley, 2002). Agritrade later developed a new company with its partners I.M.A. and Sorn Milk, called WildCare Dairy Products, with the purpose of developing the White & Wild brand. There are presently almost 50 farms involved in producing milk for the scheme, with all producers coming from the Sorn Milk Group, south west Scotland. At present around 10 % of total milk production (Scottish average dairy herd being 130 cows) from the farmer's group is sold on supermarket shelves at a 6 p per litre premium, of which the farmer receives 3 p to promote biodiversity, the Wildlife Trusts 2 p, and the WildCare Dairy Group 1 p to aid marketing, administration and sales (Whitley, 2002).

Farms participating

The farms involved have to meet a range of minimum standards (Table 1). In addition, each farm has to commission a Farm Biodiversity Action Plan (Farm BAP) which is undertaken by a Farm Conservation Adviser from the Farming and Wildlife Advisory Group (FWAG). The Farm BAP highlights the conservation interest of the individual farm and lays out a unique holistic programme of agreed environmental improvements for 10 % of the farm area. The programme includes payments for both capital items such as hedge plants and fencing, and annual payments for areas put under environmentally-positive management. Many of the options are similar but more flexible than the government Rural Stewardship Scheme (Frame and Tiley, 2003).

Table 1. Minimum standards for White & Wild producers (adapted from Loudon and Lyon, 2003).

Maintain, enhance and preserve all existing wildlife habitats, wetlands, species-rich areas, hedgerows, water margins and woodlands
Consider water quality and field margins, through keeping fertiliser and farmyard manure away from watercourses, hedges and dykes
Internal hedges to be cut only in December to March once every three to four years, leaving hedgerow trees.
For roadside hedges which are cut every year, each year's cut should be around 8 cm further out from the previous year's cut until a hedge of 2 m by 2 m is achieved.
Silage to be cut in blocks to allow wildlife to escape.
Manage conservation headlands around arable fields.
Standing deadwood to be retained where safe, ivy not being removed from trees.
Farms to avoid over-tidiness with clumps of species such as nettles (*Urtica dioica*) and blackberry (*Rubus fruticosus*) encouraged to be retained.

Product marketing

The marketing has been carried out with UK-wide television promotions, national newspaper coverage and successful local events, including families of the milk producers attending supermarkets to promote this niche product. The partnership with the Wildlife Trusts is also a key aspect of marketing, with its logo featuring strongly on the product's labelling. The partnership has provided many benefits, from increased brand recognition to a core group of potential purchasers in the form of trust members and volunteers, and the scheme has won several plaudits including an award for innovation. However, to win and maintain brand loyalty will require continuous advertising and relaying the biodiversity benefits to customers.

Biodiversity and economic benefits

A variety of habitats and species highlighted under United Kingdom and local biodiversity action plans are benefiting from various management options (Table 2) adopted under the White & Wild scheme, though the extent to which the scheme could assist in UK and local biodiversity targets will depend on the future growth of the White & Wild brand.

The scheme was established primarily to try and increase returns to dairy farmers during the current period of low returns for what is a bulk commodity product, and also to enable environmental gain. The achievement of increased farm revenues at this time would help in supporting dairy farming and the rural economy and critically, the retention of farms within the dairy sector.

The scheme also has the potential to bring in significant additional benefits to the rural economy with an increased demand for local contractors to undertake environmental works such as fencing, pond creation and hedge / tree planting related to the farm's individual work plan.

Table 2. UK and local BAP species to benefit from management under White & Wild.

Management / Creation option	UK and local BAP species / habitat to benefit
Species-rich grassland	Species rich grassland and orange tip butterfly (*Anthocharis cardamines*)
Wetland	Marshy grassland and rough pasture, curlew (*Numenius arquata*), redshank (*Tringa totanus*) and snipe (*Gallinago gallinago*)
Grazing, silage and hay fields	Lapwing (*Vanellus vanellus*) and corncrake (*Crex crex*)
Scrub	Lesser whitethroat (*Sylvia curruca*), song thrush (*Turdus philomelos*) and juniper (*Juniperis communis*)
Ponds	Farm ponds and lochans and common frog (*Rana temporaria)*
Arable field margins	Arable field margins, yellowhammer (*Emberiza citrinella*) and brown hare (*Lepus europaeus)*
Un-harvested crops	Unharvested crops, yellowhammer (*Emberiza citrinella*) and reed bunting (*Emberiza schoeniclus*)
Hedgerows	Ancient hedgerows, pipistrelle bat (*Pipistrellus pipistrellus*), and grey partridge (*Perdix perdix*)
Woodlands	Wood and scrub pasture, brown long-eared bat (*Plecotus auritus*) and bullfinch (*Pyrrhula pyrrhula*)
Water margin	Riparian trees, water vole (*Arvicolo terrestris*), brown trout (*Salmo trutta*) and otter (*Lutra lutra*)

Conclusions

White & Wild milk is a developing brand, which sells at a premium in selected supermarkets, the premium being used for environmental improvements on the farms. Fifty dairy farmers are currently involved with about 10 % of the milk so far, attracting the premium. Marketing initiatives are increasing the volume of sales. The participating farmers agree to implement a host of environmental actions on their farmlands and already, for example, bird nesting boxes have been set up and grasslands and field boundaries are being managed to encourage wildlife diversity. In addition farmers have attended training workshops. However, the future success of the White & Wild scheme depends on the willingness of supermarket shoppers to pay the premium.

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A method for assessing sustainability levels in agricultural systems (SAFE)

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Abstract

The SAFE project uses a hierarchical framework for defining step-by-step sustainable agriculture, by selection of principles, criteria, indicators and reference values. Principles are related to the functions of the agro-ecosystem which concern the three pillars of sustainability: environmental, economic and social. Criteria are specific objectives, more concrete than principles while indicators are finally assessed in relation to criteria. The values of indicators are interpreted according to reference values in order to quantify the sustainability level for these indicators. The final set of indicators should provide a representative picture of the sustainability of agricultural systems. The step-by-step definition of sustainability and the strong theoretical basis would ensure a broadly applicable system.

Keywords: sustainable agriculture, indicators, framework

Introduction

The sustainability of European farming systems is currently under debate and has become an intensely researched field. Both at the national and international levels, several organisations are analysing and testing sets of agri-environmental indicators, e.g., ECNC (Elisa project; Wascher, 2000) (EnRisk; Delbaere, 2002), OECD (Environmental Indicators for Agriculture; OECD, 2001), European Commission (IRENA; de Angelis, 2002), France IFEN (Piveteau, 1998), US National Research Council (NRC, 2000), or sustainable agriculture indicators, e.g., UK MAFF (MAFF, 2000). This paper suggests a holistic approach to the assessment of sustainability in agriculture by defining a coherent analytical framework.

Hierarchical framework structure

The SAFE hierarchical framework describes hierarchical levels to facilitate the formulation of a set of sustainability indicators in a consistent and coherent way: principles, criteria, indicators and reference values (Lammerts van Bueren and Blom, 1997). Principles are associated with the diverse functions performed by the agro-ecosystem and they have the character of an objective to be achieved. Criteria, more concrete than principles, are easier to assess and to which indicators are linked. An indicator is a quantitative or qualitative variable, which can be assessed. A set of indicators should provide a representative picture of the sustainability of agricultural systems in their environmental, economic and social dimensions. The evaluation of the degree of achievement of criteria or principle requirements is achieved by comparing the actual value of an indicator with the reference value. The list of functions of the agro-ecosystem, principles and criteria is structured in three parts corresponding to the three sustainability pillars. In the environmental pillar, principles are related to a natural resource (Table 1). There is one principle in the economic pillar, it is related to the profitability and the viability of the farms. In the sociological pillar, principles are clustered in four main challenges: food security and safety, quality of life, social acceptability and cultural acceptability.

Table 1. List of principles and criteria for the environmental pillar.

PRINCIPLES	CRITERIA
	Air
Supply of quality air function of the agro-ecosystem shall be maintained or enhanced	Air quality is maintained or enhanced
Air buffering function of the agro-ecosystem shall be maintained or enhanced	Wind speed is adequately buffered
	Soil
Soil regulation function of the agro-ecosystem shall be maintained or enhanced	Soil loss is minimised Soil chemical quality is maintained or increased Soil physical quality is maintained or increased
	Water
Supply of water function of the agro-ecosystem shall be maintained or enhanced	Adequate amount of surface water is supplied Adequate amount of soil moisture is supplied Adequate amount of ground water is supplied
Supply of quality water function of the agro-ecosystem shall be maintained or enhanced	Surface water of adequate quality is supplied Soil water of adequate quality is supplied Groundwater of adequate quality is supplied
Water buffering function of the agro-ecosystem shall be maintained or enhanced	Flooding and runoff regulation is maintained or enhanced
	Energy
Supply of energy function of the agro-ecosystem shall be maintained or enhanced	Energy production is maintained or increased
Energy flow regulation function of the agro-ecosystem shall be maintained or enhanced	Energy use is efficient
	Biodiversity: biotic resources
Supply of biotic resources function of the agro-ecosystem shall be maintained or enhanced	Agricultural biodiversity is maintained or increased Natural biodiversity is maintained or increased
	Biodiversity: habitats
Supply of habitat function of the agro-ecosystem shall be maintained or enhanced	Diversity, number and area of habitats is maintained or increased
Supply of quality habitat function of the agro-ecosystem shall be maintained or enhanced	Functional quality of habitats is maintained or increased
	Ecosystem integrity
Ecosystem stability regulation function shall be maintained or enhanced	Resistance of the ecosystem is maintained or increased Resilience of the ecosystem is maintained or increased
Ecosystem processes regulation function shall be maintained or enhanced	Control of energy flow of the ecosystem is maximal Control of material flow of the ecosystem is maximal

One or several indicators will be defined for each criterion. Each indicator will be tested on its informational quality and cost / benefit ratio. A panel of 10 experts, employing the Delphi technique will carry out validation of indicators (Bockstaller and Girardin, 2003). Each indicator will be evaluated against the set of criteria on a 5-point scale. A matrix will be constructed, incorporating indicators and their assigned values (1-5) for different criteria. Multivariate analysis will be used for determining appropriateness of indicators.

The validity of a sustainability indicator depends also on the quality of the chosen reference values (Wefering *et al.*, 2000). Diversity of sustainability indicators in this research makes it necessary to apply different evaluation strategies: absolute or relative (von Wirén-Lehr, 2001). Absolute evaluation relies on the existence of previously defined reference values. Relative evaluation is based on the comparison of different systems between themselves or with selected reference systems. All the above-mentioned types of indicators and reference values may be applicable to different spatial scales (plot, farm, landscape / region).

Conclusions

Many indicator sets and frameworks for sustainable agriculture have already been presented in the literature (e.g., Adriaanse, 1993; OECD, 2001; Hammond *et al*., 1995; Wascher, 2000). Examples are the 'pressure-state-response' (PSR) framework used by the OECD (2001); the 'pressure-state-impact-response' (PSIR) framework used by UNEP and RIVM (Hardi and Zdan, 1997); 'driving force-pressure-state-impact-response' (DPSIR) used by the EU, EEA (Washer, 2000) and the 'driving force state response' (DSR) framework. Unfortunately, most of these frameworks suffer from a series of drawbacks. Frequently encountered weaknesses of existing frameworks are, firstly, partial coverage of the sustainability issue, partial capture of the key factors and key processes and partial reflection of the complex chain of causes and effects. Secondly, many existing frameworks lack a hierarchical structure or a systematic organization of issues and aspects related to sustainability. Thirdly, many frameworks have a sector or problem based character. Finally, amongst the many initiatives, only a few studies deal with sustainability assessment at the field or farm level. Most studies work at a larger scale, mainly the national level. Important links between management by the farmer and impacts and effects on the agro-ecosystem and its sustainability levels are therefore inadequately addressed. In contrast to the other frameworks, SAFE is clearly organised around the major action domains of public administration and policy makers dealing with agriculture. It gives an exhaustive view of the properties of the agro-ecosystem that makes it possible to weigh the impact of agricultural practices at different levels. The development of the SAFE project will provide a coherent set of sustainable farming indicators. The step by step definition of sustainability and the strong theoretical basis of each concept ensure a broadly applicable system that could be used by different actors: farmers, farmer advisers, researchers and decision makers.

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Evaluation of milk production systems on the basis of sustainability indicators

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Abstract

Dairy farming is the most important branch of agricultural production in Switzerland. Farms that intend to produce milk in the future are forced to adapt their production systems and reduce their production costs. The question of which production systems will be sustainable and successful in the long-term under the changing conditions has to be answered comprehensively. A new generation of a farm level model is presented. Different production system options are available to optimise milk production on dairy farms. Variables such as herd size, breed strategy, herd management, feeding and grassland management systems as well as stable and storage systems and the type of mechanisation are considered. Constraints on workload and environmental effects are included. A comprehensive evaluation of selected production systems is achieved by a sustainability index, which includes economic, social and ecological-ethical aspects. Results show that the sustainability index rises as the production volume increases, and also that the type of production system is significant with respect to the sustainability index. A comparison of the different systems shows in all scenarios that full-time grazing is more sustainable under Swiss conditions than systems with a high proportion of indoor feeding. While the indoor feeding system (TMR) is indeed characterised by high labour efficiency and land productivity, in comparison to full-time grazing it has a lower hourly work income and a higher workload. Systems with a high proportion of indoor feeding therefore have to compensate for this drawback with higher production volumes.

Keywords: milk production, dairy farming systems, sustainability

Introduction

In recent decades, milk production in Switzerland has been subject to continuous changes due to falling milk prices. In addition, factors like social demand for environmentally sound and animal-friendly milk production as well as reduced workload are gaining in significance. A number of recent studies have investigated the consequences of the reorganisation facing the dairy sector (Gerwig and Lehmann, 2002; Flury and Rieder, 2002). Whereas Gerwig and Lehmann (2002) examined structural changes in milk production in plain areas at individual farm level, Flury and Rieder (2002) predicted the structural effects of land use in mountain areas, making statements on the advantages of alternative farm activities. Previous comparisons of milk production systems have mainly been concerned with economic ratios. Economic ratios, however, are not sufficient for statements about sustainable milk production under Swiss conditions. In view of the multifunctional significance of milk production, identifying milk production systems that are successful in the long term and hence sustainable requires an integral approach, taking into account social, ethical and environmental aspects. The results presented are a first attempt to get closer to this ambitious aim.

Materials and methods

A linear programming farm model (Hazell and Norton, 1986) to evaluate alternative scenarios and decisions was developed (Möhring *et al*., 2004) for the purpose of the research. The farm model maximises the income of a dairy farm with a given land capacity. The farm manager can choose between various technically and organisationally different milk production systems, farming intensities, crops and feeding regimes. One specific aim was to integrate the model with the life cycle assessment method. All direct emissions, all indirect emissions from buildings and machinery and the associated environmental impacts are modelled (Zimmermann *et al*., 2003). Data on labour, buildings and machines has been taken from surveys made by the Swiss Federal Research Station of Tänikon (FAT). Feeding and yield data was provided by the Swiss Federal Research Station of Posieux, Changins and Reckenholz (Gazzarin and Schick, 2004). Sustainability is assessed at farm level, with target values specifically oriented to milk production. Equal focus is put on the three dimensions of sustainability, namely the economic, social and ecological/animal welfare aspects (Allen, 1991). The indicators were selected after having evaluated various criteria, such as measurability, possibility of aggregation, ease of interpretation, etc. (Christen and O'Halloran-Wietholtz, 2002). Economic indicators, such as production costs and productivity, primarily evaluate the efficiency and thus, indirectly, the competitiveness of a production system. The evaluation of efficiency focuses on technical, biological and organisational progress. Social indicators represent the attractiveness of farming as an occupation. According to Linckh *et al*. (1997), agricultural activities can only be expected to be 'sustainable' if income, social security and social attractiveness are comparable to non-agricultural activities. Workload and work quality play an important role in this context. Schulze (1995) also considers income maintenance of the working population to be the essential social criterion of a sustainable agriculture. The indicators relevant to milk production are labour income per hour and workload. Workload has been recorded by the OWAS method (Stoffert, 1985). From the farm's point of view, ecology and animal welfare are significant in relation to social acceptance of a production method. Besides ecological indicators such as fossil fuel consumption, global eutrophication and aquatic ecotoxicity, the animal housing system is also considered (loose housing, outdoor exercise, pasture). To enable statements to be made about particular production systems, the threshold and target values for the indicators are established, on the basis of the target specifications for sustainable milk production. By aggregation of individual indicators it is attempted to combine all the sustainability parameters recorded into a single value. This so-called Sustainability Index (SI) not only permits a full comparison, but is also a means of identifying promising, sustainable milk production systems. The aggregation process should be represented in a transparent way to enable discussion, in order to validate the proposed system of indicators for milk production systems. The SI is calculated by the formula: $SI = \log(a*b*c)$, where a is the score for economic indicators, b that for social indicators and c that for ecological-ethical indicators (maximum 100 points in each case). The maximum SI value is six. The closer the value is to six, the greater the probability of a production system being sustainable. For values under five it is questionable whether the system can still be regarded as sustainable.

Results and discussion

The evaluation of sustainability is based on two scenarios (Figure 1). The first of these assumes milk production of 160 t ECM (energy corrected milk) per farm and the second scenario assumes milk production of 400 t ECM per farm. Comparison shows all the production systems in the first scenario to have a SI under five. In our opinion, therefore, the sustainability of these farms is questionable. Whereas social acceptance (ecology/animal welfare dimension) is already high, at around 70 points, lack of competitiveness (economic dimension), at under ten points in most cases, is the primary cause of this low index value. Increasing production to 400 t ECM has a positive effect on all the dimensions of sustainability. Competitiveness rises most steeply to reach just less than 70 out of 100 points for the best systems. The attractiveness of milk production (social dimension) is also significantly enhanced, rising from 28-50 points in Scenario 1 to 50-90 points. Larger production volumes have a positive influence on the ecological dimension, although to a smaller extent than in the case of the economic or social dimensions. All in all, in Scenario 2, the production systems examined attain a SI of well over five in some cases.

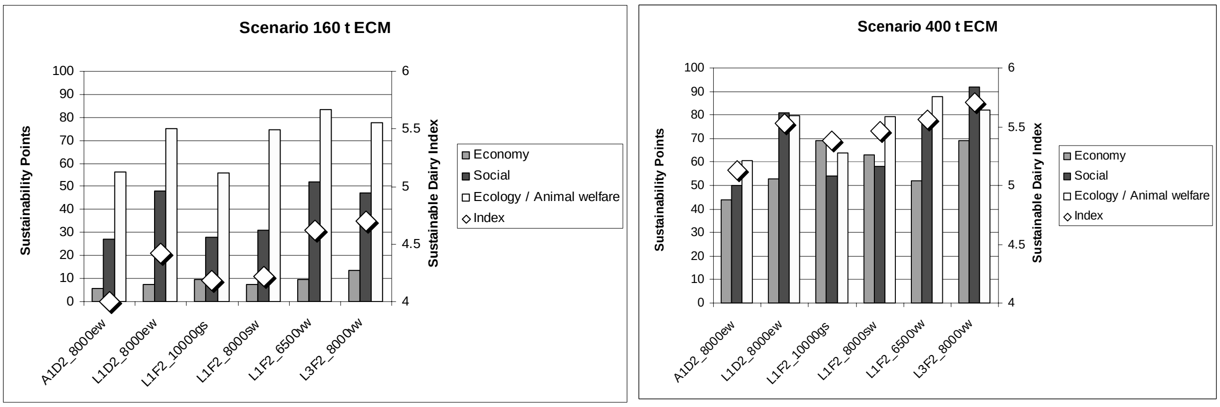

Figure 1. Sustainability Index for different production systems for two different production volumes.

Key:	A1D2_8000ew	Tied housing, non-silo system, production cow, fresh grass harvesting/summer pasture
	L1D2_8000ew	Loose housing, non-silo system, production cow, fresh grass harvesting/summer pasture
	L1F2_8000sw	Loose housing, silo system, production cow, silage/summer pasture
	L1F2_10000gs	Loose housing, silo system, high-production cow, indoor feeding (TMR)
	L1F2_6500vw	Loose housing, silo system, pasture cow, full-time grazing in summer
	L3F2_8000vw	Loose housing, silo system, production cow, full-time grazing in summer

Conclusions

In the plain region of Switzerland, production systems with a milk production of 400 t ECM have a higher sustainability index than systems with 160 t ECM. For the same milk volume, systems with a high proportion of pasture in combination with high production and low mechanisation costs may be regarded as more sustainable than intensive systems with indoor feeding.

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Combining farm models and GIS to examine farm structures, land use and effects on landscape

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Abstract

Agriculture has a significant influence on the landscape and habitats of the Alps. In the past decades, agriculture has been subject to continuous change due to falling product prices and altering demand for landscape, leading to changes in agri-environmental policy. The production intensity in the use of grassland and animal husbandry changes due to increasing economic pressure and technical progress (local intensification and extensification). This has consequences for the biodiversity and the landscape.

In order to model and control this process, on the one hand, the necessary instruments do not exist to date and, on the other hand, mountain farming systems have to be adapted to future requirements. We therefore present a quantitative agrarian structure model that permits the spatially explicit illustration of the effects of policy changes. This model is a combination of a geographical information system (GIS) with independent farm models, which are interlinked by way of a leasehold market to obtain a quantitative agrarian structure model. This instrument makes it possible to examine the scope for action by farmers in respect of new demands of the market and agricultural policy, and to make recommendations on the development of agricultural policy.

Keywords: farm model, GIS, grassland management, landscape

Introduction

An extensive reorganisation of Swiss agricultural policy was initiated in 1992 to separate agricultural price and income policy, as well as to implement ecological concerns on the utilised agricultural area with targeted economic incentives. This reorientation, which will also entail the abolition of milk quotas, was a reaction both to falling product prices and to changed social demand on agriculture (Swiss Federal Council, 2002).

Farm and sector models can provide indications as to how farmers react to such changes in the framework conditions. However, the disadvantage of such models often is that they only permit very aggregative or no spatially explicit statements at all on land use and the associated impact on landscape and ecology.

The aim of the project entitled ‘Sustainable Landscape Production Systems: a demand-oriented agricultural approach (SULAPS)’ is therefore to develop a disaggregative model which permits the spatially explicit illustration of the effects of policy changes without the usual shortcomings of not considering structural change. Alternative scenarios for the socio-economic environment and for the landscape demanded by society are then modelled and evaluated on the basis of sustainability indicators and in comparison with defined target states. The results will be used for political advice and will provide indications of the future design of the general political framework for agriculture in the mountain region.

Concept

We interlink independent mathematical farm models (one model per farm) by way of a leasehold market module to obtain a quantitative agrarian structure model. As a result, on the one hand, we are able to avoid the disadvantage of pure sector models that do not take into account changes in farm structures, as described by Happe and Balmann (2002). On the other hand, we can demonstrate the locally relevant interactions between the farms on the factor market in detail, which is impossible to do with conventional farm models. The individual farm models maximise the household income for each single farm.

In view of the small-scale approach (two investigation areas in a Swiss mountain region with a utilised agricultural area of 5.5 km^2 and 8.1 km^2 respectively), the markets for the other production factors and the goods produced can be considered independent of the model decisions. The individual plots are spatially explicitly modelled within the individual farm models and administered in a Geographic Information System (GIS). This GIS includes detailed land use information and is used on both the input and output side of the structure model (Figure 1).

On the input side, in combination with a cost distance model, the GIS supplies the requisite travelling times between farms and plots, taking into account the road network, its quality, gradient and vehicles used. The consideration of travelling time is of central interest in mountain regions, as available working capacity can have a very limiting effect, particularly in the forage harvest period. One of the factors examined is how strongly travelling time influences the decision to cultivate or not to cultivate.

The GIS will further allow a stratification of individual areas according to various space-dependent criteria, making it possible to carry out extrapolations on the utilisation potential of all the areas on the basis of random sampling vegetation mapping. These utilisation potentials are integrated in the individual farm models by way of restrictions.

On the output side, the GIS permits the visual comparison of initial situation and model results, as well as the calculation of space-dependent sustainability indicators which, for instance, require distances and details on spatial relations between habitats.

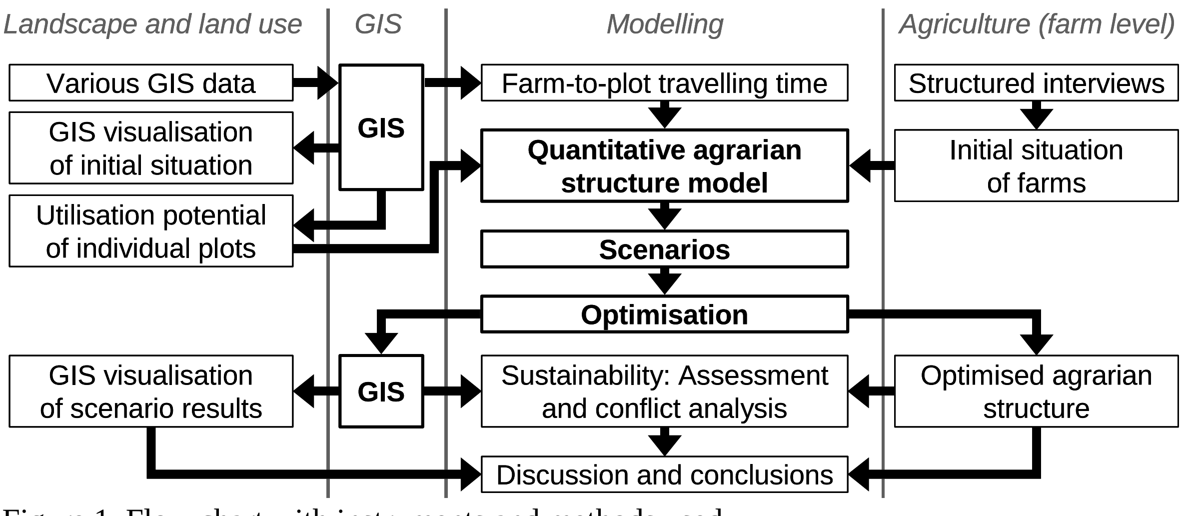

Figure 1. Flow chart with instruments and methods used.

Scenarios

The forecasting of trends in landscape and agriculture structure over the next 10 to 15 years with the quantitative agrarian structure model involves the examination of six scenarios. The variable factors of the scenarios were determined by system analysis with reference to Vester (1999). The choice was kept deliberately wide so as to clearly show up differences between individual scenarios (Table 1). For instance, in an extreme scenario, conditions on the use of individual plots are imposed on agriculture. Apart from the ‘Trend’ scenario, the assumption is that Swiss product prices and factor costs will adjust to the EU level and direct payments will assume increasing importance. Variants of today's direct payment system and today's level of contributions are therefore examined for the purposes of policy evaluation. By 'Trend' is meant the continuation of price/cost trends and of current Swiss agricultural policy, which determines the payment framework for 2004-2007.

Table 1. Scenarios for the framework conditions of Swiss agriculture in 2015.

	Scenarios					
	Libera-lisation	Supported libera-lisation	Trend	Regional value added	Landscape and ecology	Landscape and ecology with utilisation target
Product prices	EU prices	EU prices	Trend	EU prices + 15 %	EU prices	EU prices
Factor costs	EU costs	EU costs	Trend	EU costs	EU costs	EU costs
Direct payment system	Unchanged	Unchanged	Unchanged	Unchanged	New	New, with specified land use
Direct payment contributions	50 % of current level	Unchanged	Unchanged	Unchanged	Ecological payments only	Ecological payments only
Non-agricultural wage rate	90 % of current level	90 % of current level	113 % of current level	Current level	90 % of current level	90 % of current level
Structural aid	Lower support	Higher support	Unchanged	Unchanged	Unchanged	Unchanged

Interviews

The existing infrastructure of each farm and the funds available for further investment are important, particularly for the realistic modelling of investment decisions. Sixty-three out of a total 72 farm managers (88 %) cultivating plots within the project perimeter were willing to participate in a personal structured interview. These interviews covered 90 % of the utilised agricultural area in the region examined. The results serve to adjust the independent farm models to the current initial situation, thus taking path dependencies into account. Only interviewed farms can be modelled by means of individual farm models, and can therefore be part of the aggregated structure model.

Expected results

The model results, expected by February 2005, will show structures and land usage of individual farms in 10 to 15 years and their impacts on landscape and sustainability. Land usage and agricultural changes in the different scenarios will be presented in graphical form. The main result of the project is the discussion of alternatives for the legal framework in view of an efficient use of resources with respect to land use and agrarian policy, as well as targeted landscape development.

Acknowledgements

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The contribution of grassland to social benefits of agriculture – an economic analysis

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Abstract

Grasslands provide multiple benefits to society. As part of the agricultural system and of the rural landscape, they have an economic value in production and contribute to the set of rural amenities. Moreover, grasslands have option values, that reflect the benefits from potential future use, as well as existence and bequest values, that result from the knowledge of continued existence. Though these values encompass non-market benefits, they can be assessed by the means of preference-based economic valuation methods and integrated optimisation models, respectively. Yet, there exists a class of indirect use value that cannot be evaluated with preference-based approaches. This is the class of intrinsic values that result from functional benefits of biodiversity conservation, soil protection and carbon sequestration. We illustrate the importance of these values with the case of carbon sequestration through conversion of cropland into permanent grassland. The results show that, due to the induced and non-saturating flow of methane emissions, the net present value of soil carbon sequestration with permanent grassland can be negative, while this functional benefit can be positive for extensive grassland if the discount rate is sufficiently high. Altogether, the analysis indicates that preference-based valuation methods neglect functional benefits and therefore may either underestimate or overestimate the total economic value of grasslands.

Keywords: economic analysis, total economic value, intrinsic value, carbon sequestration

1 Introduction

Grasslands are by definition multifunctional. They provide multiple benefits to farmers and society. These benefits encompass values of present and future use in agricultural production, recreational and amenity benefits that exhibit public good characteristics, intrinsic values of ecosystem functions, as well as non-use values that are related to bequest motives and the knowledge of existence of particular grassland ecosystems. Altogether, these values can be referred to as 'total economic value of grasslands', a concept that has been developed in the environmental economics literature for capturing the diverse values of an ecosystem (Pearce and Turner, 1990; Munasinghe, 1993; Pearce, 1994; Garrod and Willis, 1999). The total economic value encloses the whole class of values that have a basis in human preferences, and so are amenable to economic analyses that compare the costs and benefits of preserving or developing particular ecosystems. This fundamental idea is translated here from the original context of forestry to the case of grasslands.

As illustrated in figure 1, a basic distinction is made between use and non-use values. The former type of values takes into account that grasslands can generate direct and indirect benefits for society, being through produced goods or environmental amenities. These benefits can also be referred to as material and immaterial use values. In addition, grasslands provide functional benefits, such as habitats and biodiversity, soil and water protection. These intrinsic benefits also constitute a class of indirect use values, since they can influence the fertility of grassland and thus agricultural production as well as the above mentioned amenity benefits.

	Total economic value					
	Use values				Non-use values	
Categories of value	**Direct use value**	**Indirect use value**		**Option value**		**Existence value**
	Material use value	Immaterial use value	Intrinsic value / functional benefits	Future direct and indirect use values	Value of leaving use and non-use values for offspring	Value from knowledge of continued existence
	Production value of grass biomass	Recreational / amenity values of the landscape	Ecological functions			
Valued goods and services	- Animal production - Energy production - Fibre production	- Recreation - Scenery	- Biodiversity and habitats - Soil nutrients and productivity - Soil protection - Carbon			- Habitats - Endangered species
Types of benefit	Direct and indirect market benefits	Non-market benefits and indirect market benefits	Non-market benefits	Market and non-market benefits	Non-market benefits	Non-market benefits
	Land rent and implicit value in agricultural production	Stated / revealed preferences of visitors and implicit value in land / housing prices	Functional benefits that influence production and amenity values	Options for potential future use		

Figure 1. The total economic value of grasslands.

In contrast, non-use values result from the mere knowledge of continued existence of a particular grassland ecosystem for the benefit of present and future generations. These are generally referred to as existence and bequest values, respectively. Finally, the potential benefits of future direct and indirect use give rise to a further class of value. In the economics literature, this is known as option value.

To get empirical information about the different values that are depicted in figure 1 various approaches and methods of economic valuation are required. This valuation can be based on information about market prices and production costs or shadow prices for the assessment of material use values, and on results from environmental valuation studies to estimate indirect, option and non-use values. These methods of valuation are based on the microeconomic concepts of consumers' willingness to pay (WTP), consumers' surplus and land rent.

In this article, we first introduce economic concepts of value and theoretical foundations of economic benefit assessment. Then, we address the different classes of value and the problem of externalities, and adequate approaches of environmental valuation. Furthermore, we investigate aspects of the economic relevance of functional benefits of grassland ecosystems. In particular, we analyse the social net benefit of one additional hectare of grassland for one particular case of intrinsic value. Using the example of cropland conversion to permanent grassland for greenhouse gas mitigation, we illustrate the limitation of purely preference-based valuation methods and the related risk of miscalculating the value of grasslands. Finally, this article provides some concluding remarks on the overall benefits of grasslands to society from an economic perspective.

2 Economic foundations of environmental and resource valuation

Economic valuation of the environment is a topic that emerged in the second half of the twentieth century, when a considerable amount of work has been undertaken on evaluating the costs and benefits of environmental policies and infrastructure projects (cf. Garrod and Willis, 1999; Hanley and Spash, 1993). Different valuation methods have been developed and applied to such major issues as air and water quality, biodiversity and habitat protection, and increasingly on the amenity and recreational benefits of rural landscapes.

Yet, the use and valuation of land was already an important concern for classical economists in the late eighteenth century. They realised that the value of land (the land rent) is associated with variations in land quality and fertility (Ricardo), variations in location and accessibility (von Thünen), and the limited amount of land that was available (Marx). The respective values are referred to as differential, location and absolute rent (cf. Hartwick and Olewiler, 1998; van Kooten, 1993). These concepts of land rent are not mutually exclusive. Rather they reflect different issues of value. First, differential rent is an expression of diminishing returns and the heterogeneity of land. Second, location rent manifests the transfer (transportation) costs and competition among alternative land uses in space. Finally, absolute rent is a measure of scarcity. This is not only a consequence of the limited amount of land that is available for specific purposes, but also of the trade-offs (competition) among alternative land uses.

Land rent is a flow measure of direct use value. It is a surplus-the difference between the value of the output and the cost of production on a unit of land. Land rent accrues as revenue to the owner of the property rights on the land. It is not constant in space and time. Rather, land rents vary with land quality and accessibility, and alter over time as a consequence of technical progress and price changes.

Non-market benefits of agricultural land are not in general included in the land rent, as they do not provide any revenue to the landowners. Yet, economists have developed valuation methods to assess the willingness to pay (WTP) of consumers for non-marketed goods and services. The theoretical basis of these welfare measures can be explained with the concept of consumers' surplus. For a single individual, the latter is defined as the difference between the price the consumer actually has to pay when purchasing a commodity and the price he would be willing to pay. This willingness to pay diminishes as more units of the commodity are consumed, because the extra satisfaction (marginal utility) declines the more of a good an individual consumes. This is illustrated in figure 2 by the marginal benefit curve mb, which corresponds to the consumer's demand curve for that commodity. If the price of the good is P_0, then the consumer is willing to purchase the quantity Q_0. The total satisfaction (utility or benefit) the individual can enjoy from consuming the quantity Q_0 of that good is the area under his demand curve, this is the area $A0Q_0B_0$. Yet, to purchase Q_0 he has spend money equal to the area $P_00Q_0B_0$. Hence, his net benefit is the difference between these two measures. This is referred to as the consumer's surplus AP_0B_0.

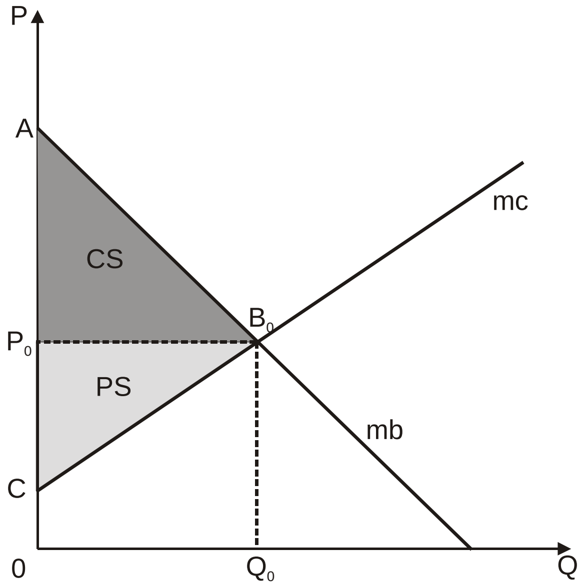

Figure 2. Willingness to pay, consumers' surplus and producers' surplus. (Legend: Q = quantity; P = price; mb = marginal benefit = demand curve; mc = marginal cost = supply curve; CS = consumers' surplus; PS = producers' surplus).

Originally formulated for an individual consumer, the above idea can be translated to the aggregate of all consumers that are on the market of a particular good. The interpretation is straightforward. Aggregate demand is given by the aggregate marginal benefit curve mb, and the consumers' surplus (CS) corresponds to the dark shaded triangle AP_0B_0 in figure 2. It is the difference between the consumers' willingness to pay (the area under the demand curve) $A0Q_0B_0$ and total expenses $P_00Q_0B_0$.

In addition to the demand side, figure 2 also includes the supply side. Total supply of the commodity is given by the marginal cost curve mc. It increases with the quantity supplied, because any increase in production requires increasingly scarce production factors. In the absence of market distortions, an equilibrium between supply and demand results in point B_0, which is characterised by the quantity Q_0 and price P_0. Thus, from selling quantity Q_0 the producers earn P_0 times Q_0. This corresponds to the area $P_00Q_0B_0$ in figure 2. The related cost of production corresponds to the area under the supply curve, this is the area $0CB_0Q_0$. Hence, it remains the producers' surplus (PS) - the difference between revenue and production cost which is represented in figure 2 by the light shaded area CP_0B_0.

For society, the total surplus form a given commodity is the sum of CS plus PS. This is the area between the consumers’ marginal benefit curve and the producers’ marginal cost curve. Correspondingly, the crucial issue of benefits assessment is not the observation of market prices. Rather, knowledge is required about the consumers’ willingness to pay (demand) for and the marginal cost of production (supply) of specified goods.

3 Direct use value and the welfare economic relevance of externalities

The direct use value of a given piece of grassland depends on the use of the material flow of biomass from the land. This either turns into in direct or indirect market benefits, depending on whether the grass biomass is sold on the market (for feeding, fibre and energy use) or employed as an implicit factor in agricultural production. In the first case, one can observe market prices for the product that is sold, and assess the demand (willingness to pay) for these products. In the second case, indirect benefits result from the on-farm use of grassland products in agricultural production. In this case, no market prices can be observed for these input factors. Nonetheless, the flow of grass biomass has an implicit value in milk and livestock production, for instance. This is also called a ‘shadow price’ (implicit price). It can be determined within the framework of an economic farm optimisation model, which takes into account the various production opportunities, product and factor prices, as well as environmental and other relevant constraints.

The value of the land is determined, in both cases, as a surplus, the rent per unit (acre or hectare) of land. As described in the previous section, land rent is the difference between the revenue of a good produced on a given unit of land and the unit costs of turning the natural services of that land into the good. It depends on the price and quantity of output and the cost of production.

Yet, a qualification must be made with respect to the assumptions under which market prices or farm models can be used for benefit assessment. Commodity prices would reflect their social marginal benefits and land rents represent the social value of the land, only under certain conditions. The latter include the assumption of perfectly competitive markets and absence of market distortions. However, since agricultural markets are characterised by distortions due the presence of externalities (external benefits and costs) these conditions are not in general satisfied.

Examples of externalities are costs of water purification and foregone recreational benefits due to water pollution, on one hand, and joy of rural landscapes and biodiversity, on the other hand. In general, these costs and benefits are neither included in factor prices (land and fertiliser prices) nor in market prices for food and fibre. Hence, market prices need to be adjusted to reflect the true social values of these products, and to achieve a socially optimal allocation of scarce resources. This is illustrated in figure 3 for an external benefit in the diagram on the left and for external costs on the right-hand side.

Externalities are a fundamental problem of welfare economics. They are real effects (positive or negative) that are imposed by one economic agent’s activities upon the utility or production possibility of at least one other economic agent, without giving compensation to producers of positive and victims of negative externalities. In other words, without adequate policy, external costs and benefits are not considered in market prices. Figure 3 shows that the consequence of this type of market failure is an under-provision of positive externalities (external benefits, EB) and an over-provision of negative effects (external costs, EC).

The social optimum with external benefits is characterised by the intersection of the social marginal benefit smb curve and the marginal cost mc of production in point B*. The socially

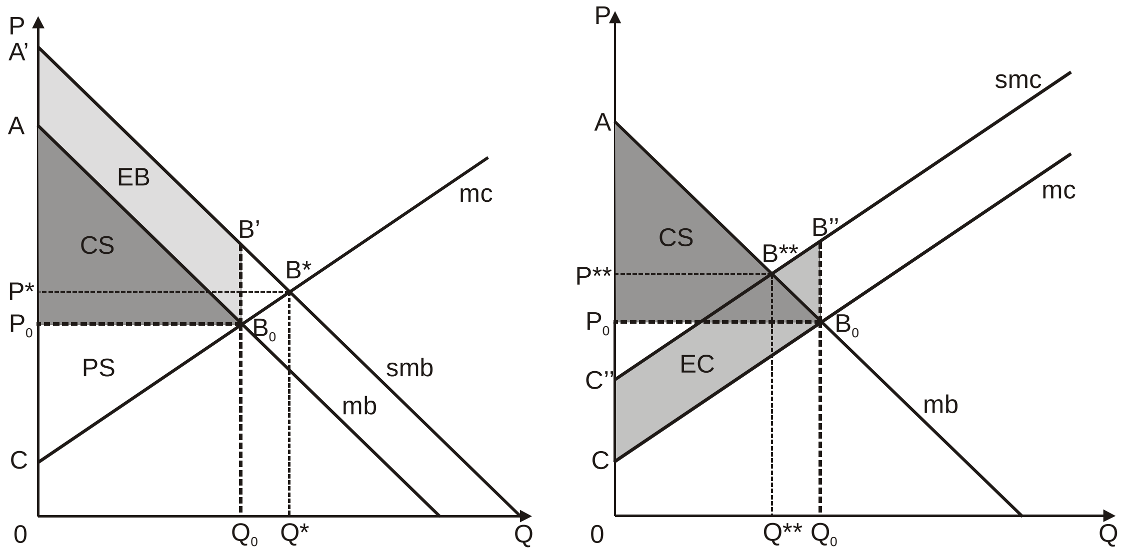

Figure 3. Social net benefits with external benefits (left) and external costs (right). (Legend: Q = quantity; P = price; mb = private marginal benefit; smb = social marginal benefit; mc = private marginal cost; CS = consumers' surplus; PS = producers' surplus. EB = external benefit; EC = external cost).

optimal quantity of the commodity is $Q^* > Q_0$, while the market only provides Q_0. In the presence of negative externalities, the social optimum is given by the intersection of the smc and mb curves in point B**. The socially optimal quantity of the good is $Q^{**} < Q_0$, while the market outcome is Q_0. Unless adequate arrangements are taken, the presence of positive and negative externalities entails social welfare losses that are represented in figure 3 by the triangles B_0B'B* and B_0B''B**, respectively.

These losses of social welfare due to external effects are particularly relevant for agricultural policy and the assessment of social benefits of agricultural systems. On one hand, agriculture provides important external benefits, such the recreational and amenity values of the rural landscape, which exhibits characteristics of a public good. On the other hand, negative externalities (external costs) of grassland management are caused by nutrient losses into the air (ammonium and nitrous oxide emissions) and water bodies (emissions of nitrate and phosphorus), and related effects upon human health and the environment. Related welfare losses can be eliminated if producers of externalities are given an incentive to internalise the marginal external benefits and costs in their decision process. One option for internalising externalities is to provide farmers, for instance, compensation or charging them a fee according to the marginal external benefits of rural landscape and marginal external costs of manure application, respectively. In figure 3, this corresponds to the differences between the smb and mb curves, on one side, and between the smc and mc curves, on the other. Apparently, this requires information about consumers' willingness to pay for environmental benefits (landscape, air and water quality). This is a topic of applied environmental economics (cf. Garrod and Willis, 1999; Hanley and Spash, 1993; Ribaudo and Shortle, 2001).

4 Valuation of environmental benefits from agricultural land

A major argument, which is used in current debates about future agricultural policies, stresses the non-market benefits that are associated with agricultural production. Bromley (2000), for instance, puts emphasis on the environmental functions of agricultural land as a provider of important amenities in rural areas, habitats for a variety of plants and animals that are not directly used but add to the biodiversity of the landscape, and ecological services that enhance the general integrity of many rural areas. These issues have increasingly been addressed in economic valuation studies over the last two decades.

Yet, grassland benefits have not in general been addressed separately. Rather, grasslands are usually regarded as part of the open space or rural landscape. Drake (1992), Kline and Wichelns (1996, 1998) and Roschewitz (1999) for instance, estimated the willingness to pay for preserving rural landscapes and open space, using the contingent valuation method. Others investigated the influence of the proximity of agricultural land on market prices for residential land and housing (e.g., Le Goffe, 2000; Irwin and Bockstael, 2001; Irwin, 2002; Smith *et al.*, 2002). Estimates on grassland benefits are only provided by Drake (1992) and Le Goffe (2000) for the Uppsala County in Sweden and the Britanny region in western France, respectively.

Estimating relative values for cropland, grazing land and wooded pastures, Drake (1992) found that grasslands are highly valued by the respondents of his survey, compared to cropland. The relative values were: grain production index = 100, grazing land 191 (median: 140), and wooded pastures 241 (200). This implies that, at least in the region of Uppsala, the preference-based value of grasslands is higher than the one of cropland. However, Drake emphasises that the results of his study are not directly applicable to other countries, because of the special type of landscape, attitudes and traditions, relative scarcity of land and the high standard of living in Sweden.

Irwin (2002) has tested the marginal values of different open space attributes in a different setting than Drake. She used a hedonic residential pricing model with data for a central Maryland region, and came to the conclusion that 'open space is most valued for providing absence of development, rather than for providing a particular bundle of open space amenities.' This may partly explain the small number of valuation studies that have explicitly addressed amenity benefits from grasslands.

In principle, the same methods as above can be used for the assessment of benefits from water quality improvement. However, due to the nonpoint-source characteristics of agricultural water pollution, the evaluation of costs and benefits of pollution control measures in rural areas cannot be restricted to preference-based valuation methods. Rather, a combination with biophysical simulation and economic allocation models at the watershed scale is suggested (cf. Oriade and Dillon, 1997). The use of such integrated agricultural optimisation models allows then for calculating abatement costs at the field, farm and aggregate level, respectively (cf. Keusch (2000) and Schmid (2001) for case studies in Switzerland, and Horan and Shortle (2001) to get an overview of empirical studies on agricultural water pollution).

In recent years, an additional class of grassland benefits has been investigated. These are functional benefits of biodiversity in various grassland ecosystems. Applying a stochastic model from financial economics to long-term harvest data from a grassland ecosystem, Schläpfer *et al.*, (2002) examined the potential 'insurance' value of plant diversity on the stability of yields and economic returns in a drought-sensitive agricultural environment.

Other classes of functional benefits of grasslands are associated with measures of maintaining soil fertility and soil protection. These include the social benefits of controlling soil erosion and surface runoff, which has been analysed by Keusch (2000) and Schmid (2001) in model-based case studies for the Lake of Baldegg watershed in Switzerland. Another issue that is currently under consideration in several countries is the conversion of cropland into permanent grassland as a measure of soil carbon sequestration (cf. Antle *et al.*, 2001; Antle and McCarl, 2002; Leifeld *et al.*, 2003). This is addressed in the following section.

5 Functional benefits: The net present value of soil carbon sequestration

Carbon sequestration in agricultural soils is a potential greenhouse gas mitigation strategy that is currently discussed in various countries. Options include restoration of organic soils, and conservation tillage and conversion of cropland into permanent grassland for mineral soils. Leifeld *et al*., (2003) estimated the organic carbon (OC) stocks and sequestration potential in agricultural soils in Switzerland, and compared their findings with international studies. For no-till farming, the average sequestration rate is 0.33 ± 0.10 t OC ha^{-1} y^{-1}. For conversion into permanent grassland, the annual rate is 0.43 (0.42 to 0.46) t OC ha^{-1} y^{-1}, with a time horizon until saturation of 50 years (Leifeld *et al*., 2003: p. 81). Thus, the total sequestration potential for 50-year time horizon is 21.7 t OC ha^{-1} (assuming constant turnover rates and constant climatic conditions).

Yet, any conversion of cropland into permanent grassland would result in an expansion of the grassland area and of the amount of grass for feeding animals. As a consequence, one must expect the number of animals, and hence the amount of animal products and animal waste to increase. This might induce additional greenhouse gas emissions, especially methane from enteric fermentation and manure holding systems. From a societal perspective, there are two crucial issues associated with carbon sequestration and induced methane emissions. First, induced methane emissions from permanent grassland use do not reach a saturation level as the process of carbon sequestration. The flow of methane emissions must therefore be considered over an infinite time horizon. Second, depending on the intensity of grassland use, the rate of methane emissions y^{-1} may exceed that of carbon sequestration.

To calculate the social net benefit of carbon sequestration, we apply a marginal analysis of land use change. This is, we consider the hypothetical case of converting one single hectare of conventionally tilled cropland into permanent grassland, and assess the net present value of

Table 1. Induced methane emissions from 1 ha of permanent grassland in livestock farming.

			Permanent grassland					
			high intensity		low intensity		extensive	
			Cattle	Sheep	Cattle	Sheep	Cattle	Sheep
Grass yield (dry matter) [a)]	GY	kg ha^{-1} y^{-1}	12,000		5,000		2,500	
Gross energy for ruminants [b)]	GE	MJ ha^{-1} y^{-1}	237,736		99,057		49,528	
CH_4 from enteric fermentation [c)]	ME1	kg CH_4 ha^{-1} y^{-1}	256.3	213.6	106.8	89.0	53.4	44.5
CH_4 from manure storage [d)]	ME2	kg CH_4 ha^{-1} y^{-1}	33.1	4.8	13.8	2.0	6.9	1.0
Total induced	ME3	kg CH_4 ha^{-1} y^{-1}	289.4	218.4	120.6	91.0	60.3	45.5
CH_4 emissions [e)]	ME4	t CO_2eq $ha^{-1}y^{-1}$	**6.08**	**4.59**	**2.53**	**1.91**	**1.27**	**0.96**
Carbon	CS1	t C ha^{-1} y^{-1}	0.43					
Sequestration [f)]	CS2	t CO_2eq ha^{-1} y^{-1}	**1.58**					

Notes:
a) Source: LBL, srva, FiBL (2001) *Deckungsbeiträge 2001*.
b) GE = 6.3 * 0.318 * GY; sources: LBL (2000: p. 632) and Minonzio *et al*., (1998: p. 62).
c) Methane rate (Ym): 0.06 for cattle, and 0.05 for sheep; ME1 = GE * Ym / 55.65 MJ GE/kg CH_4 (source: Minonzio *et al*., 1998: p. 120-122).
d) Own calculations according to Minonzio *et al*., (1998: p. 72, p. 120-122).
e) Global warming potential of methane: 21.
f) C / CO_2 = 12 / (12 + 2*16) = 12 / 44.

carbon and methane flows in a partial analysis with ceteris paribus conditions (assuming that prices and other emissions remain constant). We compare six alternatives of grassland use, including three levels of intensity (highly intensive grassland with an annual yield of 12 t dry matter ha^{-1}, low intensive use with 5 t ha^{-1} y^{-1}, and extensive grassland with 2.5 t ha^{-1} y^{-1}) and two types of animal (cattle and sheep) for feeding the grass. These six cases are represented in table 1 with respect to yield and induced methane emissions.

Using coefficients and calculation methods that are described in Minonzio *et al.*, (1998) and used in the Swiss Greenhouse Gas Inventory, table 1 allows us to compare induced emissions and sequestration rates in CO_2 equivalents (using the global warming potential of methane). It shows that, even for less intensive grassland, the flow of induced methane emissions would exceed the annual rate of carbon sequestration, reported by Leifeld *et al.*, (2003). Yet, the result could be negative, even for extensive grassland with emission rates below the sequestration rate, due to the different time horizons.

To evaluate the net effect from an economic point of view, we compare the monetary values of these fluxes under the assumption of a hypothetical carbon price and a given discount rate. In this sense, we calculate the net present value (NPV) of the two flows of hypothetical payment according to the subsequent equation

$$(1)\qquad NPV = \sum_{t=1}^{T} \frac{p \cdot CS}{(1+r)^t} - \sum_{t=1}^{\infty} \frac{p \cdot ME}{(1+r)^t}$$

where t is the time index, T denotes saturation time of the sequestration process, CS and ME are the average rates of carbon sequestration and methane emissions, respectively, and r is the discount rate (interest rate) that is important for intertemporal comparisons. In addition, we consider a hypothetical carbon price p that should be paid to farmers for carbon sequestration and charged for greenhouse gas emissions. For simplicity, we assume this price being constant, although it should increase over time in order to reflect increasing marginal damage costs of greenhouse gas accumulation as well as increased mitigation costs.

Using equation (1) and data from table 1 on carbon sequestration and methane emission rates, table 2 shows that the NPV can be negative, even if emission rates are below the sequestration rate (extensive grassland, discount rate 0.01). Moreover, it shows that with higher discount rates, the results gradually change, and the net present value of carbon sequestration with extensive grassland becomes positive, even if the grass is used for feeding animals. This is

Table 2. Net present values of carbon sequestration (SFr. ha^{-1}).

		Permanent grassland					
		high intensity		low intensity		extensive	
Discount rate	Carbon price [SFr./t C]	Cattle	Sheep	Cattle	Sheep	Cattle	Sheep
0.01	1	-148.90	-108.24	-52.21	-35.27	-17.68	-9.21
	50	-7444.84	-5412.13	-2610.43	-1763.47	-883.86	-460.38
	200	-29779.37	-21648.51	-10441.73	-7053.87	-3535.43	-1841.50
0.02	1	-69.36	-49.04	-21.02	-12.55	-3.75	0.48
	50	-3468.17	-2451.81	-1050.97	-627.49	-187.68	24.06
	200	-13,872.69	-9807.26	-4203.87	-2509.94	-750.72	96.24
0.05	1	-25.30	-17.17	-5.96	-2.57	0.94	2.64
	50	-1265.01	-858.47	-298.13	-128.73	47.19	131.88
	200	-5060.04	-3433.87	-1192.51	-514.94	188.75	527.54
0.10	1	-12.31	-8.25	-2.64	-0.95	0.81	1.66
	50	-615.59	-412.32	-132.15	-47.45	40.51	82.86
	200	-2462.35	-1649.26	-528.59	-189.80	162.04	331.44

due to the fact, that with higher discount rates the long term (time period beyond T) is valued less that for lower discount rates. In other words, with high discount rates, methane emissions in the distant future are valued less than carbon sequestration in the short term.

This example of marginal valuation illustrates the ambiguity that can be associated with long-term benefits of grassland to society. For a comprehensive analysis, the total economic value must be considered. This requires the simultaneous consideration of direct and indirect market benefits (land rent), consumers' willingness to pay for enjoying recreational and amenity benefits (immaterial use value) and to satisfy existence and bequest motives (existence and bequest value), option values to account for potential future benefits, and the various functional benefits of grasslands. As the above example shows, the latter can be positive or negative. Moreover, the result is sensitive to changes in any variable of equation (1). This exemplifies the risk of over or under estimation of the total economic value of grasslands, if the functional benefits are not adequately considered.

Yet, to extend the analytical framework for the purpose of policy analysis, one must allow for simultaneous changes within the economy and the environment that would be caused by large scale conversion of cropland into permanent grassland. In addition to the effect of induced methane emissions from feeding the grass to animals, a large scale expansion of the grassland area would also influence emissions of nitrous oxide, and other air and water pollutants such as ammonia, nitrate and phosphate. This can either go in positive or negative direction. Moreover, a large scale expansion of the grassland area and number of animals would result in a price fall for animal products, and thus in a decline of the agricultural income. These effects cannot be considered in a partial analysis, as presented for illustrative purposes in this article. Rather, a modelling approach with a wider system perspective is required for taking into account interdependencies and trade-offs within the entire system of grassland ecosystems, agricultural production and the economy. In particular, integrated economic allocation models are required. They have the advantage of implicitly evaluating trade-offs and providing results about the optimal allocation of land and other scarce resources among alternative uses and the optimal intensity of cultivation in different areas.

6 Conclusions

Grasslands provide multiple benefits to society, including various categories of use and non-use value. These values encompass material use values of grassland and biomass in production – values that determine the land rent of a given plot. In addition, grasslands provide various non-market benefits. Environmental economists have developed methods for the evaluation of non-market benefits. These methods are based on revealed or stated preferences to measure the willingness-to-pay for the preservation of specific landscape and environmental attributes, and also to capture existence, bequest and option values. Yet, preference-based methods cannot provide a complete picture about the value of an ecosystem. In particular, grasslands are characterised by various trade-offs among alternative uses and ecological functions. The related benefits are referred to as intrinsic values or functional benefits.

Taking the example of soil carbon sequestration by converting cropland into permanent grassland, we present a partial analysis that evaluates the net present value of carbon sequestration and methane emissions that are induced be feeding the grass from one additional hectare of grassland. The results show an ambiguous solution with respect to the sign of the long-term value that soil carbon sequestration could have for society. This illustrates that preference-based valuation methods tend to neglect risks and therefore overestimate the total value of grasslands (except for extensive grassland). To calculate the total economic value of grassland these benefits must be included, along with those values that can be assessed with information on market prices and outcomes and preference-based valuation methods, respectively.

Moreover, to address large scale effects of land use changes, various trade-offs must be evaluated. These trade-offs involve the economic problem of scarcity and choice. Typical questions are about the optimal allocation of land (both at a national and local scale), the optimal provision of open space and related social benefits, and the internalization of external costs and benefits that result from the existence and use of grasslands. These questions involve both the satisfaction of consumers' preferences and the production side of agriculture. The latter is the most usefully analysed by a model-based evaluation of trade-offs among alternative land uses and environmental functions. Economic optimisation models can provide information about implicit values (so called shadow prices) that are derived from a system's perspective, rather solely an expression individual preferences that, given the complexity of the issue, are not based on a complete understanding of complex systems and their dynamics.

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Grassland and water resources: recent findings and challenges in Europe

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Abstract

Three main components of the terrestrial hydrological cycle are taken into account in this paper: soil, groundwaters and streams, linked by various transfers, such as drainage, throughflow and runoff. The effects of grassland management are studied and compared with crop effects on four criteria: infiltration, soil moisture budget, overland flow / surface runoff and water quality (nitrate, pesticides, microbiological parameters).

The main result of this literature review is to point out the major positive effects of grassland on all the water quality criteria, with two local problems: nitrate and microbiological parameters. In a short second part, we develop a challenge for the European grassland researcher community: to contribute to the European efforts to improve our water resource quality. To conclude, we propose some research questions for the future.

Keywords: water quality, runoff, water infiltration, grassland management, farmer practices

1 Introduction

As focused by Briggs and Courtney (1989) 'the high yields characteristic of modern, intensive farming systems in temperate areas reflect man's ability to modify the agro-ecosystem in such a way to remove or diminish natural limitations upon productivity, and to provide a more favourable environment to crop growth'. We agree with this research on productivity as an effect desired by many farmers in Europe and helped by our Common Agricultural Policy. On the other hand, we propose to explain that farmer practices involved in these modern farming systems have major impacts on hydrological processes (Benoît, 1994).

In this trend, the grasslands have a particular position, some of them are very intensive, but some of them have for a long time been managed on an extensive way. The geography of the grasslands is also very clear in Europe: extensive grasslands are located in mountains (i.e., Alps, Pyrénées, Vosges, Jura, Central Massive, Scotland, Norway, north of Sweden, Schwarzwald, Carpathians, Tatars, ...) and Mediterranean zones (i.e., east of Spain, centre and south of Italy, south of France, Greece), intensive in Atlantic zones (Netherlands, Denmark, England, Brittany) and a mix of them in central Europe (Rhine and Danube basins).

The hydrological cycle is commonly represented as a closed system comprising major storage components such as atmosphere, oceans, ice caps, soil, groundwaters and streams. To study the relationships between grassland and water resources, we can focus upon a limited part of this cycle, the terrestrial hydrological cycle. Three main components are taken into account: soil, groundwaters and streams, linked by various transfers, such as drainage, throughflow and runoff. We focus our paper on the relationships between the diversity of grassland management and the main fluxes of water in this terrestrial hydrological cycle.

2 Grassland in the hydrological cycle

For the terrestrial hydrological cycle, Briggs and Courtney (1989) identify:
- four main components: soil, groundwaters, streams and seas,
- four main transfers: drainage, throughflow, runoff and seepage.

This cycle is vulnerable to the effects of agriculture, and, for us, in particular, through the impact of grassland management practices upon the transfer mechanism of water and the associated chemical and biological elements.

The focus is on two main management practices: (i) location of grassland in the landscape, (ii) farming practices on each grassland. These practices interact with interception and infiltration (as inputs of water) and evapotranspiration, drainage and runoff (as outputs of water).

2.1 Effect of grassland on infiltration

As the works of Holtan and Kirkpatrick show, infiltration rates on grassland are generally higher than those on arable land (Briggs and Courtney, 1989). Nevertheless, marked variations occur in grassland soils due, in particular, to differences in sward age, composition and grazing intensity.

In general, infiltration capacity increases as the pasture gets older due to the accumulation of organic material at the surface and the development of an extensive root system and of a stable soil structure. Different types of grass also have different effects, partly because of the way in which they affect soil structure, but also because of their varied resistance to animal trampling (Gifford and Hawkins, 1978).

The most important factor controlling infiltration capacity in grassland is grazing intensity. Reviewing the hydrological effects of grazing, Gifford and Hawkins (1978) concluded that light-moderate grazing may reduce infiltration capacities by about 25 % compared with ungrazed pasture, while under heavy grazing infiltration capacities fall about 50 %.

Within a field, these effects show marked spatial variability as a result of the behavioural patterns of grazing animals. Briggs (1978), for example, comparing infiltration capacities in different areas of a single pasture on clay soils, showed that in the most heavily trampled areas infiltration rates were zero, whereas in the least trampled areas the infiltration capacity was 7.6 cm h^{-1}. Similarly, Selby (1972) noted that in New Zealand, grazing may cause severe compaction, which reduces infiltration capacity, promotes surface runoff and encourages soil erosion.

2.2 Effect of grassland on the soil moisture budget

Farming does not affect the total quantity of water held in the soil in the long term, but it does affect the pattern of retention throughout the year. Thus Keuren *et al.* (1979) found that summer-grazed pastures had higher rates of evapotranspiration than winter-grazed plots but less surface runoff and subsurface outflow.

The lack of knowledge about the grassland situation has to be reduced by new researches focused on grassland management and soil moisture budget evolution.

2.3 Effect of grassland on overland flow and surface runoff

Overland flow refers to the movement of water across the soil surface either in the form of thin sheets of water (sheetwash) or as concentrated flow in rills and gullies. Horton (1933) described what has become known as Hortonian or infiltration excess overland flow.

Overland flow occurs in two situations: (i) when rainfall intensities are greater than the infiltration capacities of the soil and (ii) when local saturation of the soil in footslope or channel-side areas is created by lateral movement downslope.

Flow velocity is an important parameter in relation to runoff because it affects the time taken by water to enter the permanent stream network, and thus the response time (flashiness) of the stream system. As written by Briggs and Courtney (1989), rapid stream responses to rainfall are favoured by:

– rapid generation of overland flow during rainfall – i.e., low infiltration capacities and high rainfall intensity,
– high overland flow capacities – e.g., due to steep slopes and the development of well-defined and deep gully systems,
– short travel distances for overland flow to the stream channel – i.e., high stream densities.

Agriculture exerts all over the world a major control on processes of overland flow, both through its effect on crop cover and rainfall interception and its effect on infiltration capacity, surface roughness and surface moisture retention. For all of these processes, grasslands have a very positive effect.

The first wave of major researches began around the 1930's. Early research about the effects of cropping systems and grassland on overland flow in the USA has been summarised by Glymph and Holtan (1969), and is presented in table 1.

Table 1. Runoff from 0.01 acre (0.004 ha) plots under 5 cropping systems in Wisconsin, Oklahoma and Iowa (after Glymph and Holtan, 1969).

	Runoff (% of rainfall)		
	La Crosse (Wisconsin) 1933-1943	Guthrie (Oklahoma) 1930-1938	Clarinda (Iowa) 1933-1942
Continuous Row crop	28	13	22
Rotation Row crop	20	11	13
Rotation grain	21	13	10
Rotation Hay	**12**	**7**	**3**
Continous Grass	**5**	**1**	**1**

Recent European works are focused on the excellent effects of grassland on runoff. Chisi and Zanchi (1981) recorded the effects of different cropping, cultivation and grassland with or without drainage, on runoff and soil loss from silty clay soils in the Vicarello area near Pisa (Table 2). In each situation, overland flow and soil loss from grass are less that from arable land. A grass sward provides a more or less continuous vegetation cover which intercepts rainfall and impedes any overland flow which does occur. The improved rooting and organic matter accumulation, with the high worm activity as showed earlier by Darwin (1881), in grassland soils also means that infiltration capacities tend to be higher than in arable soils.

Table 2. Overland flow and soil loss from silty clay soils in the Vicarello area of Italy under different cropping systems (from Chisci and Zanchi, 1981).

	Undrained runoff		Soil loss	Drained runoff		Soil loss
	mm	% of water	t ha^{-1}	mm	% of water	t ha^{-1}
Conventional Tillage	25.8	3.64	4.05	17.9	2.53	3.72
Minimal Cultivation	41.1	5.81	1.61	26.9	3.81	1.52
Grassland	**21.1**	**2.98**	**0.18**	**15.9**	**2.24**	**0.15**

In the same way, Souchère *et al*. (2003b) show the effectiveness of grassland location in a watershed to reduce soil loss. Using simulations with STREAM model in a Normandy watershed (Bourville), they evaluated the increase in soil loss after the ploughing of 17 % of grassland surfaces by the farmers: the overland flow increased by 75 % and the soil loss by 85 %. To improve the situation, they simulated the effect of a 1 % increase of grassland located in strategic places: the runoff volume will decrease by 48 %.
Nevertheless, soil structural damage caused by trampling or vegetation removal due to over-grazing may allow overland flow to take place, and in some cases serious losses may be initiated. Costin (1979) illustrates these effects by comparing plots under a range of grazing regimes, from moderate to heavy stocking, in New South Wales, Australia. Higher grazing intensities resulted in lower vegetation cover and higher rates of overland flow and soil loss. Similarly, the effects of herbicides used to control rangeland weeds has been shown by Richarson and Bovey (1979).

So, grassland strips and optimal field location in the landscape is the best strategic option to reduce the overland flow and soil losses in Europe. A general plan for an ecological infrastructure based on grassland is now to be built at the European scale.

2.4 Effect of grassland on water quality

Nitrate
For many authors (Briggs and Courtney, 1989; Manion, 1995; Benoît *et al*., 1995), grassland has a better effect on water quality and water resources than crops (Table 3).

Table 3. Effect of land use on nitrate content of leached water (ceramic cups) (Benoît *et al*., 1995).

Land cover	Number of 'field-years' measurements	Average (mg NO_3^- l^{-1})	Standard deviation (mg NO_3^- l^{-1})
Forests	5	2	-
Grassland-only cut	**9**	**19**	**14**
Grassland-only grazed	**18**	**31**	**25**
Temporary grassland (leys)	**3**	**28**	**-**
Alfalfa	**13**	**23**	**8**
Winter wheat	27	46	25
Winter barley	27	46	25
Oil rapes	8	120	52
Summer barley	8	32	20
Maize (silage)	28	126	77

Under cut grassland, nitrate leaching is very low when fertilisers are applied in accord with the level of yield, until N fertiliser rates of around 400 kg N ha^{-1}. A number of recent works allows us to conclude that water quality is good in respect to nitrate under cut grassland in Europe (Ball and Ryden, 1984; Baraclough *et al*., 1984; Decau and Salette, 1994; Dowdell and Webster, 1980; Garwood *et al*., 1986; Jordan, 1989; Simon, 1995). Most of these results are presented in figure 1.

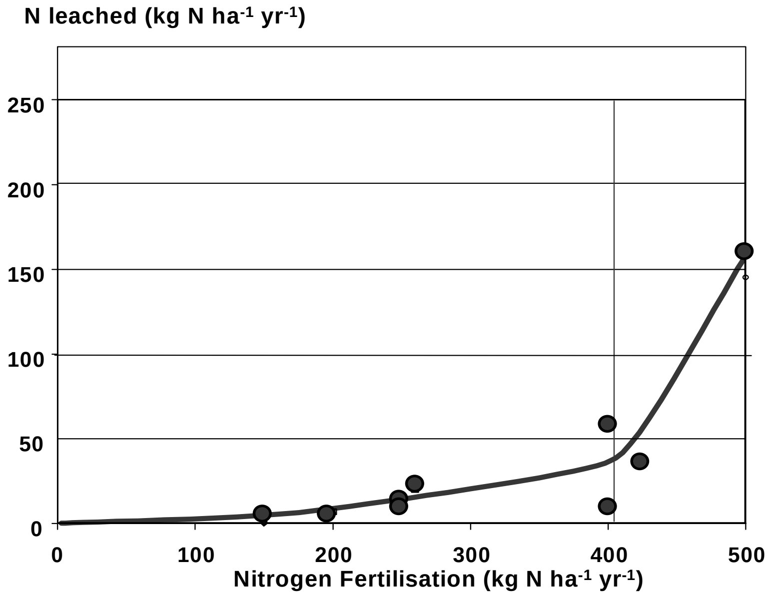

Figure 1. Influence of fertilisation on nitrate leaching for mown or cut grassland (European atlantic zones with good soil potentialities – synthesis of bibliographical data).

Without fertiliser or with low levels (less than 100 kg N ha^{-1} y^{-1}), no significant nitrate leaching is measured. Figure 1 shows a low level of nitrate leaching until 250 kg N ha^{-1} y^{-1}. For a 400 kg N ha^{-1} y^{-1} fertilisation rate, the nitrate leaching is lower if the fertilisers are concentrated in spring and summer than when they are spread throughout the year. In this case, autumn fertilisers and soil mineralisation induced an available N amount higher than the plant needs for N. Above 400 kg N ha^{-1} y^{-1}, nitrate leaching increases rapidly.

The relationship between nitrate leaching and nitrogen fertiliser level has been investigated for grazed grassland composed of pure grass stands. Figure 2 shows results for a large range of pedological and climatic contexts (UK, France, Netherlands, New-Zealand) (Farrugia and Simon, 1994; Lançon, 1978a; Lançon, 1978b; Ledgard, 1989; Lantingua *et al*., 1987; Macduff *et al*., 1989; Owens *et al*., 1994; Peyraud *et al*., 1995; Richards and Wolton, 1976; Ryden, 1983; Ryden *et al*., 1984; Scholefield *et al*., 1988; Scholefield *et al*., 1991; Sherwood and Ryan, 1990; Simon, 1995; Steele *et al*., 1984).

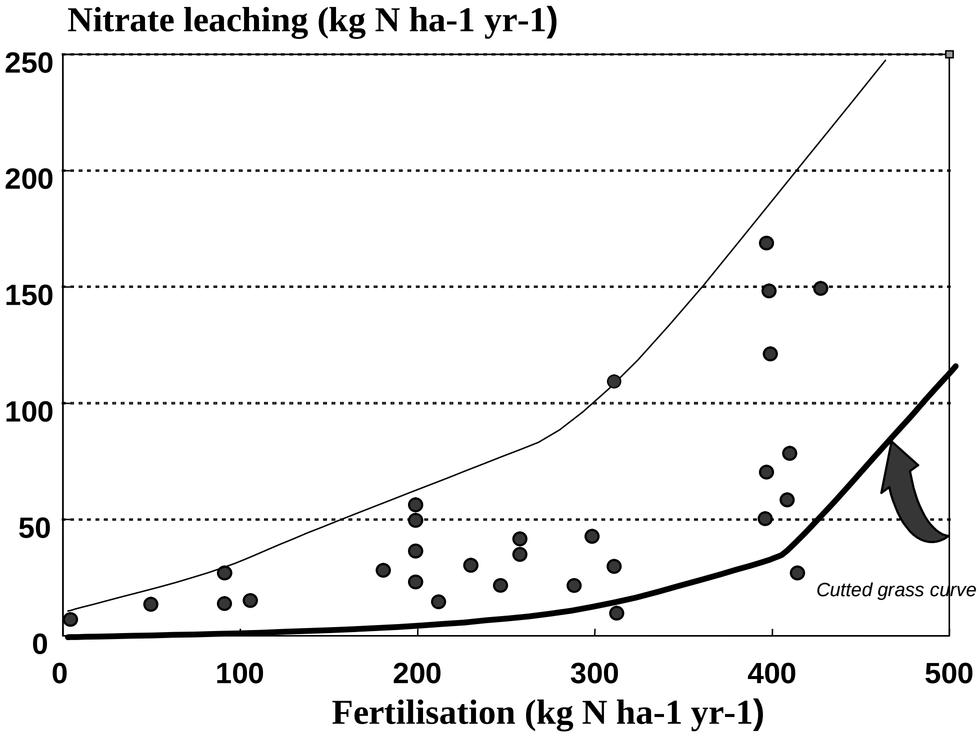

Figure 2. Nitrate leaching under grazed pastures in relation to the nitrogen fertilisation level (synthesis of bibliographical data).

Comparing with the response curve for cut grassland (see figure 1), the nitrate leaching for grazed pasture is higher. It stays in a moderate level if nitrogen fertilisation rate is low (less than 200 kg ha^{-1} y^{-1}). Then, it is very variable and able to reach very high levels if fertilisation rate is higher than 300 kg N ha^{-1} y^{-1}. This high variability between experiments shows that nitrogen fertilisation is not the single factor responsible for nitrate leaching. Stocking rate is a more synthetic index and gives a better explanation of nitrate leaching (Figure 3).

Any farmer practice which induces a decrease in stocking rate on the pasture decreases the variability in nitrate leaching. But, hay or silage harvesting on a grassland field also decreases the number of grazing days and consequently the nitrate leaching (Table 4).

Table 4. Influence of harvesting management of grassland (ryegrass) fertilised with 250 kg N ha^{-1} y^{-1} on nitrate leaching (from Decau and Salette, 1994).

Harvesting Management	Fertilisation (kg N ha^{-1} y^{-1})	Stocking rate (grazing days ha^{-1} y^{-1})	N leaching (kg N ha^{-1} y^{-1})	Concentration of leached waters (mg NO_3^- l^{-1})
Only cut	250	0	3	8
1 cut + grazing	250	290	11	35
Only grazing	250	760	24	101

The main factor influencing nitrate leaching in grazed pastures is the stocking rate. As an indicator of the stocking rate, we use the Number of days of grazing (GD), where GD = Number of calendar days of grazing x Number of animal units per hectare. For example, 500 GD could correspond to an hectare of grassland used by 50 dairy cows during 10 days or 25 cows during 20 days.

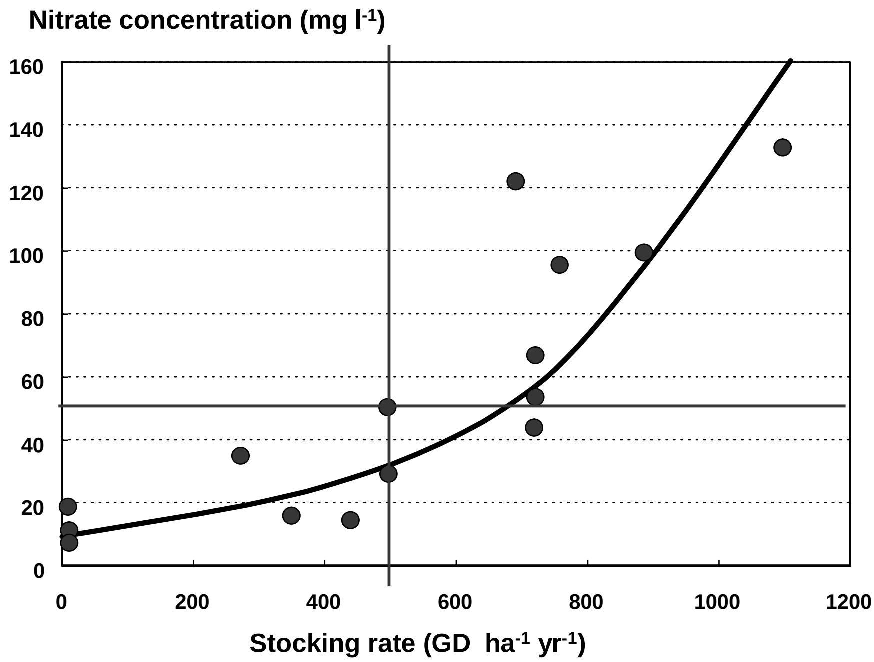

Figure 3. Nitrate concentration of leached water (mg NO_3^- l^{-1}) and stocking rate (GD ha^{-1} y^{-1}) (synthesis of bibliographical data).

Figure 3 shows that it is possible to maintain the water within the European limit of potability (50 mg NO_3^- l^{-1}) if the number of days of grazing (GD) is lower than 500. If GD is higher than 700, the nitrate concentration in water is higher than 50 mg l^{-1}.

Pesticides

In our research of papers on water quality, we did not find a paper detecting pesticide contamination under grassland. This fact is central for the future of water resources in Europe because herbicide, fungicide, and pesticide contaminations are increasing very rapidly in European waters. So, the location of grassland in watersheds is a major solution for water managers to decrease such water contaminations (Benoît *et al*., 1995; Mignolet and Benoît, 1999).

Microbiological parameters

A more critical point are bacteria, virus and parasite contaminations of water from cattle. A large number of papers recently pointed to this source of water contamination (Vallet, 1994; Brewer, 1997; Crane *et al*., 1983; Larsen *et al*., 1994; Marinova, 1995; Moore *et al*., 1983 ; Moore *et al*., 1989; Sherer *et al*., 1992). Two main management problems are identified by these works: the animal trampling in the small rivers during drinking, and the direct contamination by liquid effluents from buildings or during the spreading of slurry along the streams. New parasites are developing, as Guardia for example.

On the other hand, we find few papers dealing with the effects of water quality on herd health, but they seem very important (Meijer *et al*., 1999). This feedback effect of water contamination on animal production is a deficiency in our research.

3 How to increase the positive effects of grassland on water resources?

In Europe, the presented results indicate a new position for grassland: their capability to protect water resources and to protect soil from erosion. So, a general trend for the area of grassland to decrease should stop in order to benefit European society. Three challenges for the future are presented:

3.1 How to increase the surfaces of grassland?

During the last thirty years, there has been a global trend to decrease grassland area through three factors: becoming cropland by ploughing of productive grassland, becoming forest by plantation and becoming urban zones by building.

Now, there is a new challenge to inverse this trend and to increase the grassland surfaces. But, a lot of difficulties have been identified: (i) the CAP subsidies induced an increase in crops through high level of subsidies, (ii) industrial cheese factories favoured the use of more maize in dairy cow feeding, (iii) the efficiency of work and the level of investments induced the increase of maize in dairy cows farms (Gall Le *et al*., 1997; Mignolet and Benoît,1999; Mignolet *et al*., 1997; Mignolet *et al*., 1999). And, we can add that the 'image of modernity', including our own influence as researchers often gave a qualitative advantage to maize in livestock farming systems.

Only two main arguments are developed to increase the grassland surfaces: (i) for high quality cheeses it is beneficial and sometimes a legal obligation to use grassland, (ii) for water resource protection, grassland should be a major way in Europe (Brouwer and Hellegers, 1996; Oenema *et al*., 1998; Pflimlin and Madeline, 1995).

3.2 Where to localise grassland?

A major challenge for water resource protection is to locate grassland in sensitive areas. The present proposal is to locate new surfaces of grassland on (grass) strips in European valleys, seen as an European network of water corridors. This should produce important effects through improving water quality and reducing water runoff (Souchère *et al*., 2003a).

A possibility is to build or re-build a network of grassland along all the rivers in Europe. This European global grassland corridor network could be a major contribution of grassland for sustainable development and the management of a European ecological super-structure.

3.3 How to build a new 'image' of grassland?

Firstly, we have to know the current images of grassland for the European people. This aspect could be tested by a survey of the European population. But, as scientists, we also have an influence on this image of grassland: how can we improve the image of grassland through our work? This paper is one of a large number of contributions in this way. But, are we able to give enough arguments to change the level of C.A.P. subsidies, and to re-build this common basis for the future of agriculture?

4 Conclusions: What are the challenges for researchers in the future?

We identified the main favourable effects of grassland on water resources: runoff decreasing, no pesticide contamination, global protection against high nitrate content if moderate stocking rates are used on grazed pasture. But, some new researches have to be developed. In the future, we propose to focus on the following main research questions to improve our knowledge on grassland and water resources:

a) Increasing knowledge on grassland location

The evolution of grassland surfaces and the location of these evolutions have to be known and to be related to water data bases. We propose to EGF to manage a deal with the Land Use and Cover Changes research programme (Lambin *et al*., 1999; Lambin *et al*., 2003; Mannion, 1995; Velkamp and Fresco, 1997). All over the world, the grassland areas are one of the major cover in term of challenges for the future (Girard and Benoît, 1990; Girard *et al*., 1990; Benoît *et al*., 1993; Lambin *et al*., 1999).

b) Modelling of farmers choices

The question we want to focus is: how to preserve grasslands, where are they maintained? In an other formulation: What are the good reasons for a farmer to keep or to increase grassland? Surveys, economical studies, modelling of farmer's meaning are the main methods to evaluate the possible future of grassland (Le Ber and Benoît, 1998).

c) Increasing knowledge on grassland interests for water resources by two main trends of research

Developing a common organisation for Observational Research. As we showed above, we need more coordinated data basis to help us to build our research hypothesis. Often, it is very difficult to compare data on an European scale. Three main trends shape this challenge:

- the common development of measuring and monitoring of water quality (field and watershed scales),
- the generalisation of measuring and monitoring of animal health (quality of drinking water for animals, monitoring of parasites),
- the improvement of measuring and monitoring of animal products.

The future of researches in these fields seams to be linked to the developments in Observational Study Methodologies (measuring, monitoring, statistical analysis, building of common conceptual framework). A very useful initiative could be to initiate a European Network of Experimental Stations: 'Grassland effects on natural resources'. EGF could be the booster of this initiative.

Building a common grassland management typology. If we want to compare our results in Europe, the description of grassland management in a multi-criteria typology is a necessity. Until now some of us have precise results on water quantities and qualities (the norms and the laboratory analyses are standardised), but we have large difficulties to compare an Irish cow pasture with a Lorraine one in a same grassland management typology. A future common challenge could be to build together a European grassland management typology.

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Greenhouse Gas Budget of Intensively and Extensively Managed Grassland

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Abstract

We present preliminary results from measurements of annual greenhouse gas budgets of intensively and extensively managed grassland fields in the Swiss Central Plateau in the second year after conversion from arable land. The intensively managed field shows a nearly balanced budget (within the range of uncertainty), whereas for the extensively managed field a net release of CO_2 equivalents is estimated. The latter result is in contrast to general observations of higher C-stocks in extensive permanent grassland compared with arable soils, and may reflect a short-term conversion effect.

Keywords: greenhouse gases, nitrous oxide, carbon dioxide, grassland management

Introduction

It is widely accepted that emissions of greenhouse gases (GHG) including CO_2 and N_2O caused by human activities lead to an increase in global mean temperature and to regional climatic changes. For agricultural systems, a decrease in the N_2O emission together with an increase in the soil carbon stock (CO_2 sequestration) could help to mitigate the greenhouse effect and to fulfil the reduction commitments under the Kyoto protocol. This could possibly be achieved, for instance, through the conversion of arable land to permanent grassland and a reduction of management intensity. Here, we investigate the effect of these measures on the GHG budget using parallel measurements of the exchange of CO_2 and N_2O over an intensively and an extensively managed grassland plot previously converted from arable land. Because the fields were not grazed, we did not include CH_4 in this study.

Materials and methods

The measurement site on the Swiss Central Plateau near Oensingen was established in the spring of 2001. An arable plot (100 x 140 m) was converted to permanent grassland and split into two management regimes: (a) extensive management with no fertiliser application and 2-3 cuts y^{-1}, and (b) intensive management with four fertiliser applications (367 kg N $ha^{-1}y^{-1}$ as ammonium nitrate and slurry) and 4-5 cuts y^{-1} (Figure 1). CO_2 net ecosystem exchange was measured by an eddy correlation (EC) technique on both the intensively and extensively managed fields. The EC systems consist of fast response ultrasonic anemometers (GILL HS and R2) and open-path infrared gas analysers (LICOR 7500). The flux calculation included the common correction procedures including linear detrending, vector rotation, and Webb-correction (Aubinet *et al.*, 2000). The application of a strict data rejection procedure reduced the CO_2 flux data coverage by ca. 65 %. The most effective rejection criteria were non-stationary / non-turbulent conditions, erroneous concentration signals resulting from rain and dew, and an unacceptable footprint. All these effects are site-specific and result from the limited field size and the frequently calm (non-turbulent) conditions during night time which are typical for the Swiss Plateau. The gaps in the CO_2 flux time series resulting mainly from data rejection made it necessary to apply a mechanistic gap-filling procedure consisting of the following steps: (a) a fit of an exponential temperature dependence of the night-time respiration flux; (b) subtraction of the fitted respiration flux function from daytime data yielding the daytime photosynthetic CO_2 flux; (c) a fit of a hyperbolic relationship between photosynthetic flux and global radiation for optimum growing conditions and interaction with canopy height; and (d) calculation of missing data from soil temperature, global radiation and canopy height using the fitted functions. N_2O fluxes were measured using the static chamber technique (Denmead, 1979) and a photo-acoustic analyser (INNOVA 1312). Ten frame-rings of 0.4 m diameter were permanently inserted 20 cm into the ground, 6 on the intensively and 4 on the extensively managed field. Periodically, a closed chamber of 25 cm height was placed on the frames and the N_2O concentration change of the ventilated inner volume was monitored for at least 10 min. N_2O fluxes were calculated from the slope of the linear regression of N_2O concentration versus time. The instrumental N_2O detection limit was 20 ppb, therefore, the flux detection limit of the measurement system was 16 ng N_2O m^{-2} s^{-1}. Flux measurements were primarily centred on possible 'trigger' events such as harvesting fertiliser applications and / or subsequent rainfall. Additional measurements were carried out at regular intervals between the trigger events in order to estimate 'background' N_2O emissions. The annual N_2O budget was calculated by fitting exponential decay functions to the time course of N_2O fluxes measured during each fertiliser event, integrating these functions over time, and adding the average background contribution for all remaining days of the year.

Results and discussion

Continuous gas flux measurements on both plots started in May 2002. To calculate and present a meaningful annual budget, we take the results of a 12-month period from 1st May 2002 to 30th April 2003. It is considered to be fairly representative for the year 2002, since the growing condition of both fields was similar at the beginning and the end of this period. Figure 1 shows the cumulative CO_2 net ecosystem exchange of the two fields during the 1 year period. The largest uptake of CO_2 occurred during the first growth period from March to May. Each cut was followed by a significant net loss of CO_2 when soil respiration was the dominating exchange process. For the intensively managed field, slurry applications in May and August clearly enhanced CO_2 emission. The CO_2 loss during the cold season from mid-November to mid-March was comparatively small because soil respiration was much reduced.

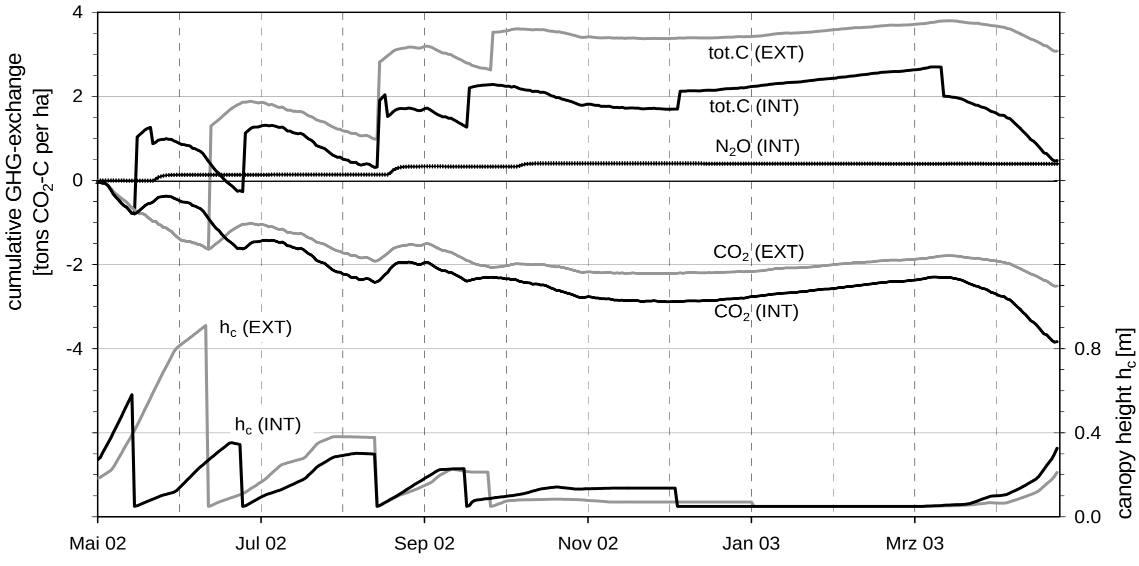

Figure 1. First-year time course of cumulative greenhouse gas exchange (CO_2, total C, N_2O) in CO_2-equivalent warming potential units, and canopy height of intensively and extensively managed grassland fields. The total C curves represent the sum of all carbon import / export processes (CO_2, slurry, and harvest). N_2O emission of the extensively managed field was close to zero and therefore omitted.

In order to determine the net greenhouse forcing effect, the total C-budgets of the grassland ecosystems must be considered, including non-volatile input and output C-fluxes in harvested crops and slurry application. The seasonal time course of the cumulative total carbon exchange is illustrated in figure 1. The positive step changes represent C removal by harvests, and the negative changes represent C inputs by slurry application. In addition to the C exchange, the N_2O exchange was included in the calculation of the total GHG budget. For this purpose, the N_2O fluxes were converted to units of t CO_2-C $ha^{-1}y^{-1}$, indicating the CO_2 equivalent warming potential for a lifetime of 100 years. Only the fertilised field showed a considerable loss of N_2O, as indicated by the cumulative curve in figure 1. Significant N_2O emissions were related to the fertiliser application, and depended on rainfall and soil moisture conditions. The total annual GHG budget and its components, corresponding to the end values of the curves in figure 1, are listed in table 1 together with estimated uncertainties. The results indicate an almost balanced annual budget for the intensively managed field (not significantly different from zero), but a considerable net C loss from the extensively managed field. The large uncertainties were mainly attributed to systematic errors in the field measurements and the data interpolation methods. For the CO_2 exchange, the large numbers of occasions when there was missing data because of unfavourable local wind conditions represented the main problem.

Table 1. GHG budget and its components for intensively and extensively managed grassland fields for the period 1 May 2002 to 30 April 2003, all values have units of t CO_2-C $ha^{-1}y^{-1}$.

Budget component	Intensively managed field		Extensively managed field	
N_2O net gas exchange	+ 0.38	(±0.15)	– 0.01	(±0.05)
CO_2 net gas exchange	– 3.82	(±1.10)	– 2.50	(±0.79)
Harvest output	+ 6.05	(±0.61)	+ 5.59	(±0.56)
Slurry input	– 1.75	(±0.35)	+ 0.00	(±0.00)
Total carbon budget	+ 0.48	(±1.20)	+ 3.09	(±0.84)
Total GHG budget	+ 0.86	(±1.21)	+ 3.08	(±0.85)

Conclusions

The preliminary results presented here reveal that the intensively managed field is characterized by a slightly positive GHG budget due to the net release of N_2O and C in almost equal amounts. However, the resulting number is not significantly different from zero considering the uncertainties of the various budget components. The extensively managed field without fertiliser application exhibits a distinctly positive GHG budget of ca. +3 t CO_2-C $ha^{-1}y^{-1}$ through a net loss of C. This is in contrast to general observations of higher C-stocks in extensive permanent grassland compared with arable soils. It may reflect a short-term disequilibrium effect in the C-cycling during the adaptation process to the new management. We will continue to monitor this development in the following years.

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Variation in organic carbon content in Flemish grassland soils

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Abstract

In 2001-2003, an intensive sampling was undertaken in Flemish grasslands on different soil types and with different managements. Because there was a need for information on how the organic carbon (OC) content can be influenced by management and by the age of the grassland (temporary or permanent), more than 1500 soil samples were taken. There was also a need for recent bulk density values in order to calculate the C storage per hectare in a robust way. The results show that permanent grasslands contained more OC in the soil than temporary grasslands; grazing also enhanced the OC content in the soil in comparison with grazing + cutting and cutting. Bulk density differed with soil depth but less with soil type (n.s.).

Keywords: grassland soil, organic carbon content, bulk density

Introduction

According to the IPCC (2000) only 3 % of the total C stock in temperate grasslands is found in the vegetation, 97 % is found in the soil. As such, grassland soils have a high potential to store large amounts of soil organic carbon (SOC).
Grasslands in Flanders are of considerable agricultural importance because they cover a large area of the total agricultural surface (almost 37 %). Furthermore, grasslands store far more OC below ground than arable crop land (Houghton *et al*., 1999; Vleeshouwer and Verhagen, 2002; Mestdagh *et al*., 2003b) and therefore they are also important in relation to C sequestration in terrestrial ecosystems. This C sequestration in terrestrial ecosystems provides Annex I countries, through article 3.4 of the Kyoto Protocol, the opportunity to mitigate their greenhouse gas emissions.
When determining OC stocks for grassland soils in Flanders, it was noticed that there was much missing information in the available C databases. No information was found concerning grassland management and type. Furthermore, no recent values of bulk density in grassland soils were available. Therefore, we undertook a study (2001-2003) mainly to investigate the influence of soil type, applied management and the age of the grasslands on the OC sequestration.

Materials and methods

Flanders is situated in the north of Belgium and has a temperate wet climate. The different agricultural regions represent different soil textures namely the Polders (clay soil), the Sandy region (sandy soil), the Sandy Loam Region (sandy loam soil), the Campines (sand) and the Silt region (loam). In 2001-2003, soil samples were collected in every agricultural region in Flanders from different types of grassland. The soil samples were taken from 0-10, 10-30 and 30-60 cm depths. The bulk density was measured with a Kopecky gimlet and rings on an average depth in each sampling zone. In total, over 1500 samples were taken. The samples were air dried and *analys*ed with the method of Walkley and Black, 1934. For the statistical analysis, the statistical computer program S-plus 6.1 (Insigthful Corporation, America) was used.

Results and discussion

The intensive sampling made it possible to assess mean OC concentrations for different management options, grassland age and for different soil types. When comparing three different management treatments (Figure 1a), namely grazing, cutting + grazing and cutting, grazing had a higher OC content than cutting + grazing and the previous two had a higher content than the cutting treatment. These trends were found for all agricultural regions (except the Campines) and the differences between the management treatments were significant (at $P = 0.05$). Results from Hassink and Neeteson (1991) and Schuman *et al*. (1999) confirm this. In Flanders, the different grassland types (cut, grazed, permanent, temporary) are strongly connected with each other because most of the permanent grasslands are grazed while the temporary ones are mostly cut. The higher OC concentrations under grazed grasslands can be explained by a higher return of organic matter to the soil under grazing. This is partly due to higher losses of plant material when compared with cutting, deposition of dung (Hassink and Neeteson, 1991); the redistribution of C within the plant / soil system and effects of animal traffic which may be enhancing physical breakdown, soil incorporation and the rate of decomposition of litter (Schuman *et al*., 1999). Figure 1b shows clearly that permanent grassland soils contain more SOC than those under temporary swards (significant difference at $P = 0.05$). Ploughing and resowing, soil organic matter *mineralis*ation, released as CO_2 in the atmosphere. Management measures, which can lead to an increase in soil organic matter (such as grazing or higher N fertiliser application), can nevertheless also lead to higher emissions of CO_2 equivalents (as N_2O and CH_4). Moreover, these interactions can lead to possible negative impacts on the environment (e.g., eutrophication of drinking water). Grazing, for example, encourages more C to be stored below ground than cutting but also results in greater emissions of N_2O and CH_4. Because of their higher 'Global Warming Potential' (1 kg N_2O = 310 kg CO_2, 1 kg CH_4 = 21 kg CO_2) the equivalent of a considerable amount of CO_2, which was extra sequestered by grazing, can be lost as N_2O and CH_4 in the atmosphere. Therefore, policy makers should be aware for the possible impacts that their policy measures can have on the ecological, economical and social aspects of agriculture (Mestdagh *et al*., 2003a).

Differences were found between the different soil types. The Polders (clay soils) contained the largest amounts of OC (170 t OC ha^{-1}) for the layer 0-60 cm, compared with the Campines (136 t OC ha^{-1}), the Sandy Region (119 t OC ha^{-1}), the Sandy Loam Region (109 t OC ha^{-1}) and the Silt Region (112 t OC ha^{-1}). For these calculations, the bulk densities in table 1 were used.

The importance of accurate values for the bulk density becomes clear when calculating OC stocks for grassland soils. Using too low or too high values can have an influence on the size of the C stocks. In Flanders, recent and specific bulk densities for grasslands are not available. The bulk density (Table 1) tends to vary with soil type and with soil depth. Significant differences (at $P = 0.05$) were only found for the bulk density between the different soil depths. In the future, more bulk densities will be measured so that variation in relation to the management can be investigated.

Table 1. Bulk density (BD) for the different agricultural regions in Flanders for three depths.

Agricultural Region	BD g C cm^{-3} (0-10 cm)			BD g C cm^{-3} (10-30 cm)			BD g C cm^{-3} (30-60 cm)		
		se	SD		se	SD		se	SD
Polders	1.42	0.089	0.265	1.54	0.033	0.098	1.53	0.038	0.114
Silt Region	1.38	0.104	0.181	1.41	0.033	0.057	1.55	0.044	0.076
Sandy Loam Region	1.34	0.037	0.217	1.48	0.024	0.143	1.52	0.051	0.299
Sandy region	1.35	0.093	0.264	1.45	0.032	0.092	1.52	0.035	0.098
Campines	1.37	0.042	0.166	1.39	0.049	0.194	1.45	0.047	0.186

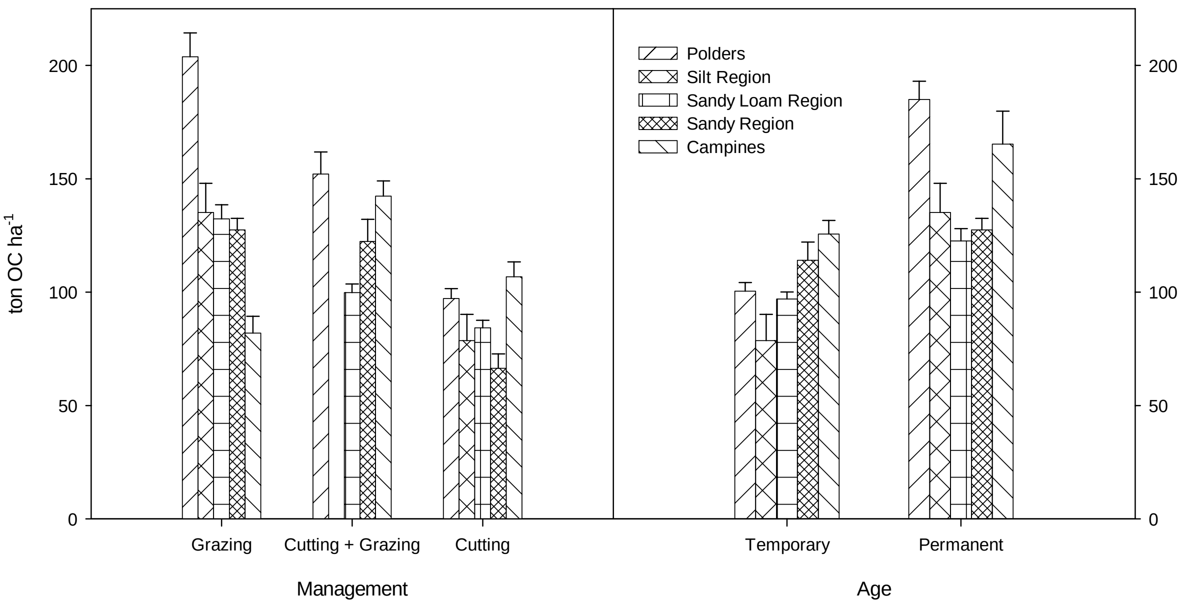

Figure 1. a) Soil organic carbon (OC) contents (t OC ha^{-1}) for different management treatments; b) OC contents (t OC ha^{-1}) for temporary and permanent grasslands both for different agricultural regions for the layer 0-60 cm.

Conclusions

Grassland age and management influence the soil OC concentrations. Permanent grasslands have higher SOC contents than temporary grasslands; grazed grasslands contain more SOC than cut grasslands. Permanent, grazed grassland (with low N fertilisation) would be a good option for C sequestration in Flemish grasslands. Recent bulk density values were measured in grassland so that calculating OC contents can be as accurate as possible. Bulk density varied with soil depth (significant) but, no significant differences were found between soil types.

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Effects of livestock management on carbon stocks and fluxes in grassland ecosystems in the Pyrenees

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Abstract

Grassland ecosystems can constitute a source or a sink in the global C balance, and their management affect their position in that balance. We aim to assess soil organic carbon (SOC) content and determine how grazing affects C fluxes and stocks in grasslands at high altitude in the Pyrenees. In a preliminary survey we found that total SOC ranges from 65 to 300 Mg ha^{-1} in these ecosystems, and is partially explained by complex combinations of variables representing topography, macroclimate and bedrock. In a second, more detailed survey, we improved the modelling of SOC by introducing management variables and standing biomass. Preliminary results of this work suggested that abandoned areas had lower SOC than grazed areas, and the higher SOC contents occurred when both sheep and cattle grazed in the area. The importance of management in soil carbon accumulation was confirmed in an experiment developed in two subalpine locations, where we found a sharp increase in active soil organic matter in grazed compared to non-grazed plots. The Eddy covariance method showed that an intensely grazed area was a slight sink for C, in spite of the elevated C efflux in August, when temperatures were very high and vegetation had been heavily grazed.

Keywords: subalpine grasslands, pasture, soil organic matter fractions, C sequestration

Introduction

Following the Kyoto Protocol, the need for a better understanding of the processes and mechanisms leading to loss and sequestration of soil organic carbon (SOC) was widely recognized. The assessment of SOC reservoirs is of interest because soil may act as a major source or sink for the increased atmospheric CO_2. In addition, increases in SOC improve soil physical, chemical and biological properties related to productivity and the buffering capacity of the environment. While changes in land use are widely accepted as key drivers of global C dynamics, the role of grassland management has only recently received attention as a substantial potential C sink (Conant *et al*., 2001). In grasslands, C enters the soil through litter fall, root turnover and carbon exudation from the roots, and is released from the soil through heterotrophic respiration and by leaching. A fraction of the C from decomposing materials is transformed into stable organic complexes. Grazing or plant defoliation affects root dynamics in a complex way. Research on the effects of grazing on SOC is inconsistent to date, with both increases and decreases reported with increased grazing pressure (Murty *et al*., 2002). A clear understanding of the effects of management on the distribution and dynamics of different SOC fractions is essential to the development of sound models to evaluate SOC storage and dynamics. Active carbon fractions have been identified as a sensitive indicator of the effects of land use and management on SOC accumulation. This work aims to quantify the C stored in the soils of alpine and subalpine grasslands in the Pyrenees, and to determine the effects of grazing on their potential for C sequestration.

Materials and methods

We conducted a preliminary survey to determine SOC content in soils of alpine and subalpine grassland in the Central and the Eastern Pyrenees. This survey included the determination of SOC of the entire soil profile, in 34 locations. We modelled SOC introducing variables related to topography, climate and bedrock. We conducted a second survey mainly centred in two Spanish pyrenean regions. In July 2003 we sampled 66 sites. At each site we recorded topography and bedrock, took 1 m^2 aboveground biomass distributed in four 0.5×0.5 m samples, and collected a sample of the first 20 cm of soil. Soil samples were analysed to determine total organic C. Climatic variables were estimated using a model that combines climatic data and topographic variables into a GIS system (Ninyerola *et al.*, 2000). Management had been previously determined by archive sources and was later verified in the field. Four livestock managements were identified: abandoned, cattle, sheep, and cattle and sheep. We used a backward regression to select climate, topography and management variables that better explained the variation in SOC in the first 20 cm of soil.

To study the effects of grazing intensity on SOC fractions, we designed an experiment in two locations in the Eastern Pyrenees. At each location we established one large plot where three treatments were randomly assigned to six 25 x 25 m subplots. The treatments were: abandoned (non-grazed); light grazing (one adult cow per subplot); heavy grazing (three adult cows per subplot). The grazing treatments were applied at the end of July for three days, the time taken for the forage in the most heavily grazed subplots to become exhausted. We collected soil samples immediately before grazing took place and one month afterwards. In each plot we sampled four 5 x 5 cm cores of soil up to 30 cm depth. Soil cores were divided into three layers, 0-5 cm, 5-15 cm and 15-30 cm. From each fresh soil sample we extracted the active C after chloroform fumigation using a K_2SO_4 solution (0.5 N, 1:5 w:v). Changes in active SOC were calculated as the difference between the active C measured one month after grazing and immediately before the introduction of the animals. In an adjacent extensive heavily grazed area we established the instrumentation to record net carbon fluxes from the ecosystem by the Eddy covariance method.

Results and discussion

In the first survey we found that SOC ranged from 65 to 300 Mg ha^{-1} in subalpine and alpine grasslands in the Pyrenees. The combination of topography, macroclimate and bedrock partially explained the wide range found ($R^2_{adj} = 0.33$, $P = 0.02$). SOC in the first 20 cm of soil constituted around 68 % of the total SOC in the soil profile. In the second survey, SOC from the first 20 cm ranged from 14.8 to 146.6 Mg ha^{-1}. The predictive power of SOC from the model increased with the addition of variables representing grazing management, interacting with climatic variables, and standing biomass ($R^2_{adj} = 0.48$, $P < 0.001$). Abandoned areas showed lower C stocks while areas grazed by both cattle and sheep had the higher SOC content (Figure 1). For all grazing treatments, predicted SOC decreased with increased precipitation (Figure 1).

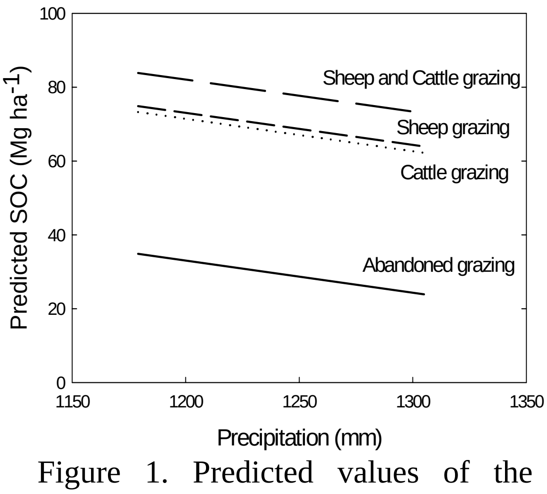

Figure 1. Predicted values of the organic carbon (SOC) in the first 20 cm of soil in relation to changes in precipitation for each grazing management. Other variables in the model were kept constant to their media values.

CO_2 fluxes measured during the six months, June to November, at the heavily grazed area in Vall d'Alinyà by the Eddy covariance method suggested that the studied grasslands act as a small carbon sink, in spite of the high temperatures and intensive grazing in August. The extent to which the soil can be a sink for C depends on the balance between the rates of the processes of C acquisition and the rate of breakdown of both the resident and the newly acquired C. Preliminary results from the controlled grazing experiment suggested that grazing produces a sharp increase of the active SOC, at least in the first 15 cm of the soil (Figure 2). This increase may be either stabilised in more recalcitrant SOC fractions or mineralised and released from soil as CO_2. The balance between these two processes will determine the role of grazing in the sequestration of C in the soil.

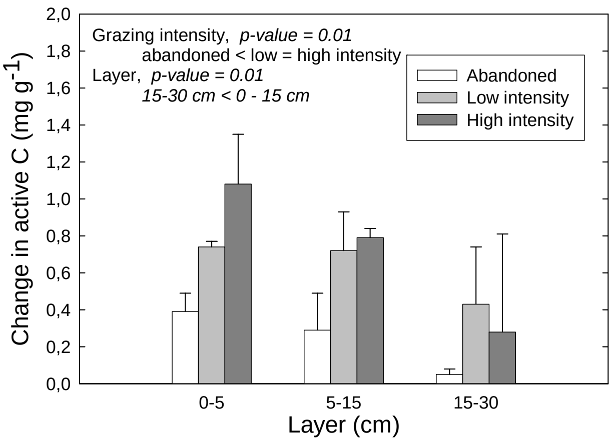

Figure 2. Effect of grazing intensity in active SOC fraction changes in three soil layers.

Conclusions

This work suggests that extensive grazing increases SOC sequestration in grassland soils at high altitudes in the Pyrenees, at least in the first 20 cm. However, further analysis should be performed to verify this hypothesis. One process that needs to be explored in more detail is the fate of the increased active SOC fractions.

Acknowledgements

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Effects of ozone on carbon allocation and dark respiration in two *Medicago sativa* cultivars

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Abstract

Ozone (O_3) causes decreased carbon (C) assimilation, increased metabolic costs, and alters C allocation. The effects of these three responses to the specific respiration rates of recently (R_{new}) and previously (R_{old}) assimilated C were analysed after short-term O_3 exposure. *Medicago sativa* plants from the cultivars 'Apica' and 'Team' were exposed to charcoal filtered air (cfa), or cfa + 209 ppb O_3 for one photoperiod (14 h). All carbohydrates assimilated during this photoperiod were labelled with $^{13}CO_2$ (C_{new}) and dark respiration of shoots and roots was measured during the following 10 h. O_3 fumigation increased allocation of C_{new} to leaves (+23 %) but reduced allocation to stems (-15 %) and roots (-21 %). In 'Apica', but not in 'Team', O_3 fumigation significantly reduced current net assimilation rate (-23 %) and consequently R_{new} in shoots (-31 %). Ozone affected the R_{new}:C_{new} ratio and R_{old} (+12 %) in the shoots, indicating that ozone stimulated use of recently and previously assimilated C in respiratory processes. Reduced C allocation to roots lowered R_{new} in roots in both cultivars, but had no effect on R_{old}. Variation in leaf damage and physiological parameters suggests there is high variation of O_3-sensitivity between and within the two cultivars.

Keywords: carbon allocation, growth and maintenance respiration, *Medicago sativa*, ozone, ^{13}C labelling

Introduction

The study is a project (B6) of the SFB 607 (*http://www.SFB607.de*). This interdisciplinary research network tests the central hypothesis: 'Regardless of the kind of stress, plants regulate their resource allocation in a way that increase in stress tolerance and resistance inherently leads to constraints on growth and competitiveness.' In the project B6, the effects of ozone (O_3) fumigation on the physiological characteristics and competitiveness of the two *Medicago sativa* cultivars 'Apica' and 'Team' are being tested. In previous studies, 'Team' was found to be more tolerant to O_3 than 'Apica' (Renaud *et al*., 1998). Ozone causes decreased carbon (C) assimilation, increased metabolic costs, and alters C allocation due to decreased phloem loading (Anderson, 2003). In the present study, the effects of these three responses on the specific respiration rates of recently (R_{new}) and previously (R_{old}) assimilated C were analysed after short-term O_3 exposure. In a conceptual scheme, total specific respiration rate is the sum of specific growth (R_g) and maintenance (R_m) respiration: $R = R_g + R_m = g\ dW\ (W\ dt)^{-1} + R_m$, where g is the growth coefficient (respired C per unit C used for structural growth) and $dW\ dt^{-1}$ is the growth rate. Assuming that $dW\ dt^{-1}$ is related to current net C assimilation ($dC_{new}\ dt^{-1}$) and that R_m is a function of degradable plant mass (old C), specific respiration rate can be expressed as $R = g\ [dC_{new}\ (C\ dt)^{-1}] + R_{old}$, where $g = R_{new}\ (dC_{new}\ dt^{-1})^{-1}$. It was hypothesised that O_3 fumigation increases g and R_m due to increased costs of repair and defence, and reduces R_g due to reduced current assimilation.

Materials and methods

Individual *M. sativa* plants were propagated from stem cuttings. Plants were grown in growth cabinets adjusted to 22 / 18 °C day / night temperature, 75 % RH, 400 µmol m^{-2} s^{-1} PFD during a 14 h photoperiod. The δ $^{13}CO_2$ / $^{12}CO_2$ of the air was -12.3 ‰. For each genotype, randomly selected individuals, which had about ten leaves on the main stem, were placed in a second growth cabinet where δ of the air was -43.3 ‰. In this cabinet, plants were exposed to charcoal filtered air (cfa), or cfa + 209 ppb O_3 (±9 SD) (cfa + 209) for one photoperiod. Dark respiration of shoots and roots was measured during the following 10 h using an open gas exchange system with infrared gas analyser and continuous-flow isotope-ratio mass spectrometer. Afterwards, plants were harvested, oven-dried and analysed for total C and C isotope composition. In this way, all carbohydrates assimilated during one photoperiod were labelled (C_{new}), and their contribution to the dark respiration (R_{new}) was analysed.

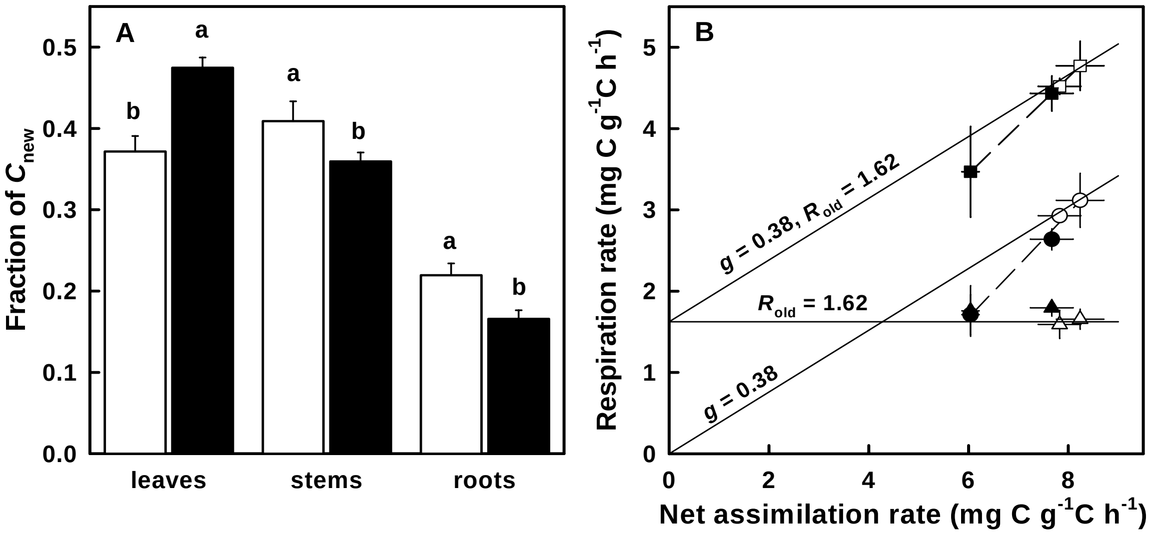

Figure 1. A) Distribution of recently assimilated C (C_{new}) in *Medicago sativa* plants after 14 h photoperiod and 10 h dark period. Plants were exposed to 0 ppb O_3 (cfa, open bars) and 209 ppb O_3 (cfa + 209, filled bars). Means + S.E., n = 8. Letters indicate differences within each organ (Fisher's LSD test). B) Specific respiration rate in relation to specific net C assimilation rate [dC_{new} $(C\ dt)^{-1}$] of whole plants. Means ± S.E. cfa (open symbols), cfa + 209 (filled symbols); total respiration (R, squares), respiration of recently (R_{new}, circles) and previously (R_{old}, triangles) assimilated C. Solid lines indicate R, R_{new}, and R_{old} of cfa plants. $R = g\ [dC_{new}\ (C\ dt)^{-1}] + R_{old} = R_{new} + R_{old}$. Dashed lines indicate linear regressions among means of all treatments for R (r^2 = 0.99) and R_{new} (r^2 = 0.98).

Results and discussion

In cfa plants, specific net assimilation rate [dC_{new} $(C\ dt)^{-1}$] was not significantly different between 'Apica' and 'Team' (Table 1). After O_3 fumigation, 57 % (±41 SD) and 22 % (±20) of the leaves showed visible damages in 'Apica' and 'Team', respectively. Ozone fumigation reduced net assimilation rate significantly in 'Apica', but it had little effect on 'Team' (Table 1). This agrees with previous studies where the authors (unpublished) and Renaud *et al*. (1998) found leaf photosynthesis to be more reduced in 'Apica' than in 'Team' after O_3 fumigation. O_3 fumigation increased allocation of C_{new} to leaves (+31 % in 'Apica', +26 % in 'Team') but reduced allocation of C_{new} to stems (-15 %, -14 %) and roots (-27 %, -16 %) (Figure 1A). This indicates that export of C_{new} from leaves was hindered, possibly due to damages in the mesophyll cells which impair phloem loading. If this additional C_{new} in the leaves is involved in respiratory processes, the growth coefficient (g) might be similar for plants of the cfa and cfa + 209 treatments. On the other hand, when accumulated C_{new} in leaves is not used in respiratory processes, *g* should decrease proportionally to the increased accumulation of C_{new} in shoots. In 'Team', O_3 fumigation did not alter *g* of the shoots, whereas *g* tended to be lower in O_3-fumigated 'Apica' (Table 1). This suggests that in 'Team' additional C_{new} in the leaves was used for tolerance mechanisms (repairing damage) and/or avoidance mechanisms (resistance), whereas in 'Apica' use of additional C_{new} was less clear. Shoot respiration of old C (R_{old}) was not affected by the current assimilation rate. This indicates that R_{old} was mainly used for maintenance (R_m). In the shoots, R_{old} was significantly higher in 'Team' (pairwise comparison within genotypes, $P < 0.0003$) after O_3 fumigation and tended also to be higher in 'Apica'. This suggests that O_3 fumigation increased maintenance costs in shoots by about 12 %. In the roots, R_{old} was not affected by the O_3 fumigation. This is plausible, as O_3 affects cells of the shoots and changes in root respiration would be likely a result of altered C allocation. In fact, in the roots R_{new} was significantly lower after O_3 fumigation due to reduced C allocation and a tendency for *g* to be lower. Regarding whole plants, ozone reduced current C assimilation rates and total specific respiration rates (Figure 1B). Reduced *g* in shoots and roots compared to small increases in R_{old} resulted in rather lower specific respiratory costs in O_3-fumigated relative to control plants.

Table 1. Effect of short-term O_3 exposure (14 h) on specific net C allocation rate [$dC_{new}\ (C\ dt)^{-1}$, mg C g^{-1} C h^{-1}], specific rates of recently (R_{new}, mg C g^{-1} C h^{-1}) and previously (R_{old}, mg C g^{-1} C h^{-1}) assimilated C and growth coefficient (*g*, g C g^{-1} C) in shoots and roots of two *Medicago sativa* cultivars. cfa, charcoal filtered air; cfa + 209, cfa + 209 ppb O_3 exposure. Means and S.E. in parenthesis (n = 8). Means within a row followed by the same letter are not significantly different (Fisher's LSD test).

Cultivar	'Apica'		'Team'	
O_3 Treatment	cfa	cfa + 209	cfa	cfa + 209
Plant				
$dC_{new}\ (C\ dt)^{-1}$	7.8 (0.43) *a*	6.0 (0.17) *b*	8.2 (0.48) *a*	7.7 (0.43) *a*
Shoots				
$dC_{new}\ (C\ dt)^{-1}$	7.8 (0.45) *ab*	6.7 (0.37) *b*	8.5 (0.50) *a*	8.2(0.45) *ab*
R_{new}	2.2 (0.03) *a*	1.5 (0.18) *b*	2.4 (0.22) *a*	2.3 (0.06) *a*
R_{old}	1.2 (0.14) *a*	1.3 (0.33) *a*	1.1 (0.07) *a*	1.3 (0.10) *a*
g	0.29 (0.01) *a*	0.23 (0.04) *a*	0.28 (0.03) *a*	0.28 (0.01) *a*
Roots				
$dC_{new}\ (C\ dt)^{-1}$	7.8 (0.44) *a*	3.9 (0.51) *c*	7.5 (0.53) *a*	5.8 (0.41) *b*
R_{new}	5.5 (0.50) *a*	2.2 (0.53) *b*	5.8 (0.97) *a*	4.0 (0.44) *ab*
R_{old}	3.5 (0.37) *a*	3.6 (0.29) *a*	3.3 (0.39) *a*	3.3 (0.27) *a*
g	0.69 (0.03) *a*	0.55 (0.06) *a*	0.79 (0.13) *a*	0.71 (0.11) *a*

Conclusions

Short-term O_3 fumigation reduced current C assimilation rate and consequently respiration of recently assimilated C (R_{new}) in shoots and roots. Ozone affected *g* and R_{old} indicating that use of recently and previously assimilated C was stimulated in respiratory processes. Variation in leaf damage and physiological parameters suggests high variation of O_3-sensitivity between and within cultivars.

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Carbon partitioning in the plant-soil-micro-organism system in a rye grass (*Lolium perenne)* sward following defoliation

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Abstract

The need to carefully examine agricultural management practices formaximizing the opportunities of sequestrating carbon (C) are well acknowledged (Lal *et al.*, 1995). The aim of this study was to quantify C partitioning in the plant-soil-micro-organism system in field-grown ryegrass. A significant decrease of shoot Callocation and a significant increase of root C allocation were observed in the few days after defoliation. However, total soil C content and soil micro-organisms were not affected by defoliation; the number of culturable cells (as colony forming units, CFU), and micro-organism activity (test based on the short term utilisation of ^{14}C glucose by rhizosphere micro-organisms) were not significantly different fromnon defoliated plants. Defoliation increased the allocation of current assimilates to the plant roots but root exudation was not affected.

Keywords: carbon allocation, defoliation, rhizosphere, microbial activity

Introduction

Defoliation causes a drastic change in the source- sink relationships between plant organs due to the removal of source leaves. Therefore, patterns of C allocation in the plant and rhizosphere are affected. Defoliation has been shown to have a neutral effect (Todorovic *et al.*, 1999), to increase (Miller and Rose, 1992; Holland *et al.*, 1996), or decrease (Mikola and Kytoviita, 2002) C allocation to the roots and root-released C. This study aimed to quantify below ground C allocation following defoliation in the field. The responses of the plant-soil-micro-organism system were investigated 2 and 4 days after defoliation, at two levels of N application, 0 and 100 kg ha^{-1}. As the quantification of rhizodeposition *in situ* is difficult, indirect indicators were used to estimate the consequences of defoliation on root-released C. It has been shown that microbial biomass activity is correlated with C release by the roots (Darrah, 1991). Thus, microbial activity, size of the microbial biomass and soluble C content of the soil solution were assessed as the main indicators of rhizodeposition for soil-grown plants.

Materials and methods

The experiment was conducted at the experimental station of INRA Mirecourt (France). Ryegrass (*Lolium perenne*) swards were sown in September 2002. Two levels of N were applied: High N, 50 kg ha^{-1} at the beginning of the season and 50 kg ha^{-1} after the first defoliation; and Low N, 0 kg ha^{-1}. PVC cylinders were set into the soil in March 2003, with one plant of ryegrass in each. The first defoliation was made at the end of April 2003, and the last on 15 May 2003. The cylinders were excavated 2 and 4 days after the last defoliation and the plants immediately harvested. The roots were carefully hand separated from the soil and washed with distilled water. Soil adhering to the roots (AS) and non adhering soil (NAS) were collected separately and the plant organs weighed and ground. Micro-organism activity was determined by using ^{14}C glucose (Nguyen and Guckert, 2001). Microbial C was estimated by chloroform fumigation-extraction (Jenkinson, 1988). Catabolic fingerprints (Biolog®) of the bacterial communities were characterized and culturable cells counted as colony forming units, CFU. Soluble C was determined by hot water extraction. Carbon and nitrogen in the plant and soil components were quantified after dry combustion using a C and N auto-analyser.

Results and discussion

Defoliation significantly altered plant carbon allocation patterns. Roots of defoliated plants accumulated more C per unit of mass than the roots of controls (Table 1). This observation is consistent with previous studies (Dyer and Bokhari, 1976; Dyer *et al.,* 1991; Holland *et al.,* 1996). It illustrates the strategy of resource allocation in defoliated plants which store resources preferentially in organs less accessible to grazers. The root-stored C is available for use in regrowth (Dyer *et al.*, 1991).

Short term *utilis*ation of ^{14}C glucose by adhering soil micro organisms was not significantly affected by defoliation (P > 0.2; Table 2). The number of culturable cells for strategy r bacteria and strategy k bacteria in AS, was not significantly affected regardless of treatment (P > 0.2). The catabolic activity of microorganisms (Biolog®, expressed as average well colour development, AWCD after 72h) showed the same pattern (Table 2). Similarly, microbial C and soil C soluble content was unchanged after defoliation (Table 1). However, soil C soluble content in NAS was increased by defoliation (P > 0.05; Table 1).

From previous results obtained under controlled conditions (hydropony, climatic parameters controlled), it was assumed that the increased root C allocation led to higher root-release C. This was not observed in the present experiment conducted in the field, with well established plants and a fluctuating climate. Therefore, defoliation either did not significantly affect the release of C by the roots (as observed in Todorovic *et al.*, 1999) or the climatic conditions prevailing at the time of the experiment (low temperature and precipitation) may have slowed down the consequences of defoliation which are usually observed in controlled conditions (Miller and Rose, 1992, Holland *et al.*, 1996; Paterson and Sim, 1999; 2000; Paterson *et al.,* 2003). Indeed, few data are available for field conditions, since the majority of studies have been conducted under controlled and optimum conditions.

In the short term, it is concluded that in unfavourable climatic conditions, defoliation would not significantly affect the patterns of C allocation in the rhizosphere of ryegrass. Further investigations under more favourable conditions more representative of the main growing period are needed in order to reach satisfactory conclusions on the quantitative effect of defoliation on root-released C.

Table 1. Carbon partitioning expressed as grams of carbon gram^{-1} of shoots and of roots. Microbial C for adhering and non adhering soil (AS, NAS) and C soluble soil content for AS and NAS. uu: unfertilised, undefoliated; fu: fertilised, undefoliated; ud: unfertilised, defoliated; fd: fertilised, defoliated. Significantly different values are indicated with s: significant at 5 % level, s*: significant at 10 % level and ns: non significant.

	Treatments			Microbial C		C soluble	
		g C g shoots^{-1}	g C g roots^{-1}	AS (mg C kg^{-1})	NAS (mg C kg^{-1})	mg kg^{-1} AS	mg kg^{-1} NAS
Day 2	uu	0.39	0.31	388	117	786	393
	fu	0.41	0.29	329	155	741	307
	ud	0.35	0.73	346	169	644	424
	fd	0.34	0.74	344	178	727	335
Day 4	uu	0.39	0.25	274	142	689	366
	fu	0.41	0.27	312	104	720	324
	ud	0.35	0.46	288	177	789	433
	fd	0.33	0.75	298	138	622	388
Statistics	Date	ns	ns	s*	ns	ns	ns
	Defoliation	s	s	ns	ns	ns	s
	N	ns	ns	ns	ns	ns	s
	DXDefXN	ns	ns	s*	ns	ns	ns

Table 2. Utilisation of ^{14}C glucose by soil micro-organisms. $^{14}CO_2$: ^{14}C respired, ^{14}CFE: microbial ^{14}C. Ratio $^{14}CO_2$ / ^{14}CFE represent the microbial activity. Culturable cells as colony forming units (CFU) for bact r and bact k expressed in log units. Data for bact k day 2 are unavailable because of experimental problems. Catabolic activity (biolog test) after 72h expressed in AWCD. uu: unfertilised, undefoliated; fu: fertilised, undefoliated; ud: unfertilised, defoliated; fd: fertilised, defoliated. Significantly different values are indicated.

Treatments	$^{14}CO_2/^{14}CFE$		CFU				AWCD	
	Day 2	Day 4	log r Day 2	log r Day 4	log k Day2	log k Day 4	Day 2	Day 4
uu	0.56	0.59	8.19	8.48	unavailable data	8.57	1242.97	411.21
fu	0.61	0.63	8.47	8.54		8.63	1436.29	604.73
ud	0.69	0.66	8.28	8.40		8.42	1298.84	371.56
fd	0.54	0.69	8.01	8.36		8.34	1342.78	724.66
Statistics								
Date	ns							
Defoliation	ns		ns	ns		ns	ns	ns
N	ns		ns	ns		ns	s	s
DXDefXN	ns		ns	ns		ns	ns	ns

with s: significant at 5 % level, and ns: non significant.

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Nitrogen supply strongly altered the net ecosystem carbon uptake in a managed grassland exposed to nine years of free air CO_2 enrichment

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Abstract

Managed grasslands on fertile soils are widely assumed to act as a carbon (C) sink. The forage species *Lolium perenne* and *Trifolium repens* were grown for nine years in the Swiss FACE (Free Air Carbon Dioxide Enrichment) experiment at ambient and elevated (600 ppm) CO_2 at two levels of nitrogen (N) fertilisation. Net ecosystem CO_2 exchange was measured using an open-flow chamber system and the C balance was calculated.

Day-time net CO_2 uptake (DCU) increased at elevated CO_2 by 21 to 31 % irrespective of N supply. Night-time ecosystem respiration (NER) increased at elevated CO_2 by 27 to 58 % and was greater at high N than at low N supply. The annual net ecosystem C uptake ranged between 205 and 615 g C m^{-2} a^{-1}. As NER, but not DCU, increased at high N supply, the annual net ecosystem C uptake was larger at low N supply than at high N supply. Elevated CO_2 tended to increase annual net ecosystem C uptake but this effect was not statistically significant. The increased DCU at elevated CO_2 was mostly compensated for by a higher NER.

It is concluded that in a managed grassland ecosystem, elevated CO_2 clearly increased the C-fluxes but had little effect on the C balance, which was primarily affected by the amount of N supplied.

Keywords: *Lolium perenne, Trifolium repens*, carbon, nitrogen, FACE, CO_2 exchange

Introduction

Not all the carbon C released by human activities contributes to the increase in the atmospheric CO_2. Besides oceans, terrestrial ecosystems are assumed to represent an additional C sink. Certification of C sequestration in agriculture has drawn political attention to this subject. In this context, grasslands may play an important role, as they cover 24 % of the terrestrial surface area and have a high capacity to sequester C. Assimilation and respiration are crucial factors with regards to C sequestration. Photosynthesis of individual leaves increases at elevated CO_2 but there is a lack of knowledge about the long-term effect of elevated CO_2 on the ecosystem net CO_2 uptake. Harvestable biomass was increased at elevated CO_2 only when N supply was high (Daepp *et al.*, 2000). Respiration may be reduced at elevated CO_2 on a mass basis, but increased at the ecosystem level. The aim of this project was to identify the net CO_2 fluxes and establish the C balance for a managed grassland ecosystem.

Materials and methods

The forage species *Lolium perenne* L. and *Trifolium repens* L. were grown as monocultures for nine years in the Swiss FACE (Free Air Carbon Dioxide Enrichment) experiment at ambient and elevated (600 ppm) CO_2 at two levels of nitrogen (N) fertilisation (14 and

56 g N m^{-2} y^{-1}). During the growing season, day-time net ecosystem CO_2 uptake (DCU) and night-time ecosystem respiration (NER) were continuously measured using an open-flow chamber system. Transparent chambers covered an area of 0.49 m^2; the difference in CO_2 concentration between inlet and outlet of the chambers was determined using an IRGA. In combination with air-flow measurements this allowed to determine the net ecosystem CO_2 exchange, which includes plant C-assimilation as well as plant and soil respiration. Based on these CO_2-fluxes, the C balance was calculated for the 2001 growing season. A more detailed account of the methods and calculations used is given by Aeschlimann (2003).

Results

DCU was increased at elevated CO_2 by 21 to 31 % irrespective of N supply. NER was increased at elevated CO_2 by 27 to 58 % and was greater both at high N than at low N supply and in *T. repens* than in *L. perenne*. In *L. perenne* the amount of harvested C was 79 to 91 % greater at high N than at low N supply. Elevated CO_2 stimulated harvested C but not more than by 11 %. The annual net ecosystem C uptake was greater at low N than at high N supply ($P < 0.0001$) and ranged between 205 and 615 g C m^{-2} a^{-1}. Elevated CO_2 tended to increase the annual net ecosystem C uptake but this effect was not statistically significant ($P > 0.05$).

Table 1. Responses of the net ecosystem carbon balance to N supply and CO_2 enrichment. Means per treatment of the growing season 2001.

Species	Nitrogen fertilisation (g m^{-2} y^{-1})	CO_2 (ppm)	Day-time net C uptake (g C m^{-2} y^{-1})	Night-time respiration (g C m^{-2} y^{-1})	Harvested C (g C m^{-2} y^{-1})	Net ecosystem C uptake (g C m^{-2} y^{-1})	Standard error (g C m^{-2} y^{-1})
L. perenne	14	360	1062	341	155	566	29
	14	600	1315	538	162	615	31
	56	360	924	442	277	205	83
	56	600	1215	599	309	307	57
T. repens	14	360	1072	479	220	372	48
	14	600	1336	758	174	404	30
	56	360	969	523	174	272	15
	56	600	1174	666	228	281	45

Discussion and conclusion

The increase in DCU at elevated CO_2 demonstrated that at ecosystem level, the assimilation at elevated CO_2 increased not only over the short-term but is also has long-term effects. Therefore, the absent (at low N) or small (at high N) stimulation of harvestable biomass at elevated CO_2 suggested that the C-flux to the soil was higher. However, higher root and stubble biomass and increased microbial activity led to an increased NER at elevated CO_2. Consequently, the increased DCU was compensated for by higher NER, resulting in no significant increase of the annual net C uptake by the ecosystem at elevated CO_2. Since NER, but not DCU, was increased at elevated CO_2, the annual net C uptake was higher at low N than at high N supply. The annual net C uptake was smaller in *T. repens* than in *L. perenne* because of the higher NER which was most probably caused by the energy costly process of symbiotic N fixation.

It is concluded that long-term exposure of a managed grassland ecosystem to elevated CO_2 strongly increased the C-fluxes in the system, but had little effect on the C balance, which was primarily affected by the amount of N supplied.

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Soil organic carbon and humus composition in legume / grass pasture

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Abstract

Soil organic carbon content and humus composition (humic and fulvic acids) are important integral indicators of soil fertility and of resistance to negative impact of management activities. The soil organic carbon (C) content, C:N ratio, humic and fulvic acids content were compared after pure grass with and without nitrogen (N) fertilisation, mixed swards of white clover and grass, of lucerne and grass and of both legumes and grass at different grazing frequencies. Both the different composition of swards and grazing frequency had an inappreciable effect on the content of organic C and C:N ratio. However, a trend was observed that a higher content of organic C was accumulated in the soil under legume / grass swards and under less frequent grazing and in pure grass without N fertiliser Humic acids which apparently conserve C in the soil tended to accumulate to a lesser extent under grass swards with mineral nitrogen applied than under grass / legume swards.

Keywords: soil organic carbon, pasture, C:N ratio, humic and fulvic acids

Introduction

Soil organic carbon (C) content and humus composition (humic and fulvic acids) are important integral indicators of soil fertility and of resistance to negative impact of management activities. The extent at which the soil can sequestrate C depends on the nature of agricultural production, land use and soil type (Follet, 2001; Eriksen and Jensen, 2001). After forests, the grasslands account for the largest area of the green ecosystems in Lithuania. Although aboveground biomass is generally small, the mean annual productivity of grassland is similar to that in forest systems. More than two thirds of the annual grassland biomass production is allocated to below ground structures: deep humus layers are common in grassland (Körner, 2002).Therefore grasslands are important for soil fertility and other multiplex processes in the soil. Grasslands differ markedly in species composition, their use, and management including fertiliser applications and this can significantly affect their organic matter content, humus structure, and C sequestration (Hassink and Neeteson, 1991). The objective of the present study was to estimate changes in the soil organic C content, C:N ratio, humic and fulvic acids content after pure grass with and without N-fertiliser mixed swards of white clover and grass, of lucerne and grass and both legumes and grass at different grazing frequencies.

Materials and methods

The experiment was conducted in Dotnuva (55º 24’ N) on a loamy *Endocalcari-Epihypogleyic Cambisols*. Soil pH varied between 6.5 to 7.0, humus content was 2.5-4.0 %, available P 50-80 mg and K 100-150 mg kg^{-1}. The experiment involved seven swards consisting of different legumes (*Trifolium repens* L., *Medicago varia* Mart.) and grasses (*Lolium perenne* L., *Poa pratensis* L., *Festulolium* hybrid) with frequent and less frequent grazing. *L. perenne* swards were with (240 kg N ha^{-1}) and without N fertilisation. The soil organic C content, C:N ratio, humic and fulvic acids content and ratio were studied in 2001-2002 in the third and fourth year of grassland use. Soil samples were taken in spring and autumn from the 0-25 cm soil layer. Plant residues visible by a naked eye were removed from the soil samples, the soil was crushed and sifted through the sieve < 0.25 mm. N content in the soil was determined by the Kjeldahl method, and the Ponomariova-Plotnikova-modified Tyurin method was used for the organic C content and the composition of humic materials (Slepetiene and Butkute, 2003). The data were statistically processed using analysis of variance.

Results and discussion

In our investigated soil under different swards and grazing frequency the content of organic C was 15.53-17.83 g kg^{-1} (Table 1), and its content during the experimental period varied little. The soil studied was rich in organic C. In the same soil, but in this case used for crop rotation, the content of organic C was 15.5 g kg^{-1} (Svirskiene and Antanaitis, 2002). Averaged data from 2001-2002 suggested that the content of organic C in the soil slightly increased in the soil under legume / grass swards. Grazing frequency of swards did not have any significant effect on the organic carbon content in the soil ($P < 0.05$).

Table 1. The effect of different swards (A factor) with frequent and less frequent grazing (B factor) on soil organic carbon content.

Swards	Carbon content (g kg^{-1})							
	2001 spring		2001 autumn		2002 spring		2002 autumn	
	F[1)]	LF[1)]	F	LF	F	LF	F	LF
Trifolium repens / *Lolium perenne*	16.87	16.23	17.43	16.63	17.83	16.63	17.00	16.13
T. repens / *L. perenne* / *Poa pratensis*	16.33	16.07	17.67	17.37	15.83	16.57	16.17	17.17
Medicago varia / *L. perenne* / *P. pratensis*	16.16	16.07	16.7	16.93	16.93	16.77	15.87	16.53
T. repens / *M. varia* / *L. perenne*	16.63	16.40	16.80	17.46	17.60	17.57	16.30	17.10
L. perenne / N_0	17.20	15.9	17.60	17.30	17.33	16.93	16.90	16.97
L. perenne / N_{240}	16.57	16.07	17.00	17.30	16.60	16.30	17.47	17.07
T. repens / *Festulolium*	16.37	15.53	16.77	17.47	16.87	16.77	17.07	16.83
$LSD_{.05}$ A factor / B factor	0.796 / 0.325		0.850 / 0.347		0.783 / 0.320		0.821 / 0.335	

F[1)] frequent grazing 5-6 grazings, LF[1)] less frequent grazing 4-5 grazings $season^{-1}$.

The C:N ratio slightly depended on the composition of swards (Table 2). It was lower in the soil under legume / grass swards than in the soil under grass swards with or without N fertilisation or under white clover / *Festulolium* swards. The grazing frequency had little effect on C:N ratio, because the difference between grazing regimes was too narrow, but the tendency was that the ratio at frequent grazing was lower.

Table 2. C:N ratio in soil of different swards (A factor) and grazing (B factor).

Swards	C:N ratio							
	2001 spring		2001 autumn		2002 spring		2002 autumn	
	F[1)]	LF[1)]	F	LF	F	LF	F	LF
Trifolium repens / *Lolium perenne*	10.00	9.54	9.43	9.89	9.72	9.62	9.39	9.85
T. repens / *L. perenne* / *Poa pratensis*	9.76	9.69	9.43	10.07	9.70	9.86	9.66	10.15
Medicago varia / *L.perenne* / *P. pratensis*	10.50	9.30	9.50	10.07	9.75	9.89	9.14	10.26
T. repens / *M. varia* / *L. perenne*	9.74	9.63	9.57	9.85	9.66	9.96	9.60	9.90
L. perenne / N_0	9.98	9.59	9.69	10.06	10.11	10.01	9.78	10.07
L. perenne / N_{240}	9.89	9.55	9.61	9.91	9.07	9.49	9.59	9.96
T. repens / *Festulolium*	9.11	10.08	9.81	10.00	9.49	9.92	9.71	9.97
$LSD_{.05}$ A factor / B factor	0.284 / 0.116		0.182 / 0.074		0.214 / 0.087		0.259 / 0.106	

F[1)] frequent grazing 5-6 grazings, LF[1)] less frequent grazing 4-5 grazings $season^{-1}$.

The indicator of organic C content during the short experimental period does not always fully reflect organic matter changes in the soil and trends of humification and mineralisation processes. This is better characterised by humic substances composition indicators, labile or active forms of humic substances. Data have shown that humic acids respond more sensitively to the processes occurring in the soil, compared with organic carbon (Table 3).

Table 3. Humic and fulvic acids of different swards (A factor) with frequent and less frequent grazing (B factor).

Swards	Humic acids mg C kg^{-1}				Fulvic acids mg C kg^{-1}			
	2001		2002		2001		2002	
	F[1)]	LF[1)]	F	LF	F	LF	F	LF
Trifolium repens / *Lolium perenne*	155	129	122	130	148	223	174	162
T. repens / *L. perenne* / *Poa pratensis*	155	141	116	141	147	211	161	169
Medicago varia / *L. perenne* / *P. pratensis*	155	135	110	129	143	190	174	164
T. repens / *M. varia* / *L. perenne*	133	128	122	138	150	200	174	158
L. perenne / N_0	135	118	119	127	177	217	176	172
L. perenne / N_{240}	112	106	102	122	157	202	162	175
T. repens / *Festulolium*	128	124	104	135	164	172	168	181
$LSD_{.05}$ A factor / B factor	15.0 / 6.14		16.2 / 6.60		8.95 / 3.65		12.0 / 4.92	

F[1)] frequent grazing 5-6 grazings, LF[1)] less frequent grazing 4-5 grazings $season^{-1}$.

Experimental findings suggest that in grass swards fertilised with mineral N, the content of humic acids was significantly lower compared with grass / legume swards. Humification processes in the soil under the swards with legumes occur more intensively, the content of humic acids provides an especially important quality on soil which contributes to increases in long-term C sequestration in the soil.

Conclusions

The soil under grazed swards was rich in organic C. A slightly higher content of organic C was identified in the soil under legume / grass swards. The grass swards contained less humic acids, compared with grass / legume swards. A significantly lower content of humic acids was found in the soil under grass swards with mineral N applied.

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The effect of sward type on the content of organic matter in a peat-muck soil

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Abstract

The grazing studies on a peat-muck soil were conducted in two experiments established in 1996. One of the aims of these studies was to determine the effect of two sward types on the content of organic matter in the investigated soil. The main grassy component (35 %) of grass-clover mixtures was *Poa pratensis* in experiment A and *Lolium perenne* in experiment B. The share of aforementioned species in grass mixtures was 54 %. The grass-clover swards were treated as a control and fertilised with 40 kg N, 35 kg P and 100 kg K ha^{-1}. N fertilisation of grass swards was differentiated on doses of 40, 80 and 120 kg ha^{-1}. The first significant decrease of soil organic matter under both experiments was confirmed after five years utilisation of the pasture. Under grazing management, the content of organic matter in peat-muck soil depended on the type of pasture sward and on the dose of nitrogen fertilisation. The presence of white clover in both sward types or the assurance of higher availability of nitrogen for *Lolium perenne* in grassy sward ensured better protection of soil against degradation. Thus, results obtained in these studies may be important for sustainable as well as for intensive grasslands.

Keywords: sward types, peat-muck soil, organic matter content

Introduction

Organic soil cultivation always causes a decrease of organic matter content in soil. However, shallow rotavation on peaty or peat-muck soils is better than ploughing because it results in less destruction of surface soil layer. Because of the sudden change in plant cover, the prompt introduction of new species and very careful management should protect soil organic matter against degradation (Warda and Krzywiec, 1998). Botanical composition of the pasture sward in post-boggy habitat seems to be important in limiting soil organic matter losses. Thus, one of the aims of the undertaken studies was to determine the effect of two sward types on the content of organic matter in the peat-muck soil.

Materials and methods

The grazing studies were conducted in two experiments established in 1996 and located on a peat-muck soil (MtII – middle decayed peat). Rotavation after chemical pre-treatment was used for cultivation before reseeding. The main grassy component (35 %) of grass-clover mixtures was *Poa pratensis* in experiment A and *Lolium perenne* in experiment B. The share of *Trifolium repens* in these mixtures was 35 %. In the grass mixtures, the part falling to white clover was divided proportionally between grasses creating the mixture. Then the content of aforementioned main species (*Poa pratensis* or *Lolium perenne*) in grass mixtures was 54 %. Apart from these species, both kinds of mixtures contained *Phleum pratense* and *Dactylis glomerata*. The grass-clover swards were treated as a control and fertilised with 40 kg N, 35 kg P and 100 kg K ha^{-1}. N fertilisation of grass swards was differentiated on doses of 40, 80 and 120 kg ha^{-1}. A randomised block design with four replications was used in both experiments. Grass and grass-clover swards were grazed rotationally with Limousine cattle four times during the grazing season. Registration of changes in soil organic matter began in

1997 (Krzywiec, 2000). Since that time analyses of soil from the level of 5-25 cm on the organic matter content have been made every year. The Tukey's test was used for statistical comparison.

Results and discussion

At the beginning of the investigations (1997) soil under sward with *Lolium perenne* contained a fraction more organic matter than soil under sward with *Poa pratensis*. The first significant decrease of organic matter in peat-muck soil under both experiments was confirmed after five years utilisation of the pasture (Table 1).

Table 1. Content of organic matter (g kg^{-1}) in the peat-muck soil under pasture sward with *Poa pratensis* (A) and *Lolium perenne* (B).

Treatment		Sward						Mean for treatment
Mixture	N fertilisation (kg ha^{-1})	with *Poa pratensis*			with *Lolium perenne*			
		1997	2001	2002	1997	2001	2002	
Grass-clover	40	793.4	766.2	755.4	820.0	785.7	764.9	780.9
Grass	40	794.6	769.0	740.6	840.0	772.4	785.2	783.6
Grass	120	809.6	749.0	732.6	829.4	764.3	750.9	772.6
Mean for sward type		767.8			790.3			
Mean for year		814.5				767.8	754.9	
Lsd ($P \leq 0.05$)								
Sward types								13.3
Years								20.9

According to Sapek and Sapek (1987, 1993) changes in the content of soil organic matter can result from changes in its chemical composition. Chemical substances creating organic matter and their relations depend on peat origin and its decay degree. Rottenness of organic matter causes the increase of nitrogen in the soil and the presence of plants with high nitrogen needs may intensify process of decay. In these studies, the quantity of organic matter wastage depended on sward type and level of nitrogen fertilisation. Interactions between sward types and treatments were also significant (Table 2).

Table 2. Losses of soil organic matter (%) under two sward types in the years 1997-2002.

Treatment		Sward		Mean for treatment
Mixture	N fertilisation (kg ha^{-1})	with *Poa pratensis*	with *Lolium perenne*	
Grass-clover	40	4.66	6.72	5.69
Grass	40	5.54	6.52	6.03
Grass	120	9.39	7.85	8.62
Mean for sward type		6.53	7.03	
Lsd ($P = 0.01$)				
Sward types (St)				0.28
Treatment (T)				0.41
T x St				0.73

The least loss of soil organic matter was confirmed under grass-clover sward with *Poa pratensis*. The value of these losses in the soil under grass-clover and grassy sward with *Poa pratensis* fertilised with 40 kg N ha^{-1} was lower than in similar conditions under sward with *Lolium perenne*. Although higher doses of nitrogen fertilisation increased the rate of organic matter wastage; it was differentiated in the investigated soil. The type of grass species in the sward had an important effect on the concentration of organic matter in the soil, where 120 kg N ha^{-1} was used. In such a case, sward with *Lolium perenne* protected soil against degradation better than sward with *Poa pratensis*. Perhaps, the assurance of a higher availability of nitrogen for *Lolium perenne* enables us to protect peat-muck soil against losses of organic matter.

Conclusions

In the conditions of grazing management, the content of organic matter in peat-muck soil depends on the type of sward covering the surface of the pasture and on the availability of nitrogen in the soil. Presence of white clover in the sward or moderate nitrogen fertilisation correlated with suitable sward type, can be one of the factors limiting degradation of soil under post-boggy habitat. Thus, the obtained results may be important for sustainable as well as for intensive grasslands.

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Net primary production and turnover rates of residual biomass in response to pCO_2 and N supply

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Abstract

The response of net primary production (NPP) and biomass allocation to elevated pCO_2 and N supply is essential for understanding the function of grassland ecosystems in the global C cycle. We measured, for the first time, turnover rates of residual biomass (stubble and roots) in *Lolium perenne* swards at ambient and 60 Pa pCO_2 combined with 14 or 56 g N m^{-2} y^{-1} using ^{14}C multiple pulse labelling. The assumed homogenous ^{14}C label was verified using ^{13}C steady-state labelling. Turnover rates of stubble were estimated by both methods within a discrepancy of around 10 %. Average turnover rates of stubble were 2.7 y^{-1}. Elevated pCO_2 stimulated harvestable yield by 9 % and stubble production by 70 % at low N and by 21 % and 0 % at high N, respectively. Turnover rates and production of roots were unaffected by pCO_2. Under elevated pCO_2, NPP was unaffected by N supply and underestimated by 20-40 % when just standing biomass was measured. The results of this study demonstrated that C isotopes are valuable tools for assessing turnover rates of residual biomass and NPP and suggested a primary allocation of biomass to stubble under elevated pCO_2 at limited N supply.

Keywords: elevated CO_2, isotopic labelling, roots, stubble

Introduction

Net primary production (NPP) is a driving force in the global carbon (C) cycle and may mitigate the increase in the partial pressure of atmospheric carbon dioxide (pCO_2). Quantifying the response of NPP to elevated pCO_2 is, thus, a prerequisite for estimating changes in the global C cycle and C inputs into the soil. In grassland, however, most information on the response of productivity to elevated pCO_2 is based on harvestable biomass above cutting height. Especially at low N supply, it is essential to quantify the production of non-harvested stubble and roots, thereafter called residual plant biomass. However, production of biomass is not fully accounted for when only standing biomass at a specific harvest is monitored. Therefore, we measured turnover rates of residual biomass using C isotope labelling, allowing us to estimate NPP.

Materials and methods

Two field experiments with *L. perenne*, perennial ryegrass, were conducted in three blocks, each consisting in one control area (ambient pCO_2) and a FACE area (Free Air CO_2 Enrichment at 60 Pa pCO_2). In experiment 1, we evaluated the use of C isotopes by comparing ^{14}C multiple-pulse labelling (^{14}C MPL) and ^{13}C steady-state labelling (^{13}C SSL). In experiment 2, we quantified effects of pCO_2 and N supply on NPP and the allocation of biomass using ^{14}C MPL. PVC tubes, 0.2 m in diameter and 0.6 m in depth, were filled with soil and inserted into the field, tightly put together to form a closed sward. The tubes were planted with *L. perenne* and fertilised with either 14 or 56 g N m^{-2} y^{-1}. The swards were fertilised with 5.5 g P m^{-2} y^{-1} and 24.1 g K m^{-2} a^{-1}, assumed to be non-limiting for plant growth. In March 2000, the tubes were divided into two sets. Set I was left in the respective CO_2 treatment and set II was exchanged between the CO_2 treatments. Harvestable biomass was determined five times in 2000. Residual plant biomass was sampled at five harvests from November 2, 1999 to March 15, 2001.

In experiments 1 and 2, ^{14}C enabled us to distinguish between old and new biomass and to calculate turnover rates of residual biomass. The swards were labelled by three pulses of ^{14}C at four-week intervals from August to October 1999. Single-pool models were chosen to describe the change of label over time, assuming for stubble and roots two pools of homogenously labelled biomass and a negligible translocation of label to other compartments. Using the cumulative effective temperature sum as the time variable, single-pool logarithmic decay models were fitted to the $\log_e$-transformed ^{14}C data. Turnover rates [a^{-1}] were derived from the fitted parameters and the production of biomass was calculated using the average standing biomass of stubble and roots multiplied by its turnover rate.

^{13}C SSL in experiment 1 was achieved on set II of tubes by establishing swards during five months (June to November) in two atmospheres with a different ^{13}C signal and by switching them between these atmospheres in March 2000. As the CO_2 gas used for FACE originated from a fossil source, elevated CO_2 had a lower ^{13}C signal than ambient CO_2 and resulted in a ^{13}C label of new photosynthates distinctive of old biomass. The fraction of old C (FOC) was:

$$FOC = 1 - (\delta_b - \delta_0) / (\delta_i - \delta_0) \quad [1]$$

where δ_0 and δ_b are the $\delta^{13}C$ in the biomass before and after the exchange, respectively. δ_i is the average $\delta^{13}C$ in harvested biomass above cutting height prior to the sampling of stubble. A single-pool logarithmic decay model was fitted to $\log_e$-transformed FOC and turnover rates y^{-1} were calculated.

Results and discussion

Turnover rates of stubble were estimated using ^{14}C MPL and ^{13}C SSL with a discrepancy of around 10 % (Table 1), which indicates that the assumption of a homogenous labelling after ^{14}C MPL was valid. Thus, labelling by multiple pulses was able to produce similar estimates of turnover rates of biomass than SSL. The high r^2 of all the linear regressions demonstrate that stubble can be assumed as a single pool after the stabilisation of the applied label into structural biomass.

Table 1. Turnover rates of stubble in experiment 1 at 36 and 60 Pa pCO_2 combined with 14 and 56 g N m^{-2} y^{-1} as measured by ^{14}C multiple-pulse labelling (^{14}C MPL) and ^{13}C steady-state labelling (^{13}C SSL).

N	pCO_2	^{14}C MPL		^{13}C SSL		Discrepancy
[g N m^{-2} y^{-1}]	[Pa]	[y^{-1}]	r^2	[y^{-1}]	r^2	[%]
14	36	2.69	0.93	2.38	0.94	13
	60	3.03	0.80	2.96	0.86	3
56	36	2.25	0.87	2.27	0.85	1
	60	2.87	0.80	2.40	0.93	12
n		15		12-15		
SE		0.38		0.23		

Coefficients of determination (r^2) of the regressions, number of measurements (n) and average standard errors (SE) of the estimates are shown. All regressions were significant at $P < 0.001$.

Turnover rates of stubble were increased by elevated pCO_2 (Table 1). Due to the limited number of measurements, this effect was marginally significant ($P < 0.1$) when determined by ^{13}C SSL only. The results are in line with Suter *et al.* (2001), who found that tillers shorter than 5 cm were increasingly produced in the stubble layer under elevated pCO_2 at the beginning of regrowth and were reduced towards the end. Concentrations of carbohydrates in stubble increased by about 35 % at elevated pCO_2 and low N supply (Fischer *et al.*, 1997). This suggests that sink activity in expanding leaves was limited by N and more carbohydrates were stored at elevated pCO_2, primarily in stubble.

Harvestable biomass was obviously not a good indicator of the plant's response to elevated pCO_2 (Figure 1): (i) it reached only 29 to 49 % of NPP and (ii) the pCO_2 and N supply had different effects on harvestable biomass, stubble and roots (Figure 1). Elevated pCO_2 increased harvestable biomass by 9 % at low N and 21 % at high N (anova: pCO_2, $P < 0.1$; $pCO_2 \times N$, $P < 0.05$), whereas the annual production of stubble increased under elevated pCO_2 by 70 % at low N and by 0 % at high N (anova: pCO_2, $P < 0.05$; $pCO_2 \times N$, $P < 0.0001$). The annual production of roots was also higher at low N (anova: N, $P < 0.1$), however, there was no significant effect of elevated pCO_2. Elevated pCO_2 stimulated NPP by 34 % at low N and 9 % at high N. Measuring the standing biomass alone, i.e., assuming a turnover rate of 1 y^{-1} for residual plant biomass, would have resulted in an underestimation of NPP by 20 to 40 %. The strong response of NPP to elevated pCO_2 at low N may be explained by higher N use efficiency in photosynthesis and reduced N exports in harvestable biomass at elevated pCO_2.

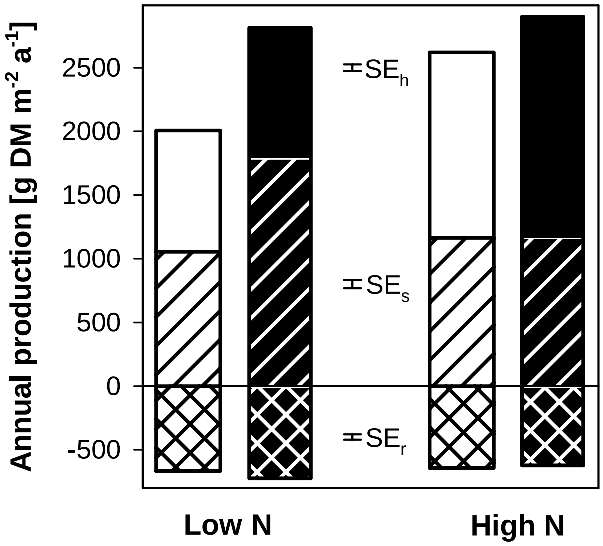

Figure 1. Net primary production (NPP) in *Lolium perenne* swards of experiment 2 as affected by atmospheric pCO_2 and N fertilisation. NPP is shown as composed of the annual production of harvestable biomass, stubble and roots.
White bars represent 36 Pa pCO_2, black bars 60 Pa pCO_2. Non-hatched bars represent harvestable biomass, hatched bars stubble and chequered bars roots. SE_h, SE_s and SE_r are standard errors of the mean for harvestable biomass, stubble and roots, respectively.

Conclusions

Experiment 1 showed that both labelling methods produced similar estimates of turnover rates of stubble, demonstrating that stubble biomass was homogenously labelled by multiple pulses of ^{14}C. In experiment 2, quantifying NPP by measuring turnover rates of residual biomass revealed distinct differences in the production of harvestable biomass, stubble and roots in response to a changed availability of resources, as induced by elevated pCO_2 and N supply. At low N supply, the results suggest a strong response of NPP to elevated pCO_2 by a primary allocation of biomass to stubble.

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Carbon flux measurements in a mountain grassland in the Italian Alps

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Abstract

In support of the Kyoto protocol, the Carbomont EU project aims to quantify the sources, sinks and the flux of carbon in non-forest mountain ecosystems of Europe. Most of the data collected in previous studies are regarding the forest ecosystems, while little is available for managed or abandoned grasslands. In order to investigate the carbon balance of grasslands, at the intensive study site Viote – Monte Bondone (1550 m asl), continuous measurements of energy and water fluxes are carried out by eddy correlation, according to the CarboEuroflux methodology, since summer 2002. The meadow, dominated by the typical secondary *Nardetum alpigenum* vegetation, is not fertilised and is cut once a year. The site seems to match the requirements for eddy covariance, showing mean vertical wind velocity proximal to zero in the main wind directions. The annual carbon uptake was about -0.88 t C ha^{-1} y^{-1}, while the NBP was -0.03 t C ha^{-1} y^{-1}, considering the dry matter removed with the cut. The carbon uptake was positive (source) between October and April, and negative (sink) only during May and June. The carbon budget of the investigated meadow may be near equilibrium, considering the traditional agronomic management of the site. Changes in climate conditions, as occurred in summer 2003, can transform the meadow into a source of carbon.

Keywords: Eddy correlation, footprint, carbon balance, grassland

Introduction

With the approval of the Kyoto Protocol, each signatory country is required to measure their carbon balance by implementing action and research. Research on the exchanges of carbon dioxide, water vapour and energy between the biosphere and atmosphere, and on the capacity of the natural ecosystem in carbon storage is promoted by the project FLUXNET, a global network of micrometeorological flux measurement sites. In Europe, a network of fifty main sites (project CARBOEUROFLUX) and more than one hundred secondary sites will be established within the VI Framework program of the European Community, involving sites currently operating on the continent. In this context the EU CARBOMONT project aims to investigate the carbon cycle in non-forest ecosystems, with particular consideration to the grassland management intensity and land use changes. Most of the data collected in previous studies are regarding the forest ecosystems, and only few data are currently available for managed or abandoned grasslands. Meadow and pasture ecosystems have shown in the last decades a high rate of change due to the reduction of the management intensity (cow stock, fertilisation, abandonment), and the analysis of these effects is important for a better understanding and forecasting of the carbon stock dynamic. In this work we present the footprint analysis and the preliminary results of the carbon balance of a mountain meadow.

Materials and methods

An eddy covariance station was installed in Monte Bondone Plateau at 1550 m asl (46°01' N; 11°02' E), in an extensive (1 cut per year, no fertilisation) managed meadow and the vegetation was dominated by the typical secondary *Nardetum alpigenum* association. The site was selected after several short anemometric campaigns carried out in different locations of the Viote Plateau, in order to understand the suitability of different sites for eddy covariance measurements. The mean annual air temperature is 5.5 °C, ranging from -2.7 °C in January to 14.4 °C in July. Mean annual rainfall is 1189 mm, with peaks in June (132 mm) and October (142 mm). Snowy cover occurs between November and April. The meteorological station was designed following the standardised methodology of the European CO_2 flux network and the collected data have been processed following the CarboEuroFlux methodology (Aubinet *et al*., 2000). In particular, the site was equipped with a Gill R3 3D sonic anemometer coupled with an open path IRGA Licor LI-7500 at 2.5 m height in order to measure carbon and energy fluxes.

Results and discussion

The installation and testing of the meteorological station was completed in summer 2002. Even if the site was situated on a gentle slope facing south, the typical mountain breeze circulation occurs. Direction NW is dominant during the night, while during the day both the west and east directions occur (Figure 1A). The choice of the site location was driven by this analysis, hence it was quite flat along the main wind directions. The footprint area is smaller in the north and south directions (Figure 1B) characterised by a higher roughness due both to the geomorphology and to the presence of trees. In the most frequent wind directions, 70 % of the flux comes within a distance of 100 m from the measuring point. Therefore, the site seems to match the requirements for eddy covariance (Figures 1C), showing mean vertical wind velocity proximal to zero in the main wind directions.

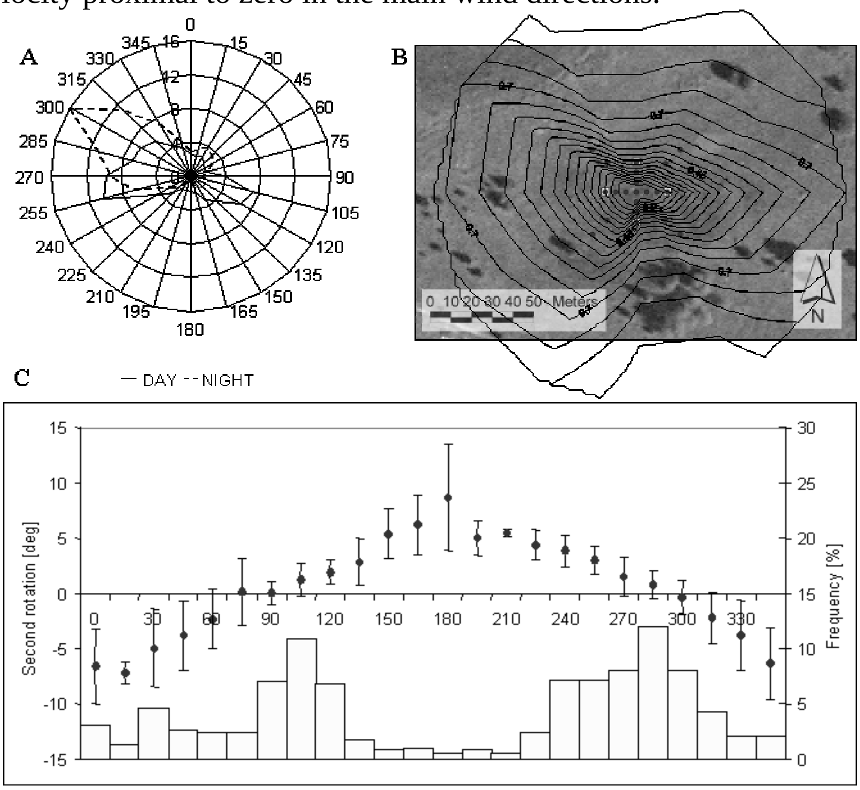

Figure 1. A. Wind direction frequency diagram; B. Results of the footprint analysis around the micrometeorological tower; C. Wind direction frequency and second rotation angle used for the fluxes estimations. On NW and East, the principal wind directions during respectively night-time and day-time, the second rotation is very low because of the flat topography.

The first year of eddy covariance measurements are summarised in figures 2 and 3. The annual carbon uptake was about -0.88 t C ha^{-1} y^{-1}, while the NBP is -0.03 t C ha^{-1} y^{-1}, considering the dry matter removed with the cut. The annual ecosystem carbon balance at the Viote-Monte Bondone meadow represents one of the lower value within the investigated grassland ecosystems (Sims and Bradford, 2002; Frank and Dugas, 2002), where the annual carbon gain range from a maximum of -3.4 to a minimum of -0.62 t C ha^{-1} y^{-1}. The carbon uptake is positive (source) between October and April, and negative (sink) only during May and June (Figure 2).

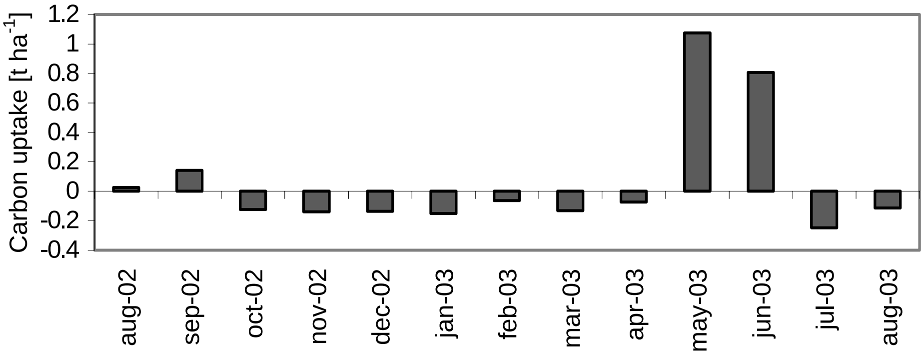

Figure 2. Monthly averaged carbon uptake at the Monte Bondone site.

The mean daily trend of CO_2 turbulent flux is represented in figure 3. Peaks of -18 μmol m^{-2} s^{-1} have been measured during the growing season, while the night time respiration reached values up to 10 μmol m^{-2} s^{-1}. The winter months are characterised by very low positive fluxes. The meadow was mown at mid July, and the anomalous high temperature observed in the summer 2003 determined high soil respiration (Figure 3), which explain the negative carbon balance of the site, which happens to become a carbon source during July and August 2003. This aspect becomes clear comparing the flux data between August 2002 and August 2003 (Figure 2), the first characterised by a positive uptake of carbon and the second by an emission of carbon from the soil.

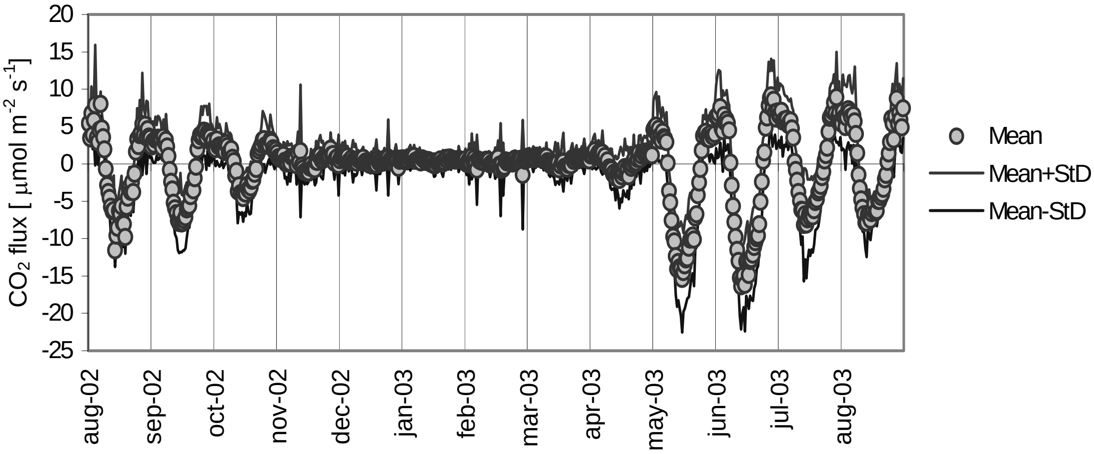

Figure 3. Monthly averaged daily trends of CO_2 fluxes at the Monte Bondone site.

Conclusions

These results suggest that the C budget of the investigated meadow may be near equilibrium considering the traditional agronomic management of the site.

Acknowledgements

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The effect of long-term elevated atmospheric CO_2 on soil amino sugars in ryegrass swards

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Abstract

Amino sugars in soil were determined in swards of perennial ryegrass (*Lolium perenne*) as bio-indicators of microbial origin under ambient (360 ppm) and elevated (600 ppm) atmospheric CO_2. Variation in amino sugar ratios between 1993 and 2000 was used as a qualitative indicator for compositional changes in the soil decomposer community. Amino sugar concentrations decreased ($P < 0.01$) under ambient CO_2 and increased ($P < 0.05$) under elevated CO_2 between 1993 and 2000 suggesting that elevated CO_2 contributed to an increased concentration of microbially derived soil components. Under elevated CO_2, ratios of glucosamine / galactosamine and glucosamine / muramic acid decreased between 1993 and 2000 ($P < 0.01$), but increased or remained unchanged under ambient CO_2. This suggests that under higher concentrations of atmospheric CO_2, bacterial derived muramic acid and galactosamine may be better preserved than fungal derived glucosamine in permanent grassland systems.

Keywords: amino sugars, elevated [CO_2], *Lolium perenne*, soil particle-size fractions

Introduction

Plants do not synthesize significant amounts of amino sugars, thus amino sugars in soil are primarily of microbial origin (Stevenson, 1982). Fluctuations in living biomass do not alter the amino sugar content because amino sugars occur mainly in dead microbial cells (Guggenberger *et al*., 1999). Most amino sugar-N is associated with clay (Zhang *et al*., 1998). Organic matter in this fraction turns over more slowly than in coarser separates. Therefore, combining amino sugar analysis with particle-size fractionation is useful in assessing the long-term effects of elevated CO_2 on 'ancient' microbial residues in soil. Particular amino sugars are indicative of either a bacterial or fungal origin, with muramic acid (Mur) and galactosamine (GalN) almost uniquely produced by bacteria, and fungal chitin consisting of glucosamine (GluN) only (Amelung, 2001). Variation in amino sugar ratios over time can therefore be used as a qualitative indicator of compositional changes in the decomposer community (Zhang *et al*., 1999).

Materials and methods

The study was carried out at the Swiss FACE (Free Air Carbon Dioxide Enrichment) experiment near Zürich (Hebeisen *et al*., 1997). Frozen (-20 °C) soil cores (0-10 cm) from 1993 (prior to CO_2 'switch on') and 2000 from *L. perenne* plots with low N fertilisation (140 kg ha^{-1} y^{-1}), under ambient (360 ppm) and elevated (600 ppm) atmospheric CO_2 were thawed, air-dried at 25 °C and sieved to < 2 mm. Samples were fractionated into four particle sizes (< 2, 2-20, 20-250 and 250-2000 µm, representing clay, silt, fine sand and coarse sand, respectively) using the procedure of Amelung *et al*. (1998). Total C and N content of the bulk soil and fractions were determined. Inorganic C was not detectable, so total C was regarded as organic C (SOC). The content of SOM was estimated by multiplying SOC by 1.724. Amino sugar extraction from the soil followed the outline of Zhang and Amelung (1996) with amino sugars converted into aldonitrile derivatives using the procedure of Guerrant and Moss (1984). Amino sugars were separated and quantified by gas chromatography-combustion / isotope ratio mass spectrometry (Glaser and Amelung (2002) for system details) using an OV17 (30 m × 0.25 mm × 0.45 µm) capillary column.

Results and discussion

Individual and total amino sugar concentrations (g kg^{-1} SOM) were significantly correlated (P < 0.001) with SOC and organic N (SON) content in all soil fractions, indicating that particle size fractionation identifies the pools of different amino sugar accumulation. Under ambient and elevated CO_2, amino sugar concentrations increased markedly (P < 0.001) as particle-size decreased from coarse sand to clay (Table 1). A total amino sugar content of 61 mg g^{-1} SOM was found in the clay fraction under ambient CO_2 in 2000. This indicates that microbially derived components contributed more to the SOM associated with fine particles than to that associated with coarse particles and confirms earlier findings (Zhang *et al*., 1999).

Table 1. Amino sugar concentrations (g kg^{-1} SOM), and ratios in bulk soil and particle-size fractions from soil taken in 1993 and 2000 from *Lolium perenne* plots under ambient and elevated atmospheric CO_2 (standard errors in parentheses).

Sample year	CO_2 status	Particle-size fractions	GluN	Mur	GalN	Total	GluN / GalN	GluN / Mur
			g kg^{-1} SOM					
1993	ambient	Bulk soil	39.3 (1.0)	5.9 (0.3)	18.5 (0.4)	63.7 (1.7)	2.1 (0.0)	6.7 (0.2)
		Clay	36.9 (0.1)	3.2 (0.1)	19.1 (0.2)	59.2 (0.2)	1.9 (0.0)	11.6 (0.2)
		Silt	37.0 (0.1)	3.3 (0.1)	14.0 (0.1)	54.3 (0.2)	2.7 (0.0)	11.2 (0.3)
		Fine sand	27.4 (1.5)	3.1 (0.2)	9.2 (0.5)	39.7 (2.1)	3.0 (0.0)	8.8 (0.2)
		Coarse sand	6.5 (0.0)	0.5 (0.0)	2.8 (0.0)	9.8 (0.1)	2.3 (0.0)	12.3 (1.1)
2000	ambient	Bulk soil	35.3 (0.1)	3.2 (0.1)	13.9 (0.2)	52.5 (0.4)	2.5 (0.0)	10.9 (0.2)
		Clay	40.1 (0.2)	3.5 (0.2)	17.8 (0.3)	61.4 (0.7)	2.2 (0.0)	11.6 (0.5)
		Silt	36.8 (0.1)	3.3 (0.1)	13.6 (0.1)	53.7 (0.3)	2.7 (0.0)	11.2 (0.3)
		Fine sand	30.7 (0.8)	3.4 (0.0)	8.6 (0.1)	41.5 (1.1)	3.5 (0.0)	8.6 (0.3)
		Coarse sand	na	na	na	na	na	na
1993	elevated[1]	Bulk soil	26.9 (0.3)	2.1 (0.1)	11.8 (0.3)	40.9 (0.7)	2.3 (0.0)	12.8 (0.4)
		Clay	37.5 (0.6)	4.1 (1.1)	12.3 (0.7)	53.8 (2.2)	3.1 (0.1)	11.0 (3.4)
		Silt	35.4 (2.0)	2.3 (0.2)	10.6 (0.2)	48.3 (2.1)	3.3 (0.2)	15.5 (1.3)
		Fine sand	9.4 (0.3)	1.1 (0.1)	4.2 (0.1)	14.7 (0.4)	2.2 (0.0)	8.6 (0.6)
		Coarse sand	5.1 (0.0)	0.3 (0.0)	1.6 (0.1)	7.1 (0.1)	3.1 (0.1)	15.4 (0.7)
2000	elevated	Bulk soil	27.4 (0.2)	4.1 (0.0)	12.5 (0.1)	44.0 (0.3)	2.2 (0.0)	6.8 (0.1)
		Clay	28.6 (0.4)	1.9 (0.1)	14.8 (0.2)	45.3 (0.5)	1.9 (0.0)	15.1 (0.7)
		Silt	34.5 (0.2)	3.1 (0.0)	11.7 (0.1)	49.2 (0.3)	3.0 (0.0)	11.2 (0.1)
		Fine sand	7.9 (0.3)	1.6 (0.0)	4.0 (0.1)	13.5 (0.5)	2.0 (0.0)	5.1 (0.1)
		Coarse sand	na	na	na	na	na	na

[1] Prior to CO_2 'switch on'. GluN-glucosamine, Mur-muramic acid, GalN-galactosamine, na-not available.

Amino sugar concentrations in bulk soil samples decreased (P < 0.01) under ambient CO_2 between 1993 and 2000 (64 and 53 g kg^{-1} SOM, respectively) but increased (P < 0.05) under elevated CO_2 (41 and 44 g kg^{-1} SOM in 1993 and 2000, respectively). Elevated CO_2 may therefore contribute to an increase in the concentration of microbially derived soil residues. Increased root biomass and root exudation of *L. perenne* at higher CO_2 concentrations (Daepp *et al*., 2001; Marilley and Aragno, 1999) leading to greater substrate availability (Zak *et al*., 1993) may help explain this. But, amino sugar concentrations in individual fractions showed varying responses under elevated CO_2, suggesting that amino sugar and SOM dynamics are different between fractions. The amino sugar ratios GluN / GalN and GluN / Mur (Table 1) varied significantly between 1993 and 2000 indicating a proportional alteration in the microbial origin of amino sugar residues. The GluN / GalN ratio increased ($P < 0.01$) under ambient CO_2 between 1993 and 2000 and decreased under elevated CO_2. Under elevated CO_2 the GluN / Mur ratio also decreased ($P < 0.05$) in the fine sand and silt fractions. This suggests that at higher concentrations of atmospheric CO_2 there is preferential preservation of bacterial residues relative to fungal residues in permanent grassland.

Conclusions

Particle-size fractionation is useful for evaluating the impact of elevated CO_2 on microbially derived residues. Higher atmospheric CO_2 concentrations contribute to an accumulation of microbially derived soil residues, with the preferential preservation of bacterial components. It has to be proven whether this preservation is due in whole or part to an actual increased production of bacterial biomass, a relative decrease in fungal biomass or different residence times of the amino sugar residues in the soil.

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Productivity of a pre-alpine pasture declines under long-term ozone exposure

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Abstract

A five year field experiment was carried out to investigate the effect of elevated ozone exposure on yield, forage quality, and species composition of permanent, extensively managed grasslands. Here productivity issues will be discussed. A species-rich old pasture, representing a semi natural grassland community in a pre-alpine environment, was selected for this study. Circular plots of 7 m diameter were exposed to elevated ozone, using a novel free-air fumigation system. In general, productivity decreased in both treatments over the years. In the first harvest (June), ozone fumigated plots tended to yield more dry matter than control plots. This situation was consistently reversed in the third harvest (October), with higher productivity in the non-fumigated control plots. A comparison of the decline of productivity shows losses under ozone fumigation to become more substantial with every new growing season of the experiment.

Keywords: ozone, free-air fumigation, grassland, yield

Introduction

Research on the impacts of ozone has been used as the basis to establish critical levels for significant negative effects under the UNECE Convention on Long-Range Transboundary Air Pollution (Fuhrer *et al*., 1997). The widespread occurrence of visible ozone injury in Europe is well documented (Benton *et al*., 2000), and various risk assessments have demonstrated that today's levels of ozone in many parts of the industrialized world are sufficiently high to cause damage to crops and forests, and to cause economic losses (*cf*. Fuhrer and Booker, 2003). Much less is known about the impact on grasslands which cover nearly one fifth of the earth’s land surface (Lieth, 1978). Considerable inter- and intra-specific differences in the ozone sensitivity were observed in several studies (e.g., Nebel and Fuhrer, 1994; Evans and Ashmore, 1992; Ashmore and Ainsworth, 1995; Barbo *et al*., 1998), leading to the expectation that ozone stress could affect plant-plant interactions within plant communities. In order to establish criteria as ecological targets in a regulatory context, suitable experimental data are needed (Fuhrer *et al*., 1997). Therefore, we used a new, chamberless and cost-effective field exposure system (Volk *et al*., 2003) to study long-term ozone-effects on species-rich grasslands.

Materials and methods

The Swiss pre-alpine site is part of a level, 30-year old field of 0.26 ha which is used for one hay cut followed by sheep grazing. A total of 48 plant species were identified, forming an *Arrhenatherion elatioris* alliance (after Oberdorfer, 1983). In 1998, six 7-m diameter circular plots containing 6 randomly distributed square subplots (0.5 x 0.5 m) were fenced off and used as permanent observation units for destructive harvests, detailed yield- and botanical analyses. These subplots were cut at 5 cm above the soil surface three times per year (mid June, early August and late October). Ozone exposure was achieved using a novel, microclimatically neutral, free-air fumigation system (described in detail in Volk *et al*., 2003).

Results and discussion

Ozone enrichment aimed and achieved an increase in ozone concentration of approximately factor 1.5. The resulting values for accumulated exposure to ozone over a threshold of 40 ppb (AOT40) illustrate, that the exposure of the plots studied was at least doubled as a result of the fumigation (Figure 1).

Ozone enrichment in fumigated plots was proportional to ambient ozone concentrations. A detailed description of the fumigation system performance is published in Volk *et al*. (2003).

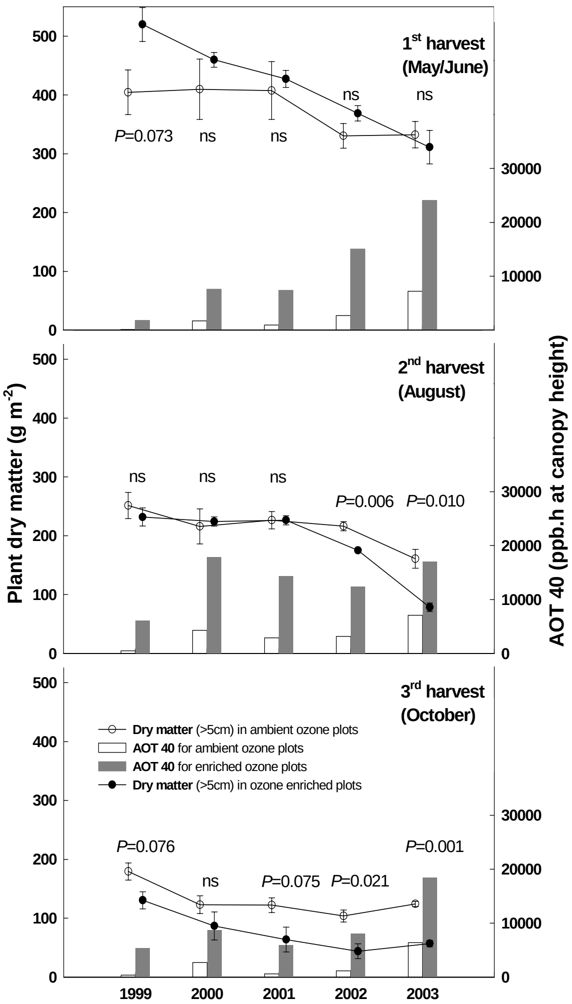

Figure 1. Dry matter yields of ozone enrichment plots (filled circles) and control plots (open circles) for five consecutive years show productivity with ozone treatment decrease from 1st to 3rd harvest. Accumulated exposure to ozone over the threshold of 40 ppb (AOT40) is at least doubled in the ozone treatment (shaded bars) compared to the control treatment (open bars). Error bars denote ± 1 SE. *P*-values are based on T-Test with the plot as replication unit (n = 3).

For all years, combined first harvest (June) yield in fumigated plots was 111 % compared to control plots. This higher average is due to the yields of the first years, when AOT40 was comparatively small (Figure 1). But with AOT40 increasing over the years due to atmospheric conditions and technical adaptations, the productivity difference between the treatments disappears and even seems to become reversed in 2003. Thus, we assume that the early periods of higher productivity in fumigated plots are due to an unknown property of the plots, instead of the ozone treatment. Preliminary data suggest an earlier drying/warming of fumigated plots after the spring snowmelt. This subtle elongation of the growth period may give the fumigated plots a headstart, resulting in higher yields in June, given the ozone exposure is below a critical level. In the second harvest (August) though, plant productivity of ozone fumigated plots dropped to 87 % of non-fumigated plots. Ultimately, the third harvest (October) yield in ozone fumigated plots was only 59 % of non-fumigated plots. Overall productivity, measured as total dry matter yield per year, with combined data from fumigated and non-fumigated plots, decreased in 2003 to 62 % of the 1999 original value. This process is apparent in both fumigated and non-fumigated plots and is thus independent of the ozone treatment. Instead it reflects the nutrient depletion, resulting from the lack of fertilisation that was part of the experimental design. A comparison of the declining annual relative yields, separated by treatment (Figure 2), shows, that the productivity in ozone fumigated plots drops much faster than in control plots. Ultimately, in the fifth year of the study, the yield loss of ozone enriched plots exceeds the loss observed in control plots by 23 %.

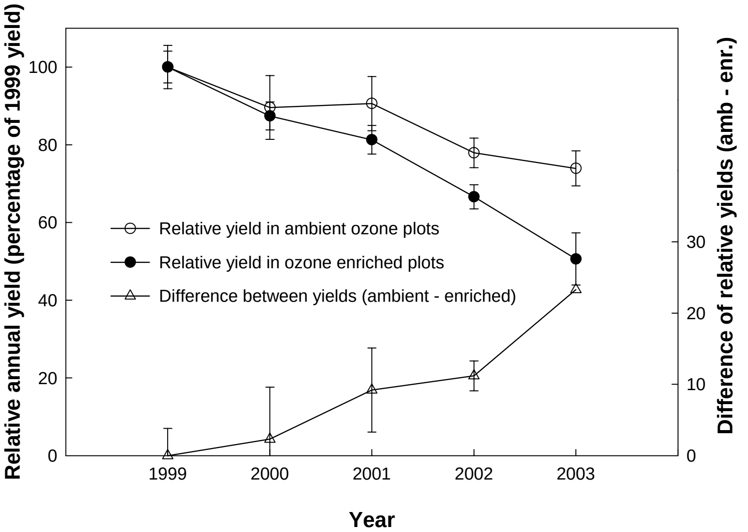

Figure 2. Comparison of relative yields of ozone enriched plots (filled circles) versus control plots (open circles) with 1999 yield = 100 %. Faster decrease of productivity in ozone enriched plots results in a Δ_{yield} of 23 % in 2003 (open triangles).

This implies, that about half of the total yield loss of ozone enriched plots is an ozone induced loss. During our study the productivity of the experimental pasture has not yet reached a new steady state. Thus, with a database covering five years, we can not predict at what level grassland productivity under high ozone concentrations will reach a new, stable equilibrium.

Conclusions

Substantially decreased productivity under long-term ozone treatment suggest a larger than expected air pollution impact on the pasture under investigation. If ozone exposures like those applied in this experiment would occur as a result of summer smog, the pre-alpine grasslands studied would suffer severe damage.

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Species rarity, agricultural management and environmental factors in permanent grasslands

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Abstract

Complete plant species lists were recorded on 1215 permanent grassland sites in north eastern France, including mountains and plains. Rarity coefficients were determined for each species by assigning a numerical species rarity value from rankings in flora handbooks. The average of the rarity coefficients of all species present gives a rarity indicator for each grassland site. Linear regressions were calculated between the rarity indicator and i) pastoral value, ii) Ellenberg's ecological indices, and iii) management indices for each grassland. The results showed that the rarity indicator decreases linearly with the soil nitrogen levels ($r^2 = 0.60$, $P < 0.0001$), the sensitivity to frequent cutting ($r^2 = 0.55$, $P < 0.0001$), the sensitivity to animal treading ($r^2 = 0.47$, $P < 0.0001$), and the pastoral value ($r^2 = 0.48$, $P < 0.0001$), but there was no linear relation to other environmental factors. Therefore, for a wide range of ecological conditions, agricultural practices such as fertilisation, cutting and grazing play an important role in the presence of rare species in permanent grasslands. The effects of environmental factors, their effect were much more complex and no direct relation could be deduced.

Keywords: biodiversity, species rarity, pastoral value, agricultural practices, linear regression

Introduction

Grassland biodiversity is usually assessed by simple indicators such as the number of species or the Shannon-Weaver Index. Although biodiversity is important, species rarity should also be taken into account. Rarity is a term applied to those species of low frequency and a low density at regional scale, and which require protection (Delavigne, 2001). At present, rarity is ascribed to a large number of species in international lists (completed for instance by the UICN) or national lists (the Red Lists in France for instance). However the data and methodology to assess the global rarity value of ecosystems, such as grasslands or forests, are lacking. In this paper we have focused attention on two points: i) the calculation of a rarity indicator to assess the rarity value of a grassland site; ii) the identification of the major factors which influence the grassland rarity value.

Materials and methods to calculate grassland rarity indicators

Determination of specific rarity coefficients: As proposed by Janssens (1998) for similar circumstances, a specific rarity coefficient was determined for each grassland species in north eastern France by attributing a numerical value to its rarity level as ranked in flora handbooks (des Abbayes, 1971; Lambinon, 1999). The 13 levels of rarity identified in these handbooks, were transformed into a specific rarity coefficient, ranging from 1 for very common species to 13 for the very rare species.

Calculation of grassland rarity indicators: Two indicators were calculated to assess the grassland rarity value (Equations 1 and 2):

Equation 1 $I_R d = \sum B\%i\ Ci / \sum B\%I$

Equation 2 $I_R p = \sum Ci / n$

where I_Rd and I_Rp are two grassland rarity indicators calculated respectively from the species abundance, and the species number in a grassland. Ci is the specific rarity coefficient (from 1 to 13) of the species i. B%i is the surface cover percentage of the species i and n is the number of species having a positive and recorded Ci.

Description of the data set: In order to determine precisely B%i, floristic analyses were carried out using the De Vries method (de Vries, 1949) on 1215 permanent grassland sites in north-eastern France. The dataset included a wide range of ecological contexts, from mountains to plains, and of pedo-climatic conditions. For each site, a pastoral value (Daget and Poissonet, 1971), Ellenberg's ecological indices, and management indices were calculated using FLORA-sys software (Plantureux, 1996). The ecological indices characterise: soil nitrogen fertility, soil pH, soil moisture, light and temperature (Ellenberg *et al.*, 1991). The management indices, animal treading and cutting frequency (Klapp, 1965), are scored on a scale from 1, for grassland dominated by species very sensitive to a given factor, to 10, for grassland dominated by species very resistant to the factor.
Grassland rarity indicators based on the species abundance (Equation 1) orspecies number (Equation 2) were calculated for each of the 1215 sites. Linear regressions were calculated between the rarity indicator values and the ecological and management indices.

Results and discussion on the variation of grassland rarity with environmental and anthropogenic factors: The rarity indicator values based on species number showed better correlations with the management indices and some of the ecological indices than those based on species abundance (Table 1). Linear regression analyses showed that grassland rarity values based on species number decreased linearly and significantly with the soil nitrogen fertility index (Figure 1b, $R^2 = 0.60$, $P < 0.001$), the resistance to cutting frequency (Figure 1a, $R^2 = 0.55$, $P < 0.001$) and the treading index ($R^2 = 0.55$, $P < 0.001$). A linear tendency was observed with soil pH ($R^2 = 0.36$, $P < 0.001$) but no linear relation was identified between grassland rarity value and soil moisture, light intensity, ortemperature.

Table 1. Correlation coefficients (r) between the grassland rarity indicator (based on species number or species abundance) and ecological and management indices, from 1215 grassland sites (ns for non significant, *P* always < 0.001).

	Treading	Cutting	Soil moisture	Light	Temperature	Soil pH	Soil N fertility
Species number	0.68	0.74	0.29	0.37	0.50	0.60	0.77
Species abundance	0.72	0.45	ns	ns	0.42	0.44	0.78

If a link between soil nitrogen fertility and nitrogen fertilisation, and soil pH and calcareous amendments is assumed, these results show that the rarity value of a grassland ecosystem has a linear relation with agricultural management intensity. This is supported by the linear relation between the grassland rarity and pastoral values ($R^2 = 0.48$, for I_Rp and $R^2 = 0.53$ for I_Rd, $P < 0.001$), pastoral value being a good indicator of agricultural management intensity (Daget and Poissonet, 1971). The more fertilised a grassland, or the higher the stocking rate or cutting frequency, the higher was the pastoral value and the lower the grassland rarity indicator. The effects of soil moisture, light and temperature, were much more complex and no linear relationwas deduced.
Furthermore, as the results found with $I_Rp$were better than those found with I_Rd, the assessment of a grassland rarity indicator can be adequately made with a list of species and it is not necessary to know the species abundance to calculate a grassland rarity value.

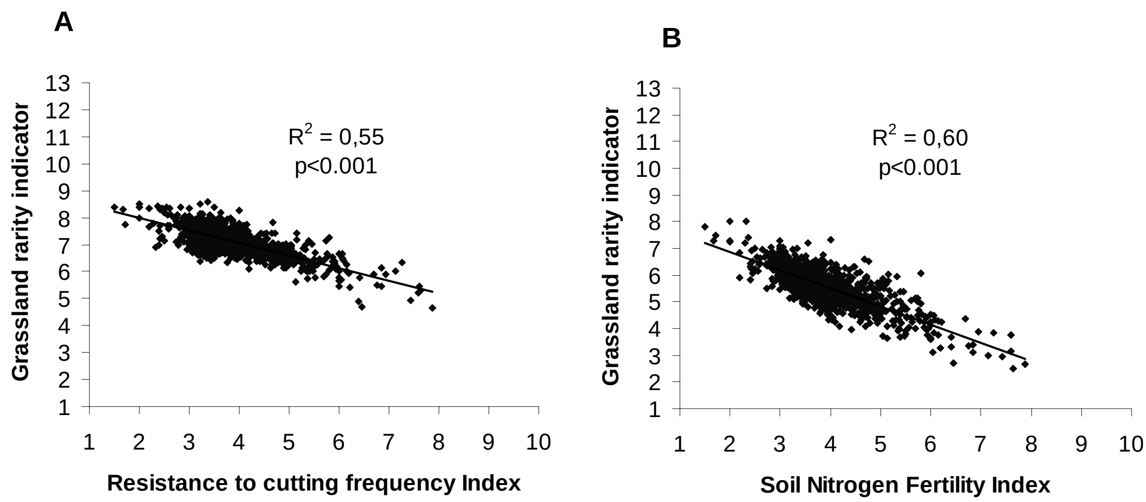

Figure 1. Linear relation between the grassland rarity indicator and i) the index of plant species resistance to frequent cutting (A), or ii) the index of soil nitrogen fertility (B).

Conclusions

It is concluded from our results with data from north eastern France that a simple indicator, I_Rp, based on the average of the rarity coefficients of the constituent plant species is a good predictor of the rarity value of grasslands in relation to agricultural practices. I_Rp has the advantage of being easily calculated from a list of species. Nevertheless, this indicator would require precise rarity coefficients to be adapted to other regions. Further investigations will also be necessary to quantitatively link agricultural management intensity with ecological and management indices for the determination of grassland rarity values from agricultural practices.

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Effects of ecological compensation areas on species diversity in the Swiss grassland - an overview

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Abstract

Forty percent of Switzerland is comprised of agricultural grassland. Due to this large area and the strong effect of management intensity on biodiversity, grassland management is crucial for species richness of the entire country. In 1993, an agri-environmental program to reverse species decline was implemented by the Swiss government. To date, 100,000 ha of meadows and pastures are managed as ecological compensation areas (ECA). The results of investigations to quantify the effects of ECAs on the species diversity of plants, birds and arthropods are summarised. Plant species richness in ECA litter meadows is satisfactory, whereas it is deficient for ECA hay meadows. Whereas the effect on birds is positive or negative, depending on the guilds, while it is mostly positive for butterflies, grasshoppers, carabid beetles and spiders. The results indicate that the measures are only partially successful in enhancing or conserving floral and faunal species richness.

Keywords: ecological compensation, grassland, biodiversity, agri-environmental program

Introduction

In 1993, an agri-environmental program was introduced by the Swiss government with the aim to reverse species decline. Within this program, the farmer needs to manage at least 7 % of the farm's utilised agricultural area (UAA) in accordance with rules laid down for ecological compensation areas (ECA). In return the farmer will receive basic payments per year and per hectare. The ECA – types and rules concerning grassland are listed in table 1 (Günter *et al*., 2002). In 2002, ECAs covered 115,000 ha (11.2 % of the UAA in Switzerland), of this 92 % of the area is grassland. The aim of this paper is to give an overview of results showing effects of ECAs on biodiversity in grassland. Most results have been elaborated within the evaluation programme launched by Agroscope FAL Reckenholz in 1996. The main-objective is to answer the following questions: What is the effect of ECAs on bird and plant species at the large regional scale in the Swiss Plateau? What is the effect of ECAs on the assemblages of plants, birds, spiders, ground beetles, butterflies and grasshoppers in three case study areas of 6 km^2 each? The methods to assess the effects of ECAs are given in Dreier *et al*. (2002, 2004) for plants, Spiess *et al*. (2002) and Dreier *et al*. (2004) for birds, Jeanneret *et al*. (2004) for spiders and butterflies, Peter and Walter (2001), Walter *et al*. (2004) for grasshoppers and in Pfiffner and Luka (2000) for ground beetles.

Results and discussion

Plants: From 1401 vegetation relevés undertaken within the Swiss plateau region, only 26 % of the extensively used ECA meadows and 13 % of the low input ECA meadows fulfilled the criteria for the desired botanical quality by the ECO-quality ordinance (Dreier *et al*., 2002).

By way of contrast, a more satisfactory result was established for the ECA litter meadows where 85 % met the criteria.
Birds: Surveys that examined the presence of 39 indicative species were undertaken on the Swiss plateau in 23 locations ranging in area between 5 and 10 km^2. Significant higher density of territories around ECAs than expected were found for Yellowhammer (*Emberiza citrinella*), Red-backed Shrikes (*Lanius collurio*), Whitethroats (*Sylvia communis*), Marsh Warblers (*Acrocephalus palustris*) and Green Woodpeckers (*Picus viridis*). The contrary was established for Skylarks (*Alauda arvensis*). The remaining species were too rare to allow a statistical analysis. The average density of indicative bird species was found to be very low at 14 species per km^2 (Spiess *et al*. 2002). ECAs were found to increase the territories of species that require a landscape mosaic of hedges, woodland fringes and grassland. Species which require extensively used open areas were found to be less frequent near ECAs.

Table 1. ECA grassland types, share of total ECA area and regulations.

ECA type (% of tot. ECA)	Regulations and supplementary subsidies
Extensively used meadows (40.1 %)	• Size: ≥ 0.05 ha, duration of contract: ≥ 6 years • Mowing is compulsory, no fertiliser applications • Specific punctual herbicide treatment against problematic weeds is possible if mechanical control is insufficient • Mowing at least once a year, no earlier than indicated for the respective production zone (e.g., for lowlands 15th June) • Only mowing, no grazing except for the last use in autumn (e.g., for lowlands no earlier than 15th September) • Use of officially certified seed mixtures for creation of new meadows • Supplementary subsidies 450-1500 CHF ha^{-1} y^{-1}
Extensive pastures (5.7 %)	• Size: ≥ 0.05 ha, Duration of contract ≥ 6 years, grazing at least once a year • No fertilisation apart from manure of grazing animals • Only punctual herbicide treatments • No areas dominated by ubiquists and nutrient indicators • No supplementary subsidies
Wooded Pastures (1.7 %)	• As extensive pastures. Specific fertilisers (no free nitrogen) and application of plant treatment products may be granted by cantonal forest authorities • No supplementary subsidies
Low input meadow (32.2 %)	• Solid manure and compost are allowed but should not exceed 30 kg N ha^{-1} y^{-1} • All other regulations as for extensively used meadows • Supplementary subsidies 300-650 CHF ha^{-1} y^{-1}
Litter meadows (5.7 %)	• Size: ≥ 0.05ha, Duration of contract: ≥ 6 years • No fertilisers and plant treatment products • Mowing once a year after 1st September, litter has to be removed • Supplementary subsidies 450-1500 CHF ha^{-1} y^{-1}

Butterflies: During a case study undertaken in Ruswil (20 km NW of Lucerne) in 1998, 2000 and 2002, only 3 to 4 butterfly species were observed on average in both, ECAs and conventionally managed meadows. With the exception of the results from 1998 (Jeanneret *et al.*, 2004.), no significant differences were found between the meadow types. By way of contrast, Bosshard and Kuster (2001) observed between 16 and 23 species three years after sowing a meadow with an ECA seed mixture. Thus, some regions are in a disastrous situation with no visible sign of improvement whilst in other regions freshly sown meadows attract comparatively high numbers of species.
Grasshoppers: In the canton of Zurich, two case studies were undertaken in 1990 and 2000 in order to compare grasshopper populations. A significant increase in the distribution area of grasshoppers was observed in ECAs for 11 of the 20 grasshopper species. Both studies

showed the importance of already existing species rich areas as a source for the repopulation of ECAs – in this cases small, legally protected nature conservation areas. In one study, the time since the area is managed according to the ECA-management directives was also found to be important (Peter and Walter, 2001; Walter *et al*., 2004). The remarkable increase of the distribution area of threatened grasshopper species due to ECA-meadows is very encouraging. Furthermore, the results support the argument to place ECA near already existing species rich areas.

Ground beetles: No differences in species richness were found between ECA and conventionally managed meadows. However, ECA meadows supported more specialised species and three times more individuals of threatened species (Pfiffner and Luka, 2000). Hence, ECA meadows seem to have a positive effect by supporting threatened ground beetles.

Spiders: In a case study undertaken in Ruswil in 1997, no difference in species number of spiders between ECA and conventionally managed meadows was found. However, species assemblages were observed to be significantly different (Jeanneret *et al*., 2004). ECA meadows thus lead to an enrichment of regional spider assemblages although a benefit of ECAs for rare or threatened species has not yet been observed.

Conclusions and reaction of research and policy

The results of the eight-year projects suggest that, although the measures of the agri-environmental program are heading in the right direction, further efforts are still necessary to increase biodiversity in agricultural areas. The policy makers' reaction on these ambivalent results was the adoption of the 'ECO-quality ordinance' in 2001 by the Swiss Government. It aims to increase the quality of ECAs. The ordinance includes incentives for defined quality criteria and incentives for constructing ECA networks aimed at target species. There is also a shortage of information about the effect of ECAs on biodiversity in the alpine region and within pastures. Research is now being undertaken to define quality criteria for extensively used pastures and new ECA elements. The national research foundation has initiated the program 'Landscape and Habitats of the Alps' which includes projects that examine the effect of ECAs on biodiversity.

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Restoration steps of agriculturally improved grassland on humic soil-management, seed bank and scale

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Abstract

The dynamics of vegetation was investigated in a five-year experiment involving two different grazing intensities (with small animals), two cuttings, and unmanaged plots. This was undertaken in areas with different initial levels of botanical diversity. The effects of the different restoration methods were dependent of the initial state of the vegetation, and extensive grazing was not the best option for the first step in the restoration process. New species did not come from the soil seed bank, but from the surroundings. The 'nature quality' of the areas was in agreement with indicators for potential botanical nature and was measured independently of the species composition.

Keywords: 'nature quality', initial conditions, landscape, species sources, soil heterogeneity

Introduction

In Denmark, many old, species-rich grasslands on humic soil have been improved agriculturally, and as such, have diminished in biodiversity. To achieve the aims of the National Biodiversity Act some of these areas must be restored, with extensive grazing often recommended. However, only small effects on species composition have been found when changing grazing management from intensive to extensive systems (Marriott *et al.*, 2002). This paper focuses on the effects of different management methods on grasslands differing in initial species diversity.

Materials and methods

A six-year experiment (1997-2002) involving two different grazing intensities (with small ruminants: sheep or steers < 1 year old), two annual cuttings, and unmanaged plots was investigated in areas which differed in initial levels of botanical diversity (HighD and LowD). The grazing management was only in operation during the years 1997-2000. There were two replicates of each treatment within each paddock. The effect of management on species composition was analysed in 10 × 10 m plots using five permanent extended Raunkiær circles each year, in late June. An 'importance value' of the species was calculated as an accumulated Frequency Sum (a-FS) (Hald and Petersen, 1992). The viable seed bank (0-20 cm) was estimated from soil samples taken in spring 1997. To investigate the local species-pool for desired meadow species in the surroundings, an inventory was made of the 56 low-lying meadow paddocks in the surroundings. Root MSE (= SD) was calculated as the residual term of the GLM model year × paddock × treatment × plot, df = 259.

Results

Prior to the start of the experiment in 1997 the mean species number was 20.1 in HighD and 12.8 in LowD. The cultivated species differed between areas. While *Poa pratensis* dominated in LowD, *Festuca rubra* and *Trifolium* spp. co-dominated in HighD. The relative importance of cultivated species in the vegetation decreased with time, although there was a tendency to stabilise in year 5 in all management regimes (Table 1).

Table 1. Changes in importance of cultural species during experimental years and between treatments, measured as a-FS, number of species and a-FS of forbs, sedges and rushes excluding *Juncus effusus* and *J. conglomeratus*. Mean values per plot (5 m^2), df = 259.

Year	1997	1998	1999	2000	2001	2002
a-FS cultural species, SD=7.1 SE=2.9						
Unmanaged, N=6	36.0	23.9	21.1	14.7	10.1	11.4
2-x-cut, N=6	35.1	32.2	31.1	27.8	23.0	24.8
Grazed, N=6	32.7	27.2	27.7	24.1	-	-
Number of species per 5 m^2, SD=2.8 SE=1.1						
Unmanaged, N=6	16.8	14.5	16.9	17.5	16.5	15.9
2-x-cut, N=6	16.1	16.0	16.7	18.1	17.0	16.2
Grazed, N=6	15.2	14.8	15.7	16.2	-	-
a-FS forbs, sedges and rushes, SD=9.2 SE=3.8						
Unmanaged, N=6	34.3	27.3	35.1	40.8	52.1	51.7
2-x-cut, N=6	35.2	33.1	36.3	40.6	40.3	40.5
Grazed, N=6	30.3	23.9	26.0	29.7	-	-

The decrease was generally most pronounced in unmanaged plots over the years. However, changes in the number of species per unit area was surprisingly little affected by management. With LowD, the result in 2000 was a general increase in species number with all management regimes, except at low intensity grazing (Table 2).

Table 2. Initial state in HighD and LowD and results in 2000 measured as number of species, a-FS of forbs, sedges and rushes excluding *Juncus effusus* and *J. conglomeratus*, a-FS of moss carpet, df = 259. Initial state is mean of unmanaged and two-cut plots in 1997.

Year	1997	2000			
Management Area	Initial state	Unmanaged	2-x-cut	Grazed High int.	Grazed Low int.
Number of species per 5 m^2, SD=2.9 SE=0.6					
HighD, N=24	20.1	18.8	20.3	20.8	19.0
LowD, N=24	12.8	16.2	15.6	14.0	10.9
a-FS forbs, sedges and rushes, SD=9.2 SE=1.9					
HighD, N=24	59.2	57.8	59.8	44.3	46.8
LowD, N=24	10.3	23.9	21.4	17.0	10.9
a-FS moss carpet, SD=4.6 SE=0.9					
HighD, N=24	18.0	14.6	19.8	16.3	10.5
LowD, N=24	3.3	8.7	13.1	4.9	10.3

In HighD, management regimes did not affect species density. Many of the species desired in restored meadows are forbs, sedges or rushes. The importance of this group increased with time in the unmanaged and cut situation, although tended to stabilise in the final year (Table 1). In the grazed situation, the importance of this group fluctuated, but remained at an unchanged level. In LowD, the result in 2000 for the forbs, sedges and rushes was a general increase with all management regimes, especially in the unmanaged plots (Table 2). In HighD the response of this group of species was low, and negatively affected by grazing. The importance of the moss carpet in the initial year was highest in HighD and lowest in LowD (Table 2). The importance of the moss carpet increased during the experimental period in all management situations in LowD and decreased in HighD. The increase in LowD was greatest in the cutting management and least in high grazing intensity. The seed bank of the topsoil had both a higher number of species and a higher density of seeds (Table 3). The seed bank was richer in HighD compared to the LowD pastures. The seed bank contained species not found in the vegetation: weed species and species belonging to wetter habitats with long-lasting inundation. Among the common meadow species potentially able to spread from the 56 surrounding sites to the target area (LowD), a total of 47 species did not occur in LowD.

Half of the sites contained only ten or less of these species. The values for indicators of potential botanical quality of degraded sites, that are measured independently of the species composition of the vegetation (Hald *et al*., 2003), showed a good relationship with the relative botanical quality in HighD and LowD (not shown).

Table 3. Number of species and seeds in the seed bank at two depths in HighD and LowD. Mean per sample, representing 110 cm^2. SD calculated as paddock × depth × sample, df = 79.

Area	HighD		LowD	
Depth (cm)	0-10	10-20	0-10	10-20
Number of samples (N)	16	16	23	23
Species density, SD = 3.4	26.2	17.9	12.5	9.0
Seed density, SD = 129	442	214	126	66

Discussion

Having an unmanaged regime for a few years proved to be the best first step option to decrease the importance of cultural species during restoration. In addition both cutting and unmanaged regimes were the best options to increase the importance value of the group of target meadow species (forbs, sedges and rushes). However, the size of the effect was dependent on the diversity in the initial situation. In the low diversity area a number of new meadow species established for first time in the unmanaged plots. However, the beneficial effects of the unmanaged plots levelled off after five years. This coincided with the increased cover of the moss carpet. The intensity of the grazing system had only a small effect on the target group of species. Marriott *et al*. (2002), and the results from the current study might be used to hypothesise about the initial response in vegetation when restoring degraded grassland: dominant cultivated species react to a break in management regimes, and subordinate species will increase to fill in the gaps in the sward. Low intensity grazing was not able to achieve this first step in the process. The seed bank in the area was not very active in restoring the meadow as the seed bank was most poor in the low diversity area where the need for new species was highest. Species could potentially be introduced to the restoration area by using grazing animals as vectors from the surrounding area. However, it is important as to which sites are chosen for such co-grazing.

Conclusions

Reductions in the proportion of the dominating species in the sward is necessary to make space for desired target species. A first step in a restoration project is thus to consider the best option to reduce dominant competing species. The dominant species may be cultural species and the option chosen may depend on the specific species.

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Ecosystem effects of biodiversity manipulations in European grasslands

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Abstract

We present a multisite analysis of the relationship between plant diversity and ecosystem functioning within the European BIODEPTH network of plant diversity manipulation experiments. We report the responses of fifteen ecosystem process variables, measured across three years in plots of varying plant diversity at eight different European grassland field sites. All the aspects of diversity and composition that we examined, both numbers and types of species, produced significant impacts on ecosystem processes. In general, communities with higher diversity were more productive and *utilis*ed resources more completely by intercepting more light, taking up more nitrogen and occupying more of the available space. Diversity had significant effects through both increased vegetation cover and more efficient nitrogen uptake when this resource was abundant through nitrogen fixed by legumes. However, additional diversity effects remained even after allowing for differences in vegetation cover and for the presence of legumes in communities. Diversity effects were stronger on above rather than below ground processes. Ecosystem effects of plant diversity varied between sites, between years or with both. However, in general, diversity effects were lowest in the first year and stronger later in the experiment, indicating that they were not transitional nor due to community establishment.

Keywords: BIODEPTH, biodiversity, complementarity, ecosystem functioning, legumes

Introduction

During the last decade the relationship between biodiversity and ecosystem functioning was studied in several experiments manipulating diversity. Such research, which is driven by the change and loss of diversity, is seen as a result of human activities and climate change. Identifying general patterns in a developing research area such as this can be a major obstacle because even well replicated ecological studies are often conducted at single points in space and time, and often focus on one or a small number of variables. This paper reports the results of a large scale pan-European project (BIODEPTH – BIODiversity and Ecological Processes in Terrestrial Herbaceous ecosystems) that examined the relationship between plant diversity and ecosystem functioning in experimental grassland communities. A major aim of BIODEPTH was explicitly to address the consistency of biodiversity effects on ecosystem functioning in space and time over a range of climatic and soil conditions and with different local species pools. This allowed us to test how diversity effects are modified by natural environmental variation and how these ecosystem effects of biodiversity develop over time.

Methods

This study was carried out at eight experimental sites: Germany, Greece, Ireland, Portugal, Sweden, Switzerland and two sites in the UK (Silwood Park near London, and Sheffield). Sites differed widely in climate, soil conditions, and other major environmental factors

(Hector *et al.*, 1999). A total of 480 experimental grassland communities (2 x 2 m) and 200 different species compositions were established from seed under field conditions that differed both in number of plant species (five levels of species richness, ranging from monocultures to higher diversity mixtures drawn from the local species pools) and of functional groups (1, 2 and 3 functional groups with grasses, N-fixing legumes, non-leguminous herbs). Each diversity level was replicated with several different species mixtures. The highest diversities approximately matched background levels of diversity in comparable semi-natural grasslands at each site. All plots were replicated in a second block. Invading species were removed regularly, and no fertilisers were applied. We measured 15 different ecosystem functions and characteristics, e.g., above and below ground biomass production, cover, canopy structure and light use, root length, nitrogen in above ground biomass and soil nitrogen, and decomposition. The effect of biodiversity on above ground biomass production was partitioned into a ‘selection effect’ and a ‘complementarity effect’ following Loreau and Hector (2001). The data were *analys*ed using a general linear model approach combining analysis of variance (ANOVA) and multiple regression. The sequential analysis included the effects of site, block, species richness, functional group richness, and species composition. Repeated measures analysis for the first three years of the experiment was performed by including experimental year as a main factor.

Results

The effects of diversity on cover and above ground biomass varied with site and year (Figure 1). Across all sites and years the complementarity effect of species richness on above ground biomass production was positive. During the third year, both, canopy height and centre of gravity of vertical biomass distribution significantly increased with diversity, although the effects varied with site. Diversity related changes in above ground biomass and canopy structure also affected light interception and transmittance. Levels of transmitted PAR at the base of the canopies generally declined with increasing diversity. Total nitrogen content in above ground biomass increased with diversity in parallel with the increase in above ground biomass. The effect of species richness on root biomass was consistent across sites and generally slightly positive.

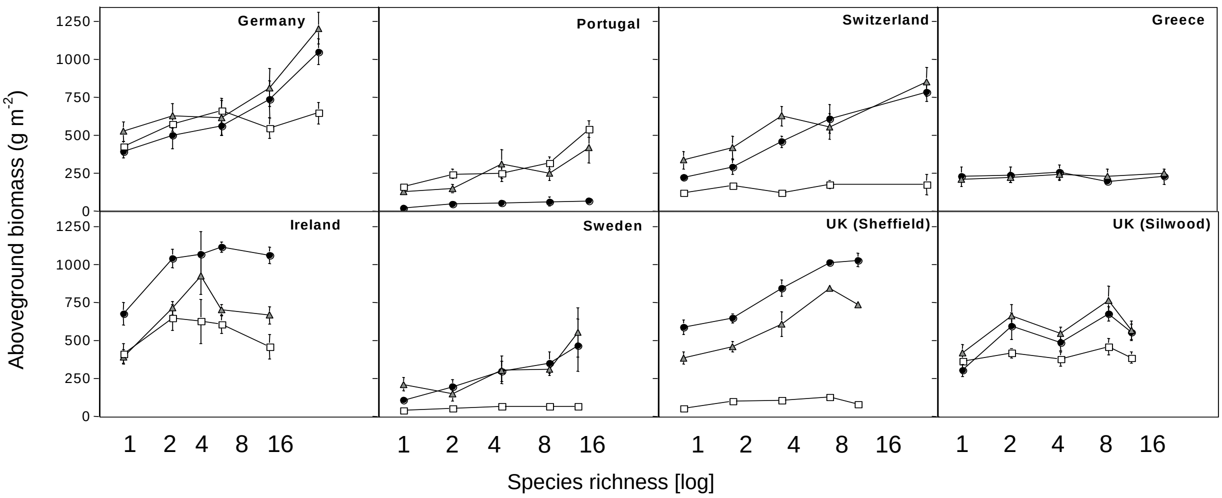

Figure 1: Species richness effects on above ground biomass of all sites in the first three years of the experiment. Year 1: open squares, year 2: grey triangles, year 3: closed circles. Means ± S.E. of all mixtures within species richness levels.

Total inorganic (soluble) nitrogen concentrations differed strongly between sites, with mean values ranging from 1.7 mg kg^{-1} (Greece) up to 29.0 mg kg^{-1} (Switzerland), reflecting different soil types, former land use and soil fertility. At most sites, soil N decreased with increasing diversity in the presence of N-fixing legumes. Diversity had a positive effect on cotton decomposition, clearly driven by the Greek site, which showed the strongest response to an increase in species richness. In general, a significant part of the differences between species assemblages (after having included the effect of species and functional group richness in the models) was explained by the presence of legumes (Spehn *et al.*, 2002).

Conclusions

Altering biodiversity through changes in the numbers and types of plant species and functional groups in our experimental communities significantly affected all fifteen ecosystem processes examined. In general, high diversity communities had stronger complementarity effect values, exploited more resources by intercepting more light, taking up more nitrogen and utilising more 2- and 3-dimensional space, and were more productive. These longer-term results give greater support to niche differentiation models than to sampling and selection models, as complementarity was the stronger underlying biodiversity effect. Diversity effects were stronger above than below ground. In particular, clear diversity effects on decomposition were only observed at one site. We saw statistically significant differences between sites and years and different ecosystem processes were affected by different aspects of diversity and to different degrees. However, from a general perspective, this extended analysis reveals stronger and more extensive effects of altered plant diversity than shown in our more restricted earlier analyses. Our results therefore reinforce our previous findings and extend the generality of diversity–ecosystem functioning relationships to multiple sites, years, and processes. However, because the effects of biodiversity vary with time and site understanding this variation will help integrate the results of biodiversity manipulation experiments with studies of the control of ecosystem functioning at the larger scale.

Acknowledgements

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Plant diversity and nitrogen dynamics in experimental grassland systems

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Abstract

Recent experiments looking at the relationship between plant diversity and ecosystem processes underlined the importance of both species richness and composition for nitrogen dynamics in grasslands. This paper discusses results from the German site of the pan-European BIODEPTH project where plant diversity was experimentally manipulated, creating replicate communities of varying number of species and functional groups (grasses, legumes, non-leguminous herbs). Aboveground nitrogen pools, soil nitrogen concentrations and nitrate leaching were all significantly affected by both plant diversity and community composition. Nitrogen fixation by legumes appeared to be the most important functional trait influencing N dynamics. In general, nitrogen pools in aboveground plant parts decreased with decreasing number of species and functional groups, which was related to a parallel decrease in aboveground biomass. Bulk soil nitrogen concentrations and nitrate loss to the groundwater increased with decreasing diversity. These results strongly support the view that diverse communities are more effective in nitrogen uptake if additional N input through fixation occurs, and that this effect is not only due to reduced abundance of legumes but also through complementary resource use.

Keywords: BIODEPTH, biodiversity, complementarity, legumes, nitrogen dynamics

Introduction

During the last decade, the investigation of the consequences of altered biological diversity for ecosystem functioning has been a major focus of ecosystem science. Based on the perception that observational studies with communities differing in biodiversity cannot be used to detect causal relations between diversity and ecosystem processes (due to confounding factors, e.g., abiotic conditions or former land-use), some experimental approaches have been put forward. Such experiments manipulated some aspect of biodiversity (species richness, number of functional groups, evenness) under constant environmental conditions and analysed several aspects of ecosystem functioning as response variables. A majority of those studies were done with grassland systems (see Loreau *et al*., 2002).
In this paper, I focus on diversity effects on nitrogen dynamics at the German experimental site within the pan-European research project BIODEPTH (BIODiversity and Ecological Processes in Terrestrial Herbaceous ecosystems), which established grassland communities differing in plant diversity at eight locations throughout Europe (Hector *et al.*, 1999).

Methods

At the German BIODEPTH site (Bayreuth; 49°55´ N, 11°35´ E; 355 m asl), a total of 64 experimental grassland communities (2 x 2 m) were established from seed under field conditions that differed both in number of plant species (0, 1, 2, 4, 8 and 16 species) and functional groups (1, 2 and 3 functional groups with grasses, N-fixing legumes, non-leguminous herbs). Each diversity level was replicated with several different species mixtures, using the pool of native species of managed meadows (*Arrhenatheretum*). All plots were replicated in a second block. Invading species were removed regularly, and no fertilisers were applied. Plots in adjacent meadows were used as reference. I assessed nitrogen dynamics

by measuring aboveground biomass-nitrogen, soil extractable nitrogen, net N mineralisation, and nitrate leaching (for details on experimental design and methodology see Scherer-Lorenzen, 1999; Scherer-Lorenzen *et al.*, 2003; Spehn *et al*., 2002).
Data were analysed with the analysis of variance regression approach to test for the effects of blocks, of the presence of vegetation, of species richness, number of functional groups, and of all other residual effects between mixtures.

Results

The total plant nitrogen content decreased significantly with decreasing species richness (ANOVA, log-linear contrast: $P_{1996} < 0.001$; $P_{1997} = 0.004$; $P_{1998} = 0.025$) and number of functional groups (ANOVA, linear contrast: $P_{1996} < 0.001$; $P_{1997} < 0.001$; $P_{1998} = 0.001$; Figure 1A), which was related to a parallel decrease in aboveground biomass (Hector *et al.*, 1999). Generally, communities with legumes had significantly higher nitrogen contents than communities without this group. Analysis of δ^{15}N-values clearly indicated that legumes were actively fixing nitrogen and that transfer of symbiotically fixed nitrogen to non-fixing plants was possible, increasing stand productivity (Spehn *et al*., 2002).
The total loss of nitrate was highly dependent on the specific species composition of the communities, plots with legumes lost significantly more NO_3^- than plots without them. In bare ground plots, and in several low diversity mixtures containing legumes, the nitrate concentrations were higher than the official threshold value for drinking water of 50 mg l^{-1}, and maximum values of up to 350 mg l^{-1} were measured in clover monocultures. Generally, nitrate leaching increased with decreasing diversity (Figure 1B), although this pattern was only significant in plots containing legumes (log-linear regression: $P_{1998} < 0.001$). A higher number of species led to a reduction of legume dominance, to a reduced NO_3^--supply through N-mineralisation, and to a complementary uptake of nitrate by grasses and herbs (Scherer-Lorenzen *et al*., 2003).

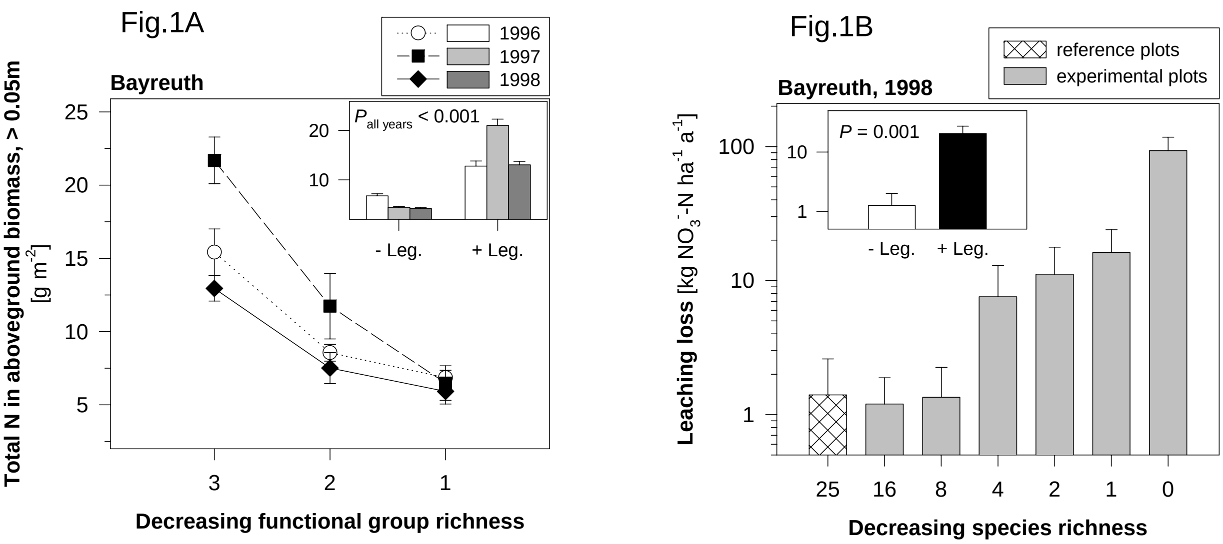

Figure 1A. Total nitrogen content in aboveground biomass as a function of decreasing number of functional groups. Biomass was cut at 0.05 m above the soil surface. - Leg: communities without legumes; + Leg.: communities with legumes. Means ± s.e.
Figure 1B. Cumulative nitrate loss (logarithmic scale) by species richness in 1998. Mean ± s.e.

Without additional N-input through legumes, plant diversity had no influence on available mineral N pools of the soil and on net N mineralisation (Scherer-Lorenzen, 1999). However, if legumes were present, mineralisation rates and N pools increased significantly with decreasing species numbers (data not shown).

Conclusions

Nitrogen dynamics were strongly influenced by the functional characteristics of the component species: the ability for symbiotic N_2-fixation being the most important one. The effect of species richness was of minor importance, although the additional nitrogen input due to fixation was used more efficiently in highly diverse systems, leading to higher productivity and N content in the biomass, and to substantially lower nitrate leaching. This effect was not only due to reduced abundance of legumes, but also through complementary resource use, thus diversity of co-occurring species provides an insurance against substantial nutrient loss.
In general, the results presented here, and those of the whole BIODEPTH project, provided powerful evidence that ecosystem functioning in semi-natural grasslands is altered by the loss of plant diversity. Many of the results predict accelerating loss of function as more species are lost from an ecosystem. However, several aspects of diversity are important for ecosystem functioning, including species richness, number of functional types, and the identity or characteristics of individual plant species. Many of the processes and services provided by this type of ecosystem were impaired by a loss of biodiversity, underlining the need for conservation of high diverse grasslands in Europe. In particular, the results suggest that low diverse grass-clover mixtures of ley-farming systems may be detrimental for groundwater quality.

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Biomass production following N-fertilisation in experimental grassland communities differing in plant species richness and composition

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Abstract

In Umeå, Sweden, a manipulated plant biodiversity experiment was established in 1996, as part of the pan-European BIODEPTH project. Twelve species of grasses, legumes and other forbs were combined in experimental communities of 1 to 12 species. The composition of the communities was maintained by weeding during each summer. The vegetation was cut once a year in August. In June 2002 and 2003 one half of each plot was fertilised with ammonium nitrate (50 kg N ha^{-1} y^{-1}). The most important factor for biomass production was the presence of legumes, regardless of fertilisation treatment. In plant communities with legumes biomass also increased as the number of plant species increased. N-fertilisation increased plant biomass in all plant communities without legumes, and in monocultures of all legumes except *Trifolium pratense*. The fertilisation-induced increases in biomass were highest in grass communities with *Phalaris arundinacea* and *Dactylis glomerata*. Fertilisation-induced increases in plant community biomass were also negatively correlated with the biomass of legumes in the unfertilised parts of the respective plots. Plant communities that produced less biomass with fertilisation always included one or more *Trifolium* species. Possible mechanisms behind these patterns, such as occurrence of plant pathogens and competition between species are discussed.

Keywords: ammonium nitrate, biodiversity, nitrogen uptake, competition, plant pathogens

Introduction

The roles of species richness in ecosystem functioning have been widely discussed in recent years. A positive relationship between biomass production and plant species richness has often been found in plant diversity experiments in grasslands (Loreau *et al.*, 2002). In those experiments the presence of legumes were an important factor that could not be fully separated from the species richness factor. Legumes host N_2-fixing bacteria, and their presence could be viewed as a form of N-fertilisation. The aim of this study was to evaluate the effects of N-fertilisation *per se* on plant biomass and species composition in a long-term plant species diversity experiment.

Materials and methods

An experimental field was established as the northernmost site of the pan-European BIODEPTH (BIODiversity and Ecological Processes in Terrestrial and Herbaceous ecosystems) project (Hector *et al.*, 1999). The site is located at the Swedish University of Agricultural Sciences in Umeå, Sweden (63°45 N, 20°17 E). The soil is a fine silty sand with low clay content (4.1 % clay, 57.9 % silt, 38.0 % fine sand) and a pH around 6.0. Sixty-six plots, each measuring 2.2 x 5 m, were sown with a total density of 2000 seeds m^{-2}, divided equally among 1, 2, 4, 8, or 12 species of vascular plants in 28 unique species mixtures in early June 1996. Each mixture was duplicated or, in some cases, triplicated. The species used in the experiment included four grasses (*Dactylis glomerata*, *Festuca ovina*, *Phalaris arundinacea* and *Phleum pratense*), four legumes (*Lotus corniculatus, Trifolium hybridum*, *T. pratense* and *T. repens*) and four non-leguminous herbs (*Achillea millefolium*, *Leucanthemum* *vulgare, Ranunculus acris* and *Rumex acetosa*). All plots were hand-weeded during the growing season. Due to winter damage, some or all species of the plots were re-sown in spring 1999, 2000 and 2002. On the last two occasions there was no substantial soil preparation. In June 2002 and 2003, 50 kg N as ammonium nitrate was applied to one half of each plot with 4 mm of water. The fertilised and unfertilised parts were separated by plastic plates, 35 cm deep. For further details of the experimental design, see Mulder *et al.*, (2002).

Aboveground biomass (> 5 cm) was sampled once a year in the middle of August from an area of 0.1 m^2 in the middle of the plots. The plants were sorted into species, dried (60 ^oC) and weighed. Weeds present in the harvested sample were included in the plant community biomass. At the time of biomass sampling, the entire plots were cut at a height of 5 cm and the biomass was removed.

Statistical analyses were made using the general linear model module in SYSTAT 10.2. Forward stepwise regression, with $P < 0.1$ as entering requirement and Log_{10} of plant species richness was used in the analyses**.**

Results and discussion

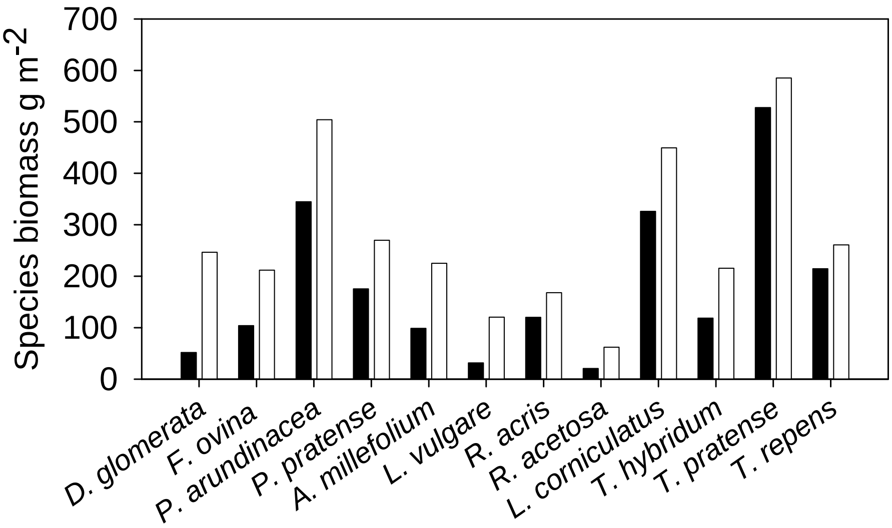

Figure 1. Mean biomass of the monocultures from the two experimental years. Filled and unfilled bars represent unfertilised and fertilised (50 kg N ha^{-1} y^{-1}) plots, respectively.

Fertilisation increased the aboveground biomass in monocultures of all species (Figure 1). The absolute increase in biomass was generally largest in the grasses, but the herbs *A. millefolium* and *L. vulgare* and the legumes *T. hybridum* and *L. corniculatus* also grew substantially better with N-fertilisation. In monocultures, there was no correlation between the biomass in unfertilised plots and the fertilisation response. Furthermore, N fertilisation did not change the effect of species richness on biomass: the presence of legumes and increases in species richness always significantly increased plant community biomass (Figure 2). When plots with and without legumes were analysed separately, a significant positive correlation was found between species diversity and community biomass in plots with legumes. In general, grasses benefited most from the fertilisation in the poly-cultures as well as in the monocultures. Fertilisation increased grass biomass in all communities, and a strong positive correlation was always found between the increases in grass biomass and in community biomass. In contrast, the biomass of the herbs increased more in plots where community biomass was lower in the fertilised parts. In such plots legume biomass production was much lower in the fertilised parts than in the unfertilised parts, probably due to increased competition from grasses and herbs. Fertilisation is well known to promote competition from grasses, causing legume biomass to decrease (Whitehead 1995). Pure grass communities with the grasses *D. glomerata* and *P. arundinacea* showed the largest absolute increases in community biomass after fertilisation.

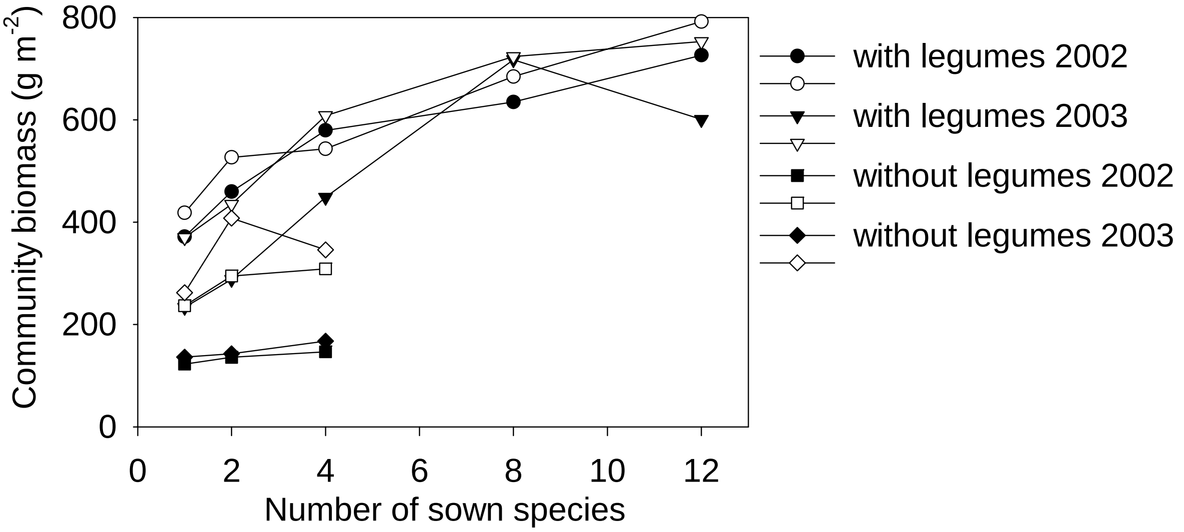

Figure 2. Mean aboveground biomass (> 5 cm) in plots with and without legumes at each level of species richness. Filled and unfilled symbols represent unfertilised and N-fertilised plots, respectively.

The two experimental years were both very dry. In both years, growth of *T. repens* was apparently reduced due to the drought. *Trifolium hybridum* was heavily infected with mildew in both years and all clovers (*Trifolium* spp) showed signs of root rot in spring 2003 in many plots. Positive effects of the fertilisation in the species-rich communities would probably have been weaker if the clover biomass had not been reduced by plant pathogens and drought, since there was a negative correlation between legume biomass in the unfertilised plots and the increase in plant community biomass observed in the fertilised plots.

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Grassland and landscape aesthetics

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Abstract

Both mountains and permanent grassland are vital elements of the traditional countryside in Switzerland, and therefore of high recreational value. Changes in agriculture structure and cattle production usually result in the disappearance of grassland of low nutrient supply. The loss of traditional low intensity grasslands, which are usually species-rich habitats, is not only important from biological diversity perspective, but also from the point of view of tourist attraction and recreation. In order to quantify the benefit of agricultural activities for landscape scenery, the method by Hoisl *et al*. (1989) is good as it allows landscape aesthetics to be measured in both a reproducible and a quantitative way. A comparison of landscapes with prevailing crop production with landscapes with prevailing grassland has shown that the value of landscape aesthetics is statistically significantly higher in grasslands. However, in typical grassland landscapes the countryside character can be badly affected e.g., by the occurrence of high silos and silage bales. Hoisl's tool can also be used as a means to improve landscape aesthetics as it can help to identify optimal location for the construction of silos.

Keywords: landscape aesthetics, land use, landscape perception, countryside, visibility analysis

Introduction

Having the choice of a range of destinations for a one-day holiday trip, the attractiveness of a landscape is an important or very important consideration to 90 % of Swiss people when making their decision (UNIVOX, 2002). For most of those interviewed 'naturalness', i.e., a countryside which is not heavily affected by human activities, was the most important asset contributing to the beauty of a landscape. Consequently, there is an increasing demand to be able to measure 'naturalness' of landscapes in a reproducible way. In addition there is considerable interest in being able to quantify the influence of agriculture, and in particular grassland production, on landscape aesthetics. There are many methods to assess landscape aesthetics, with several of these being based on the use of interviews.
The aim of the paper is:

1) To present the method of Hoisl *et al*. (1989) as a quantitative and reproducible method to assess landscape aesthetics.
2) To compare the landscape aesthetics value of the different regions in relation to the amount of grassland production.
3) To show which perception factor(s) have a dominant influence on landscape aesthetics.
4) To identify measures in grassland production help to enhance landscape aesthetics.

How do we measure landscape aesthetics?

Despite the fact landscape aesthetics is assumed to be arbitrary and person dependent there is a comprehensive and quantitative approach to measure landscape aesthetics: The method described by Hoisl *et al*. (1989), which relies on Nohl's 'epistemological model' (Nohl, 1980; Nohl, 1988). The model assumes that the amenity function of a landscape is maximised, if it provides an optimal mixture of stimulation, orientation in space, the feeling of freedom, and identity. In order to assess landscape aesthetics using the method by Hoisl *et al*. (1989), a first step involves portioning the landscape in question into patches of approximately 1 km^2 each. Next, the value of the 3 perception factors (i.e., 'variety', 'naturalness', and 'character') is quantified individually for each patch by attributing each landscape element a predefined value. For each patch the values of the three perception factors are summed up and standardised (Hoisl *et al*., 1989; Schüpbach, 2000).

The importance of grassland in landscape aesthetics

The outcome of landscape aesthetics assessments based on Hoisl's method is shown in figure 1 for 7 regions in the Swiss Central Plateau. The regions differed both in relief (from hilly to flat) and in the amount of grassland. The values show a gradient from landscapes with prevailing crop production to landscapes with prevailing grass production. The difference between the two groups of landscape types for the values of landscape aesthetics was statistically significant (5 % level, t-test for groups).

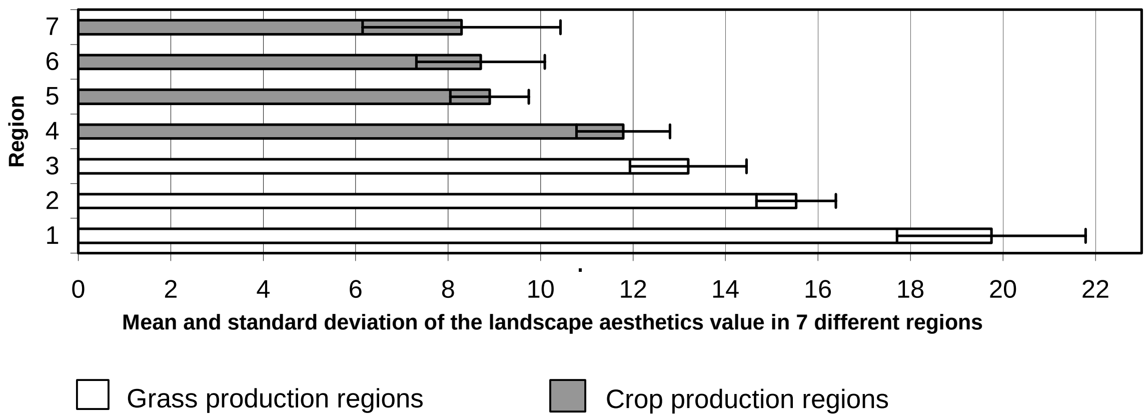

Figure 1. The values of landscape aesthetics in landscapes with different land use types arranged in a gradient according to increasing amounts of grassland. Amount of grassland: 50-80 % in grass production regions, 20-40 % in crop production regions (1: St. Gallen region, 2: Greifensee mountain region, 3: Greifensee hills, 4: Greifensee valley bottom, 5: Seeland, 6: Yverdon region, 7: Reusstal).

The first factor of a principle component analysis explains over 50 % of the total variance. The loadings of the first factor reaches -0.852 for the 'character' perception factor and -0.823, for the 'naturalness' perception factor, respectively, whereas the loading of the perception factor 'variety' is as high as -0.535. The present analysis are showing the fact that the value of landscape aesthetics is mainly defined by the perception factors, 'naturalness' and 'character'. The scale of the 'naturalness' perception factor reflects land use intensity. Both arable land and settlement areas have the lowest value, whereas the highest values are attributed to surfaces with no or only slight agricultural impact, such as wetlands, semi-dry meadows with low nutrient supply, or shrub. Nevertheless, intensive crop production landscapes can reach a value of landscape aesthetics that is nearly as high as in a landscape with intensive grass production, provided there is a sufficient amount of semi-natural surfaces e.g., wetlands or scrub. However, in an average agricultural landscape such semi-natural landscape elements are often missing. In those landscapes, grassland and especially extensively used grassland, is the only extensive landscape element. Usually the value of the 'naturalness' perception factor and hence the value of landscape aesthetics is strongly dependent on the percentage of grassland.

Modern grass production systems are associated with silos and silage bales. However, as far as they are considered to be inappropriate technical elements, they have a negative impact on the aspect of a traditional countryside. These elements are considered by 'character' perception factors (Hoisl *et al.,* 1989). Therefore grassland production can negatively affect the perception of a landscape. In theory the 'character' perception factor is calculated by attributing an area of impact to each silo depending on its size (Hoisl *et al*., 1989; Schüpbach, 2000). In practice however, the visibility of the silos can be restricted e.g., by relief characteristics or tree cover. This aspect can be considered by a visibility analysis. In the case of the Greifensee watershed this effect was quantified: In a first step, the value of the 'character' perception factor was calculated relying on the whole theoretically impacted area. In a second step only the actually visible part of the impacted area was taken into account. In the first calculation, the 'character' perception factor for the whole region yields a mean value of 10.0, whereas in the second calculation (only the actually visible part of the impacted area is considered) it yields a mean value of 23.7. The difference between the two values is statistically significant (1 % level, t-test pair wise).

Discussion

In the literature, 'naturalness' and 'character' are widely used as landscape aesthetics factors, and play a key role in many landscape aesthetics assessment projects (de Groot *et al*., 2003; The Landscape Institute and Institute of Environmental Management and Assessment, 2002). In our analysis landscape aesthetics was highly dependent on both the amount and intensity of grassland use, the aesthetic value of landscapes depending largely on the 'naturalness' perception factor. The Greifensee mountain region (Figure 1) which has a high value for landscape aesthetics, is a hilly landscape enjoying different (grass)land use intensities. However, the 'character' perception factor is just as important. As the analysis showed, relief and tree cover can help to hide anaesthetic storage facilities associated with grassland products. By means of a visibility analysis, places hidden by hills or trees for facilities of infrastructure can be found in order to maintain a high value of the 'character' perception factor.

For landscape aesthetics grassland systems with meadows and pastures of different intensity are advantageous. In particular, extensively used grassland elements contribute a lot to a high value in landscape aesthetics.

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Effects of species richness and spatially heterogeneous nutrient supply on early- and mid-successional plant communities

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Abstract

In recent experiments a positive relationship has been found between grassland diversity and ecosystem performance. However, there is controversy about the potential causal mechanisms, in particular, whether the relationship results mainly from a selection effect or from a complementarity effect. We tested these possibilities with replicated experimental communities, consisting of early- and mid-successional species, grown in soils with homogenous and heterogeneous nutrient distribution.

We assumed that there would be more complementarity among mid-successional communities because of lower niche overlap and a stronger relationship between species richness and ecosystem functioning. Furthermore, the species richness–functioning relationship was expected to be steeper in the heterogeneous than in homogeneous soils, because there is more potential for niche separation in the former. Finally, the heterogeneity effect should be most pronounced in mid-successional communities, where there is a combination of these two effects. A pilot experiment with monocultures and 6-species mixtures conducted across a nitrogen gradient did not confirm our hypotheses of a higher complementarity effect in mid-successional plant pools. Nor were there generally higher selection effects under high nitrogen conditions, though a second larger experiment is still in progress.

Keywords: diversity, succession, grassland, complementarity, ecosystem functions

Introduction

Several studies on grassland ecosystems have revealed positive species diversity - ecosystem functioning relationships (Tilman, 1996; Hector *et al.*, 1999; Naeem *et al.*, 2000; Wilsey *et al.*, 2000; Reich *et al.*, 2001), and some have shown that this is primarily due to complementarity (Hector *et al.*, 1999) rather than selection (Loreau *et al.*, 2001). The selection or sampling effect comes about when a few high biomass species dominate the mixture. The complementarity effect is caused by species in mixtures contributing proportionally more biomass than expected from their monoculture yields. We wanted to see how these effects varied between two different plant communities, composed of early- and mid-successional species, and under the different environmental conditions of a nutrient gradient or of uniform versus heterogeneous environment. We expected complementarity to be higher in the mid-successional plant pools, as we assumed mid-successional species to have a higher degree of niche separation than early-successional species, and therefore a higher ability to be complementary. Furthermore the selection effect was expected to be higher under high and uniform nutrient levels, since dominance of a few species is known to occur under such conditions (Tilman, 1987; Mooney *et al.*, 1996; Vitousek *et al.*, 1997). The results of a pilot experiment (monocultures and 6-species mixtures grown under a nitrogen gradient) are presented here. The analysis of the main experiment (monocultures, 3-species and 6-species mixtures in uniform and heterogeneous environments) is still in progress, but will be shown on the conference poster.

Materials and methods

A pilot field experiment was set up in May 2002 at the Swiss Federal Research Station for Agroecology and Agriculture (FAL) in Zürich-Reckenholz. 30 early-successional and 30 mid-successional plant species were each divided into 5 non-overlapping pools, which all contained the three functional groups: grasses, herbs and legumes. Each experimental plot included one pool and consisted of 6 small subplots (0.5 x 0.5 m) for the monocultures and a larger subplot (1 x 1 m) for the 6-species mixture. Plots were repeated at 4 different levels of nitrogen (no additional nitrogen, 4 g N m^{-2}, 8 g N m^{-2}, 12 g N m^{-2}) to simulate an environmental gradient. Biomass was harvested at the end of September 2002. For the partitioning of the diversity effects (net, complementarity and selection effect) we used the method of Loreau and Hector (2001).

Results and discussion

Nitrogen addition had a significant effect ($F_{(1,\ 222)}$, P < 0.0001) on aboveground biomass production in monocultures and in the mixtures (Table 1 and figure 1). Pools differed significantly in above ground biomass production ($F_{(8,\ 222)}$, P < 0.0012), reflecting the importance of the particular composition of plant species. Monocultures and mixtures were significantly different ($F_{(1,\ 222)}$, P < 0.043), with the mixtures producing a higher mean yield and lower standard deviations. Low standard deviations indicate a stabilising effect in the mixtures by reducing the variance of the average yields. Other factors, including successional stage, were not significant. Thus there was no difference in overall production between early-successional and mid-successional plant pools.

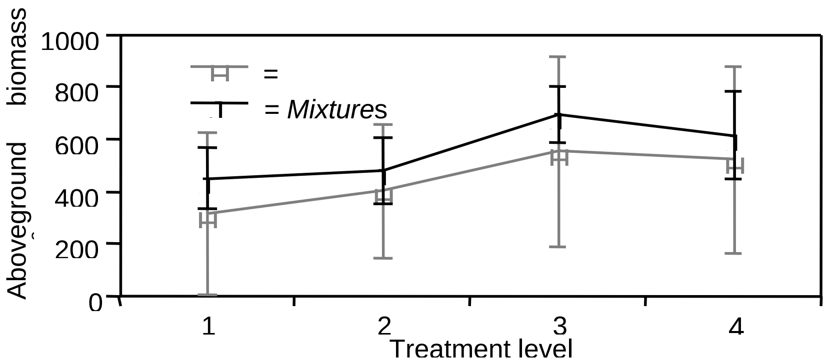

Figure 1. Total above ground biomass of monocultures and mixtures along the Nitrogen gradient. Treatment level 1 = no additional nitrogen, level 2 = 4 g N m^{-2}, level 3 = 8 g N m^{-2}, level 4 = 12 g N m^{-2}.

The net biodiversity effect was significantly positive, which means that mixtures had higher yield than would have been expected on the basis of monoculture yields (Table 1). There was no overall complementarity effect and, contrary to our expectations, the complementarity effect did not differ between the two successional stages (Table 1 and figure 1). There was a significant positive overall selection effect, but no main effect of nitrogen (Table 1). Fridley (2002) found an increasing selection effect with increasing fertilisation in his study, but he used a single species pool and his 9-species mixtures often contained species in common. The variation of the net, complementarity and selection effects among pools along the nitrogen gradient, seen in the treatment x species pool interactions (Figure and table 1), cancelled out any differences between successional stages, treatment levels or pools. We therefore conclude, that it is difficult to make general conclusions about successional stages, although effects might develop over a longer time period.

Table 1. ANOVA of the net, selection and complementarity effect of all pools across the four nitrogen treatments. To meet the requirements of the analysis, values are square root transformed but the original positive and negative signs preserved.

	Net effect					Complementarity effect					Selection effect				
Source	d.f.	SS	MS	*F*	*P*	d.f.	SS	MS	*F*	*P*	d.f.	SS	MS	*F*	*P*
Grand mean	1	268.1	268.1	22.684	<0.001	1	3.0	3.0	0.186	0.671	1	195.7	195.7	8.347	0.009
N-treatment	1	3.3	3.3	0.280	0.611	1	5.8	5.8	0.070	0.798	1	0.1	0.1	0.002	0.968
Successional stage	1	52.9	52.9	4.479	0.067	1	27.8	27.8	0.335	0.579	1	50.8	50.8	0.786	0.401
Pool	8	94.6	11.8	0.261	0.964	8	664.1	83.0	1.706	0.221	8	516.9	64.6	2.861	0.069
N-treatment x Pool	9	406.9	45.2	3.826	0.006	9	437.9	48.7	3.055	0.018	9	203.2	22.6	0.963	0.497
Residual	20	236.4	11.8			20	318.6	15.9			20	469.0	23.5		

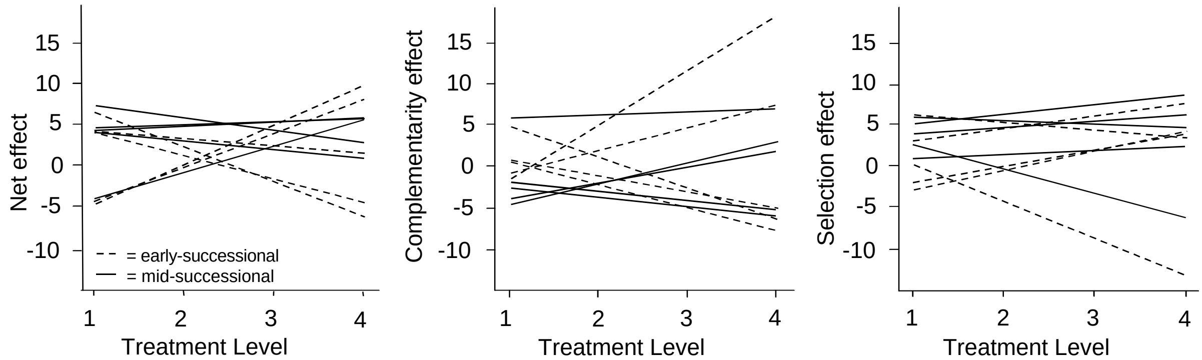

Figure 2. Variation in biodiversity effects across nitrogen treatments for early-successional (dashed lines) and mid-successional (solid lines) pools. Treatment levels as in figure 1.

Conclusions

The results of our pilot experiment show that although there was a significant net effect of diversity, the selection and complementarity effect depend on the particular composition of a plant species pool and on the nitrogen availability in the ecosystem. The successional stage on the other hand had no influence on these effects. Hence we found no evidence for the presence of higher complementarity effects in mid-successional species.

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Sward height distribution and temporal stability on a continuously stocked, botanically diverse pasture

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Abstract

Grazing by livestock is widely used for the restoration of biodiversity in semi-natural grasslands. It is well established that faunal diversity is strongly dependent on vegetation structure and floristic composition. It is also likely that heterogeneity of sward height pattern caused by herbivores and its stability have important influences on grassland fauna. However, few studies have examined sward height distribution and its temporal dynamics in semi-natural grasslands. In an experiment on continuously stocked botanically diverse grassland subjected to either severe, moderate or lenient grazing intensity treatments, these aspects were measured in detail. Within permanent quadrats the sward height and cover of plant species were recorded and the temporal stability of patches were followed over the grazing season. In late summer, the variability of sward height distribution was highest in the severe treatment. The highest temporal stability over the whole season was under the lenient grazing treatment, whereas much lower stability was found under the severe and moderate grazing. This result indicates that under lenient grazing with the biggest surplus of forage, patches that were initially avoided stay tall throughout the grazing season and the cattle graze those areas repeatedly which are characterized by a comparatively high *Trifolium repens* cover.

Keywords: grazing intensity, plant species richness, sward height distribution, spatial heterogeneity, temporal dynamic, grassland management

Introduction

Vegetation structure of grass-clover swards or other species-poor swards has been widely evaluated with regard to their effects on grazing behaviour and animal intake as well as consequences on interspecific plant competition and resultant vegetation changes (Rutter *et al*., 2002; Edwards *et al*., 1996; Tallowin and Brookman, 1996). However, little is known about the sward height distribution and temporal stability of patch types on continuously stocked botanically diverse pastures (Rook and Tallowin, 2003). In 2002, these aspects were measured in detail. The objectives of this study were: (1) to describe the effects of different grazing intensities on sward height distribution and (2) to compare the effect of grazing intensity on temporal stability of sward height pattern and botanical composition.

Materials and methods

The study was conducted in Somerset/England (51°03' N, 2°36' W) on a 15 ha species rich semi-natural, neutral grassland that contained 16-18 higher plant species per m². Three grazing intensity treatments (continuous stocking), which aimed to maintain target sward surface heights (SSH) of either 6-8 cm (severe), 8-10 cm (moderate) or 10-12 cm (lenient), respectively, were established in April 2000. In order to study the sward height distribution and temporal aspects in detail, three quadrats (5 × 10 m) were marked permanently within one replicate of each grazing severity treatment in April 2002. The quadrat positions were selected so that the most abundant sward communities within the paddock were represented within the study areas. Each quadrat was divided into 0.5 × 0.5 m cells, resulting in 210 grid pattern cells. Horizontal sward profile in the quadrats was recorded by measurement of compressed sward height (CSH) with a drop disc in each cell. In order to get further information about the determinants of the measured CSH, the area under the disc was assessed by estimation of the cover of plant families. Drop disc sampling was undertaken at the same positions in May, July and September. To compare the variability of sward height between the different treatments the interquartile ranges (percentiles 75 to 25) were used. Patch temporal stability was estimated by calculating the percentage of cells that stayed within a height category (short or tall) over the grazing season. The Kappa-index, which quantifies mosaic fixation, was calculated.

Results and discussion

Table 1 shows the variability of sward height distribution, here presented as interquartile range, in the different treatments at three occasions. The average over the three quadrats per paddock is accompanied by a high standard error mean for the severe grazing treatment. The between quadrat differences are less pronounced in the moderate grazing treatment and are least in the lenient grazing treatment. It was predicted that variability of sward height distribution would be greatest in the lenient grazing treatment because of the considerable imbalance between amount of forage on offer and herbage intake and thus the greatest selectivity by the grazing animals would occur. However, comparison of the interquartile range shows that this hypothesis was only partially validated. With progress of the grazing season the variability in the severe treatment became greater, particularly in quadrats where *Cirsium arvense* was common. *C. arvense* was avoided by the grazing cattle and thus the individual plants were allowed to grow taller whereas the area around these plants was grazed extremely short.

Table 1. Interquartile range (cm) as a measure of variability of sward height distribution in severe (sev.), moderate (mod.) and lenient (len.) grazed treatments, (sem in parentheses, n=3).

	May			July			Sept		
	sev.	mod.	len.	sev.	mod.	len.	sev.	mod.	len.
Mean (sem)	3.4 (1.3)	5.7 (0.5)	6.0 (0.6)	4.0 (2.0)	2.5 (0.3)	4.8 (0.6)	4.0 (2.3)	2.3 (0.6)	3.4 (0.1)

The temporal stability, represented by the Kappa-index, of tall patches and short grazed areas is shown in table 2. In the lenient treatment more than half of the cells, that initially contained either tall or short sward, stayed within the same sward height category over this period. In the moderate treatment the stability was markedly lower, particularly of the short grazed patches. In the severe treatment, what were initially short grazed patches showed the most dynamic changes, with more than 75 % of these short patches becoming taller. The overall pattern of patch stability and contrasts between the three treatments remained similar over the whole season, albeit with more variability.

Table 2. Kappa-Index as a measure of temporal stability of different patch types (Kappa-Index = 1 indicates complete mosaic fixation and therefore perfect stability, (sem in parentheses, n=3).

		May to July			July to September		
		severe	moderate	lenient	severe	moderate	lenient
tall	Mean (sem)	0.48 (0.057)	0.43 (0.195)	0.54 (0.091)	0.47 (0.240)	0.36 (0.219)	0.53 (0.047)
short	Mean (sem)	0.25 (0.157)	0.36 (0.024)	0.56 (0.073)	0.37 (0.233)	0.26 (0.157)	0.60 (0.057)

In order to determine possible mechanisms underlying patch height dynamics, relationships between patch height and presence of dicotyledonous species within selected plant families was examined. The *Asteraceae*, *Ranunculaceae* and *Fabaceae* were the most common families present in the quadrat areas. The presence of *C. arvense* (*Asteraceae*) appeared to be the key factor in influencing tall patch stability in the severe treatment, having a significant higher cover in those cells that stayed tall throughout the season. There were, however, initially tall patches in the severe treatment that were grazed later in the season, but these patches did not contain *C. arvense*. In the lenient treatment there was a significantly higher cover of *Trifolium repens* (Fabacea) in patches that were initially short and stayed short throughout the season (Figure 1). Patches that did not contain *T. repens* at the start of the grazing season tended to be those that became taller later in the season. It appeared that preferential grazing by the cattle on patches with *T. repens* was a key mechanism behind the maintenance of short grazed sward patches in the lenient treatment.

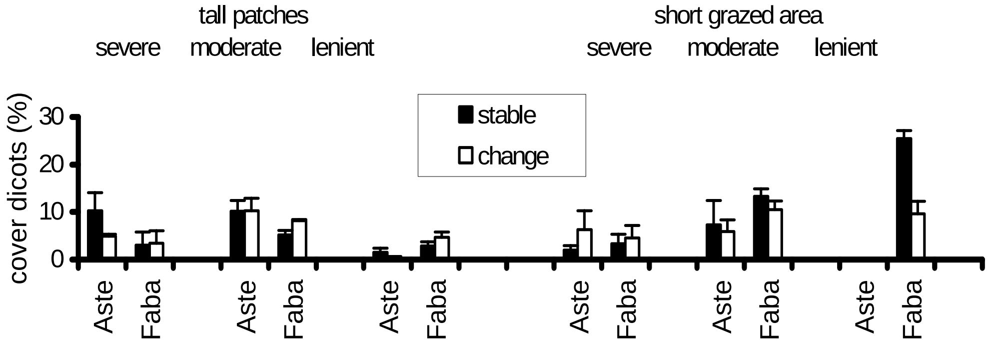

Figure 1: Cover (in %, error bars represent standard error of the mean) of all species within the *Asteraceae* (Aste) and *Fabaceae* (Faba) in cells (706.5 cm², n = 630) with tall or short sward heights in May, that either stayed within this sward height category (= stable) or changed into a shorter or taller sward height category (= change) during the grazing season.

This means for the lenient grazing treatment, that once formed the mosaic of heavily grazed areas and lightly grazed patches, will probably govern the grazing pattern (Bakker *et al*., 1983). The study has shown, that information on means of sward height and species composition will not be sufficient to describe the situation on a continuously stocked grassland. As the variability of both measures can have large effects on invertebrates, it is important to have a detailed understanding of how they change over both space and time.

Acknowledgements

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Belowground biodiversity as an indicator for sustainability of soil use

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Abstract

This paper describes the Biological Indicator for Soil Quality (BISQ) that has been applied in the Netherlands for the assessment of the ecological soil quality on a national scale. As an example, part of the results of the monitoring activities on managed farms on sandy soils are described.
Biodiversity in the soil decreases with increasing management intensity. The abundance of nematodes remains rather constant, showing ecological shifts within their feeding guilds. Aside from bacterial feeding nematodes, the abundance of other guilds, and taxonomic groups decreases. For instance, the total abundance of earthworms decreased with increasing intensity and the relative number of species living in the topsoil decreases, suggesting decreased macroporosity in the top layer of the soil. The potential bacterial activity increases, going from organic to conventional farming, but then decreases, when the management intensity is increased further. The Soil Quality Index (SQI) decreases from 80 % for conventional farming to 68 % for intensive farming systems.

Keywords: soil ecology, soil functions, biodiversity, soil quality assessment, soil fauna

Introduction

Soil organisms are important for the functioning of soil ecosystems with respect to degradation of organic material, nutrient cycling, soil structure and water regulation. Living organisms are reliable indicators of environmental quality, as they provide the best reflection of the actual fitness of their habitat and ecological changes therein. Diversity, abundance and activity of soil organisms indicate therefore the degree of sustainability of soil management.
We achieved a biological indicator for soil quality (BISQ), based on belowground food web interactions and ecological processes. Within this project, we monitored the biodiversity of soil organisms (microorganisms, microfauna and mesofauna) in 50 cattle farms and correlated it with the management system of each farm.

After an extensive survey the following processes were selected as a basis for the monitoring activities:
- fragmentation and degradation of organic material,
- recycling of nutrients,
- soil structure evolution (bioturbation and aggregate formation),
- availability of nutrients for plants,
- stability of the belowground ecosystem.

The indicative variables are potential rates of several processes, and biodiversity within and abundance of functional groups.

Monitoring data as such do not have indicative power. The aim of the soil quality indicator is to produce an integrated view of the ecological status of the soil relative to the (desired) optimal situation, with respect to a series of specific life support functions of the soil. Therefore it is necessary to deduce references or goals. So far, political or managerial goals have not been chosen, other than the claim that soil has to be used in a sustainable way. In general, pollution or disturbances force the selection of a very few resistant species. In such situations the ecological basis for belowground processes may become very narrow. When even resistant species disappear – or become inhibited – as a result of future and as yet unknown human activities, the related process stops and the life support function remains permanently affected. Hence, we based the indicator system for life support functions of the soil on the following hypothesis: *The threat to vital soil processes can be expressed by comparing the number of species in functional groups in a certain area with its reference (undisturbed locations).* Due to redundancy of species, a process may continue to exist with fewer species (in the case where other species of the same functional group disappear). However, it is obvious that the risk of instability and uncontrolled fluctuations will increase.

Materials and methods

The monitoring activities were performed within the framework of the Dutch soil quality network (DSQN), a national monitoring network, originally designed to obtain national information on abiotic soil status and trends. The biotic variables measured were abundance and diversity of nematodes, earthworms, enchytraeids, and micro-arthropods, nitrifying activity, microbial functions (community level functional profiles by the Biolog-system, genetic diversity, total activity and numbers of bacterial cells).
The DSQN data on chemical soil composition were used to relate the occurrence of organisms to abiotic conditions and land-use. To obtain insight into the ‘length of the scales’ for each parameter, 100 additional plots from outside the network have been sampled, such as organic farms, nature areas and polluted areas. All biotic and abiotic data are collected in a database.

Datahandling
In our study the resulting data are presented in the form of a centripetal diagram of all indicator values scaled against a historical, undisturbed or desired situation (Figure 1). Field indicator values could then be uniformly scaled against indicator values measured at the reference sites. The indexed indicator values can be further aggregated into an SQI using the average factorial deviation of the biological indicator reference value. This index is calculated as:

$$SQI = 10^{\log r - \frac{\sum_{i=1}^{n} |\log r - \log S_i|}{n}}$$

where *r* is the value of an indicator on the reference site, *S* is the value of the indicator at the site under investigation; *i* is the number of indicators measured on the site. (*r* and *S* expressed as percent). In this SQI, a value of 50 % has the same weight as one of 200 % of the reference value (both a factor of 2). For our reference, SQI equals 100 % and each deviation from that value reflects a decrease of SQI (i.e., too many species is also regarded as negative effect).

Results and discussion

We present here part of the results of a monitoring activity on 20 conventional farms (average livestock units (LSU) 2.4), 20 intensively managed farms, average livestock 1 unit higher and 10 organic farms (the *a priori* chosen reference, with a mean of 1.7 LSU). One LSU equals the amount of cattle excreting 41 kg nitrogen ha^{-1} y^{-1}. The average results of the indicative variables at all the organic farms were scaled as 100 % and the results for conventional and intensive farming are shown in figure 1. It can be seen that the amount of bacteria decreases slightly with increasing intensity of the farm management. The expected increase of bacterial activity is shown in the increased potential carbon *mineralis*ation rate and in the increase of

the relative amount of bacterial feeding nematodes. In general it seems, that the nematode diversity decreases as do the diversities of the different functional groups of nematodes, with the exception of the bacterial feeders. As bacterial biomass decreases along a livestock gradient (Mulder *et al.*, 2003), our results suggest that both the bacterial communities in the soil and the bacterial feeding nematodes are more active.
On the other hand, abundances of earthworms decrease slightly with management intensity and also the relative amount of epigeïc species decreases, indicating variations in: i) macroporosity in the top layer of the soil and ii) litter quality and related nutrient turnover.
The average soil quality indices for the two groups of non-organic farms were 80 and 68 % respectively, where again the reference value of 100 % was assigned to the organic farms (further results of the pilot study of 1999 are given in Schouten *et al.* 2002).

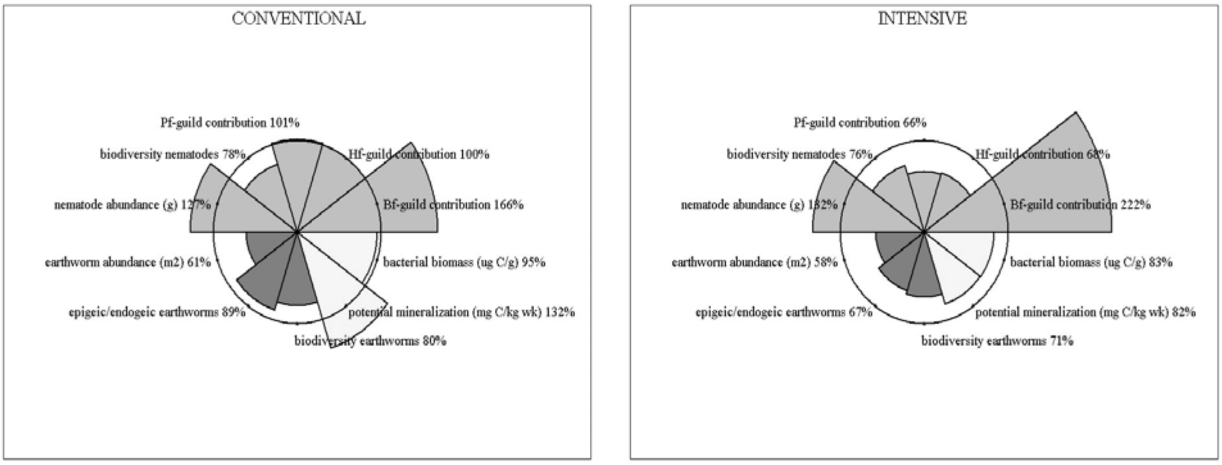

Figure 1. Plots of the most significant proxies (α = 0.05) under conventional and intensive farming. From top to bottom: nematodes (Pf = non-parasitic plant feeders, Hf = hyphal feeders, Bf = bacterial feeders), bacterial cells (carbon content and potential C *mineralis*ation) and earthworms. The circle represents the chosen reference (organic farms) and equals 100 %.

Conclusions

It could be shown that there was a negative correlation between aboveground farming intensity and the belowground functional diversity of soil organisms. The decreases in abundance and biomass of microorganisms, microfauna and mesofauna indicate a decrease in sustainability of soil use, resulting in a negative effect on the soil buffer capacity (a phenomenon that will consequently affect other ecosystem processes) and top-down effects of management (Mulder *et al.*, 2003 and 2004).

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Grassland pattern at farm scale and relationship with species richness

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Abstract

Human activities and agricultural practices enhance landscape linearity, e.g., crop farming produces a regular shaped landscape with straight and distinct boundaries between arable fields (Moser *et al*., 2002), whereas livestock farming tends to lead to irregular shaped units with less distinct boundaries. The objective of this study was to explore biodiversity at farm scale, and to assess the relationship between plant species richness (S), or species richness/area ratio and permanent grassland on cattle breeding farms in North-Eastern France. For study purposes, each grassland category was described by the number of shape characterising points (NSCP), and the Patton index. The relationships between specific richness and grassland perimeter, or NSCP/perimeter ratio were also tested. These three widely used landscape indices were compared to a novel index of shape and boundary complexity that is proposed at farm scale: $I_E = D/S^2$, where D = interval between farm buildings and grassland, and S = grassland surface. The results show that specific richness is correlated to grassland areas, distance and I_E. In one study, the new I_E index is correlated with specific richness ($r^2 = 0.71$, $P = 0.003$). The results show that conventional indexes are not suitable descriptors for landscapes modelled by cattle breeding farms, whereas the new index (I_E) shows potential for predicting species richness in such landscapes.

Keywords: agricultural practices, biodiversity, livestock farming, grasslands, shape complexity.

Introduction

Conservation strategies for sustaining biodiversity must allow that species richness and ecological processes are controlled by parameters operating over a range of scales. In Europe, landscapes are largely modelled by agriculture, e.g., livestock farming leads to irregular shaped units with less distinct boundaries, whereas crop farming induces a regular shaped landscape with straight and distinct boundaries between arable fields (Moser *et al*., 2002). Few studies have attempted to assess the link between biodiversity and landscape pattern at farm scale. Floristic diversity is a measure of biodiversity that is subject to manipulation by agricultural practice. However, measurement of biodiversity parameters (α-, β- and γ-diversity), on large spatial scales (such as a farm), are costly and time consuming. Such measurements therefore are not useful in aiding decision makers, or policy and rural managers who urgently need simple indicators of biodiversity, providing links between landscape patterns and species richness (Dauber *et al*., 2003). The objective of this study is to develop indicators useful for the rapid assessment of biodiversity at farm scale. The focus in this paper are: i) on the identification of evaluation criteria to characterise grassland patterns at farm scale, and ii) the exploration of the relationships between shape or boundary complexity of permanent grassland, and plant species richness at farm scale.

Materials and methods

The study was carried out on two cattle breeding farms situated in North-Eastern France. Floristic records were determined via a handling technique (de Vries, 1949) on all 36 permanent grasslands on the two farms. Floristic diversity was described by two floristic diversity values: the specific richness and the Shannon diversity index (Shannon and Weaver, 1949). Each grassland form complexity was characterised by three evaluation criteria determined from the literature (Forman and Godron, 1986): i) the Patton index of shape complexity, ii) the number of shape characterising points (NSCP), and iii) a new index of shape and boundary complexity at farm scale, which takes into account the distance (D) between farm buildings and grasslands, and the grassland surface (S): $I_E = D/S^2$. In order to explore the relationship between floristic diversity and complexity of permanent grasslands, the floristic diversity values were compared to the values of grassland form specificities (area, perimeter, Patton index and NSCP) and to I_E index. Relationships were analysed by Spearman Rank Correlation and the significance of the influence of each indices was evaluated by step by step multiple linear regression analyses. All statistical analyses were made using the Statbox statistical software (Grimmer Logiciels, 1997).

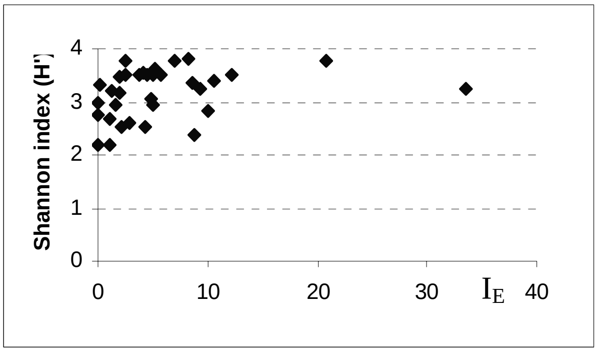
Results and discussion

The maximum observed specific richness was 48 and the maximum Shannon diversity index was 3.8. The results showed that the specific richness is correlated to the grassland area (S), the distance between farm buildings and grasslands (D), the perimeter and the I_E indice (Table 1). Shannon diversity index is significantly correlated with distance and I_E index. The new I_E index is significantly correlated with specific richness (r = 0.37, *P* = 0.03) and Shannon diversity index (r = 0.37, *P* = 0.02).

Table 1. Relationship between specific richness or diversity index with shape or boundary characteristics (n = 36), significant correlations in bold.

	Area (A)	Perimeter (P)	Distance (m)	Patton index	NSCP Index	I_E index
Specific richness (S)	**r = -0.45** ***P* < 0.01**	**r = -0.45** ***P* < 0.01**	**r = 0.34** ***P* = 0.04**	r = -0.10 *P* = 0.54	r = 0.25 *P* = 0.14	**r = 0.37** ***P* = 0.03**
Shannon diversity index (H')	r = -0.23 *P* = 0.18	r = -0.19 *P* = 0.27	**r = 0.40** ***P* = 0.02**	r = -0.13 *P* = 0.44	r = 0.14 *P* = 0.56	**r = 0.37** ***P* = 0.02**

a)



b)

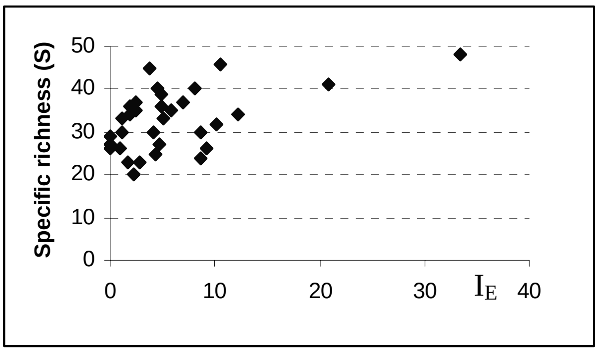


Figure 1. Relationship between a) Shannon diversity index, and b) specific richness with the I_E index of permanent grasslands for two cattle breeding farms (n = 36).

For the studied permanent grasslands, diversity index and specific richness were not linearly related with the I_E index of grasslands of the two studied cattle breeding farms (Figure 1).

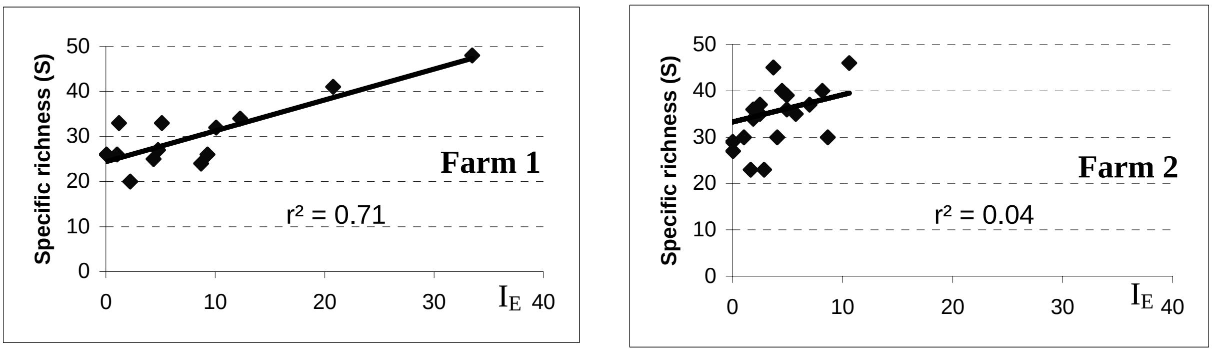


Figure 2. Relationship between the specific richness and the I_E index in farm 1 (n = 16) and farm 2 (n = 20).

The specific richness was correlated to I_E index ($r^2 = 0.71$, $P < 0.001$) in farm 1, but not for farm 2 (Figure 2). In multiple regression analyses, area in combination with Patton index explained 11.5 % (adjusted r^2, $P = 0.05$) of the Shanon diversity variation. Multiple regressions on the different grasslands' characteristics or index showed that area and I_E indice explained 18.9 % ($P = 0.01$) of the variation of specific richness. No other single factor or combination of parameters improved these results. The results highlight the role of the distance between farm buildings and permanent grasslands. This is due to the fact that agricultural practices usually become more extensive the further the fields are far from farm buildings, because the transfer of materials or animals are longer and more expensive.

Conclusions

The results show that despite the variety of indexes, few are adapted to assess biodiversity at farm scale. The novel index I_E shows promise for predicting species richness in grassland vegetation, but further work is required to develop it as an indicator for the global diagnostic assessment of agricultural practice effects on floristic diversity at farm level.

Acknowledgements

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Herbage production in relation to land use changes in Mediterranean rangelands

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Abstract

During the last few decades, rapid socioeconomic evolutions induced major changes in traditional land use practices in Mediterranean rangelands. Agricultural extensification, along with the reduction of fuelwood collection and livestock raising, have led to extensive woody plant encroachment in the majority of European grasslands. In this study, conducted in Lagadas county, northern Greece, the dynamics of herbage production was investigated along an extensification gradient. Herbage production was measured across four land use types (abandoned fields, grasslands, open shrublands and dense shrublands / woodlands), representing, respectively, sequential successional stages related to land extensification. In four representative 30 × 30 m plots per land use type, total aboveground herbage biomass was harvested at its peak stage (May-June). It was found that herbage production was significantly decreased as woody plants established following extensification and succession from abandoned fields to woodlands.

Keywords: herbage production, land use changes, extensification, Mediterranean rangelands, succession

Introduction

Mediterranean areas are characterized by a variable ecological environment and a diverse landscape shaped by complex human-environment interactions. Rangelands in the Mediterranean basin amount to 52 % of its total area (Le Houerou, 1981), while in Greece they cover about 40 % of the country, representing the largest land use type (N.S.S.G., 1997). The Mediterranean region is facing major land use changes over the last few decades due to concomitant changes of the socioeconomic conditions. Rural depopulation has greatly affected the intensity of land use and resulted in a significant reduction of areas allocated to traditional practices. This extensification, along with the competitive advantage of woody plants over the herbaceous ones, have led to a widespread woody plant invasion in the majority of European grasslands.

Woody plant encroachment in grassland ecosystems is considered as a physiognomically and functionally important stage of plant succession (Debussche and Lepart, 1992). On the other hand, secondary succession following land extensification imposes radical changes in vegetation composition and key threats to grassland biodiversity (Mitchley and Ispikoudis, 1997). Hector *et al.* (1999), based on experiments in 8 European grassland sites, consider species richness and composition of plant species and functional groups (grasses, legumes and herbs) together with geographic location, as key determinants of primary productivity. Grasslands in Greece are mainly successional and maintained by human activities. Herbage production in these grasslands varies widely depending on soil and climatic conditions and mainly by air temperature and annual precipitation (Papanastasis, 1982). The aim of this study was to investigate how land use changes affect herbage production and its structure in Mediterranean rangelands.

Materials and methods

The study was conducted in Lagadas county (ca. 40º47´ N, 23º12´ E; altitude 450-550 m) in central Macedonia, northern Greece, during spring 2003. The climate is sub-humid Mediterranean type with cold winters. Soils are derived from metamorphic rocks and have a sandy-loam (SL) texture and a pH of about 5.9. Vegetation belongs to the *Coccifero-carpinetum* association of the *Quercetalia pubescentis* (Dafis, 1973). Rangelands cover the majority of the land and are mainly *utilis*ed by domestic animals, especially sheep and goats. Four land use types were identified, representing sequential successional stages related to extensification of arable cropping and fuelwood collection and reduction of grazing pressure; abandoned fields (nearly 7 years uncultivated), grasslands, open shrublands and dense shrublands / woodlands. The experimental design included four replications / plots for each of the four land use types. In the 16 plots, 30 × 30 m each, total aboveground herbage biomass (live and dead) was harvested during May-June, at the end of the growing season. Ten 0,5 × 0,5m quadrats were randomly taken within each plot and the standing plant material was cut to ground level, while the litter was also collected. The biomass was sorted out in the laboratory by hand into live (current year's) and dead (old) components, whereas in half of the quadrats it was also separated into grasses and forbs. All biomass was oven dried at 60ºC for 48 h and weighed. Data were subjected to analysis of variance; if significant the Duncan's multiple range test was used.

Results and discussion

Live biomass was gradually decreased as succession proceeded from abandoned fields and grasslands towards woodlands. More specifically, it was reduced progressively by 7.6 % from abandoned fields to grasslands, 44.5 % to open shrublands and 25.4 % to dense shrublands / woodlands. This is in agreement with Odum (1969), who correlates net community production (yield) in an annual cycle with the current stage of ecological succession, expected to be large in early stages and smaller in advanced ones. Litter (dead matter) was reduced by 3.1 % from abandoned fields to grasslands and then increased by 24.3 % and 33.6 % to open and dense shrublands, respectively.

Both live biomass and litter were found to be significantly different among the four land use types (Table 1). Particularly, live biomass produced significantly higher values in the abandoned fields and grasslands compared with the open and dense shrublands, which did not differ significantly. Herbage availability in each land use type is the factor that constrains herbivore carrying capacity and shapes grazing strategies (Jobbágy and Sala, 2000). Litter, however, was significantly increased in the dense shrublands / woodlands in comparison to the other three land use types, where no significant differences where found.

Table 1. Total above ground herbage production (g DM m^{-2}) of different land use types related to land use changes in northern Greece.

	Land use type			
Biomass	abandoned fields	grasslands	open shrublands	dense shrublands
Live	215.2a[1]	198.8a	110.3b	82.2b
Dead	168.4b	163.1b	202.8b	271a

[1]Means within the same class followed by the same letter are not statistically different at the 0.05 level.

Grasses produced the highest values in abandoned fields and grasslands, intermediate in open shrublands and the lowest in dense shrublands / woodlands (Table 2). Percentagewise, grasses were making 70 % of the total live biomass in grasslands, 53 % in abandoned fields and open shrublands and 35 % in dense shrublands / woodlands. Forb production was significantly highest in abandoned fields, whereas it did not differ significantly in the other 3 types. It comprised 61 % of the total live biomass in dense shrublands / woodlands, 45 % in abandoned fields and open shrublands and only 26 % in grasslands.

Table 2. Production of grasses and forbs (g DM m^{-2}) in four land use types related to land use changes in northern Greece.

	Land use type			
Group	abandoned fields	grasslands	open shrublands	dense shrublands
Grasses	101.3a[1]	111.4a	66.1b	23.6c
Forbs	86.8a	41.7b	55.2b	41.2b

[1]Means within the same class followed by the same letter are not statistically different at the 0.05 level.

Conclusions

Woody plant encroachment in grasslands following land use extensification results in significant reduction of available herbage production, leading to a subsequent reduction of their carrying capacity and value for domestic animals, especially sheep and cattle.

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Grazing value of grassland communities in Apennine protected areas (Italy)

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Abstract

A detailed investigation was carried out on grasslands within two protected areas of the Emilia-Romagna region (Italy), along an elevation gradient from 70 m (Gessi Bolognesi Park) to 825 m asl (Monte Sole Park). Four different grassland typologies were identified, as were their dynamic relationships and grazing value. The recent forage crops showed a similar grazing value in the two areas (46 and 50 respectively, following the method of Daget and Poissonet (1969)), while the less recent forage crops, and to a much greater extent the meso-xerophilous grasslands resulting from their abandonment, lose a consistent percentage of their initial grazing value (22 % and 61 % respectively at Gessi Bolognesi; 6 % and 42 % at Monte Sole). The motivation for the maintenance of grassland areas is therefore different in the two territories: conservation of biodiversity in Gessi Bolognesi, conservation of biodiversity, together with moderate production, in Monte Sole.

Keywords: grasslands, biodiversity conservation, grazing value, protected areas, Emilian Apennines, Directive 92/43/EEC.

Introduction

The presence of man and his activities such as agriculture, silviculture and grazing, have for centuries played an important role in shaping the landscape and plant communities. However, a major change in the relationship between man and the environment has taken place, especially during the last fifty years. Available data indicate that forest cover in Italy has increased from 5.6 million hectares (Gori Montanelli, 1950) to 8 million hectares (Ministero Agricoltura e Foreste, 1985), and to an estimated 10 million hectares in recent years. This has come about largely at the expense of traditional farming areas, that were unsuitable for systems of production-oriented agriculture.

The maintenance of areas occupied by herbaceous vegetation plays an important role from an environmental point of view. For example many semi-natural herbaceous formations are habitats protected by the Habitat Directive 92/43/EEC, and many of the territories in which they are located are Sites of Community Importance (SCI), belonging to the Natura 2000 ecological network. Apart from their importance from a conservationist point of view, the maintenance of grassland typologies may represent an opportunity to enhance many Apennine territories that are unsuitable for high levels of productivity but, which nevertheless may support economic activities that do not threaten the quality of the environment.

In this context, the present study provides an overall picture of the dynamic relations among the different typologies of grassland communities present in two protected areas of the Northern Apennines (Bologna Province, Italy) and of the changes in the grazing value (Daget and Poissonet, 1969) of these communities during the evolution of the dynamic series in question. The results obtained offer a preliminary assessment of the grazing vocation of the areas examined and, more generally, of other areas of the Apennines with similar environmental conditions.

Materials and methods

The study was conducted in two areas (Gessi Bolognesi Park, Monte Sole Park) of the Bologna province (Emilia-Romagna Region, Italy) both of which are Sites of Community Importance (SCI) following the 92/43/EEC Habitat Directive (European Commission, 1992). The two areas extend over 3965 ha and 6476 ha respectively, and are located along an ideal elevation transect going from the low hill belt (Gessi Bolognesi, maximum elevation 367 m asl) to the submontane belt (Monte Sole, maximum elevation 825 m asl) of the Emilian Apennines. The two areas are characterised by different climatic conditions (796 mm total annual rainfall, 13.7 °C mean annual temperature and a narrow xerothermic period in July and August at Gessi Bolognesi; 990 mm total annual rainfall, 11.5 °C mean annual temperature and absence of a xerothermic period at Monte Sole).

A detailed survey of the grassland communities present in the two protected areas was carried out by means of 145 phyto-sociological relevés, which were then processed by average linkage cluster analysis (Sokal and Michener, 1958) to identify the main vegetation typologies and their dynamic relationships.

The grazing value of each of the 145 communities was calculated following the method proposed by Delpech (1960) and then adopted by Daget and Poissonet (1969), applying the van der Maarel transformation (1979) to the Braun-Blanquet cover values of the species. The grazing value of the species, used for the calculation of the grazing value index of Daget and Poissonet (1969) comes from the data-base realised by Roggero *et al.* (2002). The grazing value community index ranges from 0 (plant community where all the species have no grazing importance) to 100 (plant community where all the species are excellent forage plants).

Results and discussion

The average linkage cluster analysis procedure allowed us to recognise the following four different typologies of grassland vegetation: 1) very recent forage crops, found in Gessi Bolognesi and Monte Sole; 2) less recent forage crops, also found in Gessi Bolognesi and Monte Sole; 3) semi-natural, semi-mesophilous grasslands of *Salvio-Dactyletum* found only in Monte Sole; 4) semi-natural, meso-xerophilous, grasslands of *Mesobromion erecti* found both in Gessi Bolognesi and Monte Sole. Among the four vegetation typologies, we can delineate the following two dynamic sequences: a) very recent forage crops → less recent forage crops → (periodical mowing) → grasslands of *Salvio-Dactyletum* → (abandonment or grazing) → grasslands of *Mesobromion erecti*; b) very recent forage crops → less recent forage crops → (abandonment or grazing) → grasslands of *Mesobromion erecti*.

Figure 1 shows the mean grazing values (Daget and Poissonet, 1969) of the grassland community typologies. The recent forage crops have similar grazing values in both territories (46 in Gessi Bolognesi Park and 50 in Monte Sole Park; $F = 0.61$, $P = 0.44$). The decrease of the grazing value, following the senescence of the forage crops, is on average less marked in the Monte Sole communities (from 50 to 47, equal to 6 % of the initial value) than in the communities of Gessi Bolognesi (from 46 to 36, equal to 22 % of the initial value). The less recent forage crops of Monte Sole have a grazing value significantly higher ($F = 4.45$, $P = 0.04$) than those of Gessi Bolognesi. The loss of grazing value resulting from abandonment or grazing of less recent forage crops is considerably higher. The communities of *Mesobromion* have, in fact, a grazing value of 18 at Gessi Bolognesi and 29 at Monte Sole, further emphasizing the lower forage value of the grassland communities found in Gessi Bolognesi ($F = 10.3$, $P = 0.003$). Communities of *Salvio-Dactyletum* are present only in Monte Sole; their mean grazing value (35) is not significantly higher ($F = 1.58$, $P = 0.22$) than that of the *Mesobromion* communities in the same area.

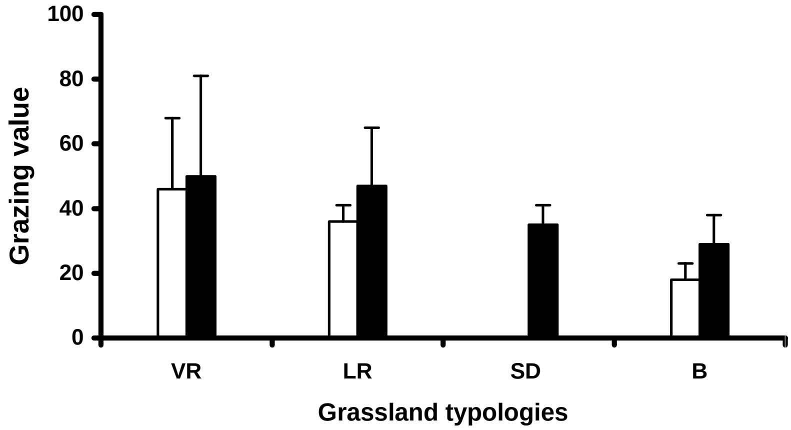

Figure 1. Mean and standard deviation of the grazing values, following Daget and Poissonet (1969), of the four grassland typologies in Gessi Bolognesi (white) and Monte Sole (black). VR = very recent forage crops; LR = less recent forage crops; SD = *Salvio-Dactyletum* communities; B = *Mesobromion erecti* communities.

Overall, throughout the entire dynamic sequence, a loss of 28 units of grazing value was recorded (equal to 61 % of the initial value) for the communities in Gessi Bolognesi and of 21 units (equal to 42 % of the initial value) for the communities in Monte Sole. Furthermore, while the final value of the *Mesobromion* communities at Monte Sole can still be considered moderate, that of the *Mesobromion* communities in Gessi Bolognesi is very poor.

Conclusions

The two protected areas considered here show different grazing vocation. In the lower Apennine hills of Gessi Bolognesi there has been a significant deterioration in the grazing value of the grassland communities, since the stage of less recent forage crops. In the medium hill and submontane belt of Monte Sole Park the grazing value of the forage crops has been better conserved over time. If suitably mowed, the grassland communities could almost completely maintain the grazing value of a less recent forage crop. In the two protected areas (Gessi Bolognesi and Monte Sole) the preservation of grassland is motivated by different reasons, being linked primarily to biodiversity conservation in Gessi Bolognesi, and also to a moderate productivity in Monte Sole.

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Relationships between Floristic Composition, Ellenberg Values and Farmer Utilization of Hay Meadows in the Central Pyrenees

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Abstract

One of the most important factors in determining the floristic composition of Pyrenean hay meadows is *utilis*ation of hay and pasture in relation to seasonal changes; this composition can be described by the ecological indices developed by Ellenberg (Ellenberg, 1994). The purpose of this paper is to establish correlations between the floristic composition, ecological indicator values and different types of management based on fertilisation, irrigation, grazing and cutting. A total of 255 hay meadows in the Broto Valley in Central Pyrenees were sampled during June-July 2001. One hundred and seventy different species belonging to thirty-four families were found. The species abundance data were used to obtain six groups of meadows by TWINSPAN classification. Each group is characterized by one or more indicator species. Production and diversity (number of species and Shannon index) appear as opposite parameters in the DECORANA analysis and are directly and indirectly influenced by the management techniques employed.

Keywords: floristic composition, hay meadows, ecological values, mountain, Pyrenees

Introduction

The Pyrenean semi-extensive meadows of the current study were cereal fields until 1960 and so the botanical composition shows interactions between typical species of open environments and those coming from current neighbouring sites (forest, streams). In order to comply with European Commission recommendations on conservation of biodiversity we wish to promote a balance between production and biodiversity. We therefore carried out a botanical classification of several meadows of the Broto Valley (central Spanish Pyrenees) illustrating their characteristics according to the different management techniques employed, together with Ellenberg Indices used as ecological indicators.

Materials and methods

A total of 255 meadows were sampled during June and July 2001 in the Broto Valley, coinciding with the traditional date of the first cut to make hay. Plots of 0.5×0.5 m were cut in each meadow, separated into species, dried and weighed. Data were used to calculate the number of species / plot, the Shannon index and the percentage of grass, legumes and other forbs. Meadows were classified using TWINSPAN, in which only species with recorded as present more than once were considered, and the ordination was done by Correspondence Analysis (CA), both of them being carried out with the DECORANA program (Hill, 1994). The calculated data and the Ellenberg Indexes (F, R, N, L, S and C) (Ellenberg, 1994) were considered in conjunction with different management techniques (fertilisation, cutting, irrigation and grazing).

Results and discussion

TWINSPAN analysis categorized the 255 meadows into six groups which were characterized by one or more species. Their ordination along the first two axes of Correspondence Analysis is presented in figure 1. Details of botanical composition and CA axes correlationed to different variables measured in the meadows have been described in Santa-Maria *et al.* 2003. Two main groups of meadows were identified: the first of these, in the centre of the CA, is composed of three types of typical hay meadows, namely:

- *Lolium perenne* and *Holcus lanatus* (G2): meadows with a high number of species, not related to high intensification, *L.perenne* presence is related, in these cases, to the normal naturalization of sown meadows;
- *Arrhenatherum elatius* (G3): characteristically semi-natural meadows of that zone. High grass contribution, cool (following the Ellenberg's ecological indices) and the most fertilised meadows;
- *Trifolium repens*, *Dactylis glomerata and Poa trivialis* (G4): Irrigated meadows, rich in organic matter, highly intensification.

The other main group includes three other kinds of meadow, with the following special characteristics:

- *Plantago media*, *Centaurea nigra* and *Daucus carota* (G1): Dry and temperate meadows with the lowest amount of nitrophilic species, not cut and irrigated, with low grass contribution, and a high number of species, because they are only grazed;
- *Centaurea nigra*, *Lotus corniculatus* and *Festuca pratense* (G5): Meadows undergoing an initial abandonment process. High number of species characteristic of forest edges and presence of animals;
- *Lolium multiflorum* (G6) Meadows maintaining original sown characteristics.

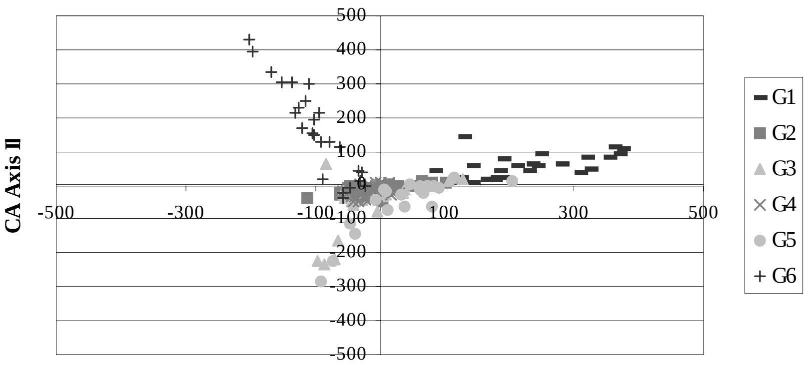

Figure 1. Ordination of meadows on the *I* and *II* axes of CA analysis. The 6 groups correspond to Twinspan classification.

The influence of management on plant species composition (Linusson, 1998) is demonstrated in this study by consideration of the correlation coefficients of management techniques and variables measured on the first two axes of CA (Table 1). Both axes summarize an inverse gradient of meadow intensification, characterized by an increase in production, a higher contribution of species with elevated N and F indexes and grass contribution, and a decrease in the number of species per plot. Cutting is an important management technique in meadows in which nitrophilic species and those adapted to high soil moisture are numerous, creating closed meadows adapted to low temperature. Fertilisation appears to act in the same way, but less so perhaps related to the low levels used in this mountainous area (Schelberg *et al.*, 1999). The effect of fertilisers in reducing the number of plant species was also evident and has been well documented in grassland communities (Smith *et al.*, 2000). Both managements induce soil changes, increasing the contribution of species with high S values. Furthermore, cutting causes a decrease in R values. Irrigation is negatively correlated to axis *II*, producing the same effect as cutting. Its positive correlation to the L index is due to the high legume contribution (with high value) in these meadows. Because grazing is widely practiced in the valley (Aguirre and Fillat, 2003), it is not correlated to diversity index. As might be expected, grazing is negatively correlated to production and positively correlated to T index, producing open meadows adapted to high temperatures.

Table 1. Correlation coefficients of measured variables to CA axes and techniques. Spearman Rho and its signification.

variables	CA *I*		CA *II*		Irrigation		Cutting		Fertilisation		Grazing	
Shannon index	0,342	**	0,219	**	0,082	ns	0,002	ns	0,053	ns	0,099	ns
Nº species/0.25m^2	0,446	**	0,267	**	-0,058	ns	-0,212	**	-0,141	*	0,059	ns
% Grasses	-0,534	**	-0,422	**	0,044	ns	0,384	**	0,220	**	-0,011	ns
% Legumes	0,159	**	0,252	**	0,170	**	-0,069	ns	-0,029	ns	0,021	ns
% Forbs	0,549	**	0,344	**	-0,030	ns	-0,361	**	-0,193	**	0,003	ns
g DM / m^2	-0,427	**	-0,299	**	0,140	**	0,613	**	0,240	**	-0,085	*
L index	0,135	*	0,107	ns	0,297	**	-0,037	ns	0,018	ns	0,029	ns
T index	0,175	**	0,452	**	0,091	ns	-0,305	**	0,000	ns	0,155	*
C index	0,142	*	0,082	ns	0,113	ns	-0,041	ns	0,015	ns	0,069	ns
F index	-0,228	**	-0,183	**	0,232	**	0,357	**	0,117	ns	-0,104	ns
R index	0,120	ns	0,261	**	-0,056	ns	-0,152	*	0,083	ns	0,032	ns
N index	-0,360	**	-0,226	**	0,139	*	0,225	**	0,142	*	-0,040	ns
S index	-0,283	**	0,132	*	0,306	**	0,246	**	0,206	**	-0,027	ns
Irrigation	-0,136	*	-0,016	ns								
Fertilisation	-0,236	**	-0,151	**								
Cutting	-0,490	**	-0,322	**								
Grazing	0,105	ns	0,034	ns								

Conclusions

Mowing is the most influential technique determining the floristic composition of these mountain meadows. Intensification is directly related to an increase in nitrophilic species, humid environments, high saline values and low pH.

Maintaining management at a semi-extensive level would offer a solution by simultaneously allowing intermediate values of diversity and good production.

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Effects of changes in grassland management on biodiversity and landscape in the Sudeten Mountains in Poland

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Abstract

On the basis of a GIS-based study the paper examines recent land use changes and their effects on biodiversity and landscape in two areas in the Polish Sudeten Mts. (ca. 3300 ha). Transformation processes in the agricultural sector in Poland in the late 1980's had a profound negative effect on the viability of mountain farms and profitability of animal production, resulting in cessation of grazing or hay cutting. Land use changes took place in 42 % of grasslands, with a marked increase in the ploughed land, resulting in an irreversible loss of biodiversity rich habitats and increased erosion. Due to massive land abandonment a traditional landscape pattern with a mosaic of land use types and biodiversity-rich semi-natural grasslands is replaced with large areas of *Deschampsia caespitosa* communities, leading, along with shrub and woody species invasion to landscape simplification and closing. A GIS model of land use adequacy valorisation, allowed the creation a detailed proposal of changes for the study area, focusing on ploughed lands not meeting the criteria of arable utilisation. Of these, 93 % were recommended for conversion into grasslands. The proposed changes seek to contribute to sustainable development of the area through protecting natural resources, including biodiversity and enhancement of landscape coherence.

Keywords: land use changes, landscape, biodiversity, Sudeten Mts.

Introduction

In the last few decades mountain regions of Europe have undergone considerable changes in land use. As a result of various socio-economic processes increasingly larger areas are threatened with land abandonment and depopulation. The Sudeten Mts. in south-western Poland, where grasslands constitute 40 % of the area, are also seriously affected by such phenomena. Traditional management techniques in the region had created favourable conditions for the maintenance of biodiversity-rich hay meadows and extensive summer pastures for sheep and cattle. Transformation processes, which took place in the agricultural sector in Poland in the late 1980's, had a profound negative effect on the viability of mountain farms, resulting in the cessation of agricultural practices in large areas of the region. The study aimed to: 1) evaluate recent land use changes in the Sudeten Mts. and their effects on biodiversity and landscape, with special grasslands consideration, and 2) assess adequacy of present land use forms and to suggest their appropriate changes, with the aim of protecting and enhancing natural resources, including biodiversity and landscape.

Materials and methods

The research was conducted in the Polish Middle Sudeten Mts., a region traditionally important for agriculture and tourism, with several 'spa' resorts and various walking, climbing and skiing routes. Two study areas were: the Bystrzyca Dusznicka River valley (ca. 3000 ha; 290-1083 m asl) with a network of 84 research points and the Mostowice village (ca. 290 ha; 700-850 m asl) located in the Bystrzyckie Mts., one the mountain chains surrounding the valley. An experimental grassland site in the village has been used since 1968.

GIS (Geographic Information System – ArcInfo 7.0) was used in IMUZ DOB Wroclaw to create a numerical database of land use and environmental factors for the Sudeten Mts., covering the area of 6000 km^2. The database enabled the comparison of previous (1965-1970) and current (2002-2003) land use patterns. Data on the previous land use were obtained from thematic maps from the above-mentioned period. Surveys on the current land use were conducted in the field and among farmers. Information about environmental factors, comprising of: elevation, slope, slope aspect, insolation as well as soil type and bedrock lithology served as a basis for establishing appropriate forms of land use for a particular area. Botanical data were collected in the network of 84 research points in the Bystrzyca Dusznicka River valley and on 20 sites in Mostowice village, with the minimum relevé area of 25 m^2.

Results and discussion

In the years 1965-1970 in the Bystrzyca Dusznicka valley 50.6 % of its total area was utilised agriculturally. Grasslands constituted 42.5 % of agricultural land, with hay meadows located in the lower part of the valley and pastures located on steeper slopes in its upper part. Surveys in the network of research points in the years 2002-2003 were aimed at assessing the quantity and quality of the changes in land use and revealed that they took place in 42 % of grasslands. They were converted into ploughed land (45.7 %), afforested (28.6 %), built up (22.8 %) or turned into orchards or vegetable gardens (2.9 %). The results indicate a marked increase in the ploughed land at the expense of grasslands.

In the areas where grasslands have been maintained total species richness averaged 18 species per 25 m^2 in 104 research points and ranged from 5 to 42. Herbs represented on average, 64 % of the total number of species. Protected plant species, present in the study sites were *Carlina acaulis*, *Colchicum autumnale* and *Acarum europaeum*. On the abandoned grasslands observed shrub and woody species included (in the order of abundance): *Rubus ssp.*, *Sorbus aucuparia, Populus tremula, Acer platanoides* and *Betula pendula*. In the Mostowice village cessation of grazing or cutting for hay was followed by the complete abandonment of agricultural practices in the majority of the area. This resulted in the expansion of low value grasses, especially *Deschampsia caespitosa* on old summer pastures. Dense swards of this species dominate the landscape and their neglected appearance is further emphasised when they contrast with utilised grasslands on the IMUZ experimental site.

The two study areas can be considered as a model example of the current trends in land use changes in mountain areas. These changes are representative for polarization of farming in mountain regions. Intensification taking place in more favourable locations such as valley bottoms and abandonment under more difficult conditions, such as ex. steep slopes. Similar polarization, reported also for the Alps (Tappeiner *et al.*, 1998) and the Spanish Pyrenees (Garcia-Ruiz *et al.*, 1996), reflects lower competitiveness of mountain farming. Market economy drives farmers to allocating the land they control to the highest valued combination of uses (Montgomery *et al.*, 1999). In the Sudety Mts. very low profitability of cattle and sheep production caused a drastic decrease in the livestock numbers in the early 1990s. This consequently reduced the necessity for maintaining grasslands as a source of animal feed. The considerable increase of ploughed land at the cost of grasslands in the Bystrzyca Dusznicka valley, which is the effect of greater profitability of cereals and winter rape production, impacts negatively on the environment. Conversion of semi-natural grasslands to arable land represents an irreversible loss of plant species and communities. It also reduces the number of valuable habitats for various vertebrates and invertebrates. Moreover, as ploughed lands have started to extend up steeper slopes, risk of erosion increases significantly. Spontaneous afforestation through shrub and woody plants encroachment as well as direct afforestation by National Forestry Services leads to the simplification and closing of landscapes.

Socio-economic drawbacks of farming in mountain regions seriously impact on the demographic structure of the settlements. In the Mostowice village in the late XIX and the first half of XX century there were 60-80 farms and families in the village. Since 1950s there has been a constant decrease in the number of farms, and, consequently, the number of inhabitants. In 2003 there only were 5 families, which rely mainly on sources of income other than agriculture. Massive land abandonment was integrally related to these processes. A traditional characteristic landscape pattern with a mosaic of land use types and biodiversity-rich grasslands (Biala *et al.*, 2002) is replaced with large areas of low value grasslands of *Deschampsia caespitosa* communities resulting in landscape simplification.
According to Wascher *et al.* (2000) 'in order to be sustainable, agricultural land should be adapted to the type of biophysical conditions of a specific region'. Adequacy of land use contributes also positively to landscape aesthetics through increasing the degree of its coherence. A model for adequacy of land use valorisation in the Sudeten Mts. was constructed in GIS from the database of environmental factors (Fatyga *et al.*, 2000) following strict criteria of land appropriateness for various land use types. Maps and data sheets for each administrative unit provided local authorities with the basis for new land development plans. A detailed proposal of changes in land use was made for different parts of the Bystrzyca Dusznicka valley, focusing on ploughed lands not meeting the criteria of arable utilisation. 36.8 % (310.8 ha) of the total area of ploughed lands were qualified for change. Of these, 93 % (288.9 ha) were recommended for conversion into grasslands; the remaining 7 % (21.9 %) were qualified for afforestation. The proposed changes seek to contribute to sustainable development of the area through protecting natural resources, including biodiversity, and enhancing landscape coherence.

Conclusions

Recent land use changes in the Sudeten Mts. have a negative impact on biodiversity, landscape, soil and water protection. There is a strong need for the implementation of agricultural support programmes, which would address the issues of natural resources protection and the viability of farming. Developing rural infrastructure and alternative sources of income, such as agri-tourism may aid the prevention of land abandonment and depopulation and have positive effects on biodiversity and landscape.

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Vegetation structure under unmanaged, grazed and cut grassland in the Giant Mountains, Czech Republic

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Abstract

Continuation of traditional hay making is not possible because of low profitability and a low livestock population. Rotational grazing by cattle and horses, combined with mulching of non-grazed vegetation was studied as an alternative management of species-rich hay meadows in the Giant Mountains. The experiment was established in spring 2000. The treatments investigated were: unmanaged (U), mown once per year (M) and extensively grazed grassland by cattle and horses combined with mulching of non-grazed vegetation (G). In spring 2003 standing biomass was highest under the U treatment. Under the U treatment we observed a decrease in the species diversity and an increase in seedlings of trees and shrubs and in tall dominant herbaceous species. Development of mown and grazed plots was similar except for white clover (*Trifolium repens*) which was more abundant in the G treatment. Low intensity grazing seems to be an acceptable alternative management for mesic and dry grasslands in the Giant Mountains.

Keywords: meadow, vegetation, alternative management, grazing, mowing

Introduction

Prior to World War II the meadows used to be mown once or twice a year and grazed by cattle or goats afterwards (Krahulec *et al*., 2001). A steep decline in the cattle population and a rapid increase in the costs of labour caused the large-scale abandonment of grassland in the Giant Mountains (Krkonoše). The species-rich meadows are endangered due to succession of trees (*Acer pseudoplatanus*, *Picea abies, Salix sp.)* or by invasion of weeds such us *Rumex alpinus* or *R. longifolius*. Continuation or restoration of the traditional management is not possible and the Administration of Krkonoše National Park must look for economical alternatives which will be able to stop degradation of the grasslands. Under the current level of state subsidies, low intensity grazing could be an economically important grassland management. The objective of this study was to evaluate whether low intensity rotational grazing by cattle and horses combined with mulching of ungrazed patches could be used as an alternative way to manage abandoned mountain hay meadows in the Krkonoše National Park.

Materials and methods

The study was carried out in the eastern part of the Giant Mountains (50°42’25” N, 15°51’31” E) at an altitude of 764 m. The experimental meadow was situated on a south-western facing slope. Soil types were cambisols developed on the slope debris from mica schists. The mean annual temperature is 4.8 °C and the mean annual precipitation is 1,101 mm. The vegetation was classified as *Polygono-Trisetion* with some elements of *Arrhenatherion*. Species were named according to Kubat *et al*. (2002). The experiment was established in four randomized blocks in spring 2000. Detail description of the collection of data is in Hejcman *et al*., (2002). The treatments were: unmanaged (U), mown once per year (M) and extensively grazed by cattle and horses combined with mulching of non-grazed patches (G). Grazing was rotational with two grazing cycles and approximately 40 % of total standing biomass was removed by grazers. ANOVA and RDA were used for the data analysis.

Results and discussion

The cover of tall grasses (*Dactylis glomerata, Alopecurus pratensis*) and forbs increased in the U plots. The most obvious was an increase of *Senecio ovatus* which is a characteristic species of clearings in the Giant Mountains. *Geranium sylvaticum* and the toxic *Veratrum album* subsp. *lobelianum* also increased in unmanaged plots and were reduced in grazed and mown treatments. Seedlings of trees and shrubs (*Crataegus sp.*, *Acer pseudoplatanus)* were found in unmanaged plots only. Standing biomass was significantly higher in unmanaged plots after three years of the different managements (Figure 1).

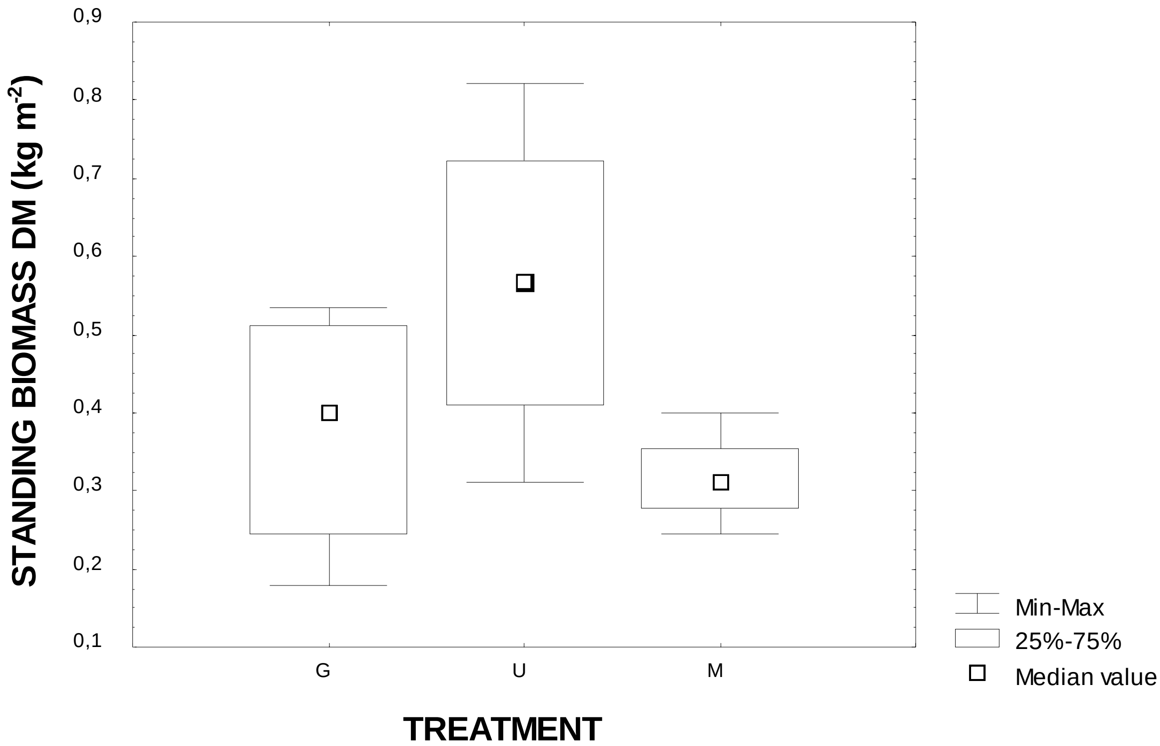

Figure 1. Standing biomass in grazed (G), unmanaged (U) and mown (M) plots after three years of divergent management.

The highest decrease in the number of plant species was under the U treatment (Figure 2). Taller and denser vegetation in unmanaged plots was probably the reason for the elimination of light sensitive species typical of regularly managed plots. There was no noticeable difference in the botanical composition between grazed and mown plots except for white clover (*Trifolium repens*) which was more abundant under the grazing treatment. These results indicate that low intensity grazing similarly and mowing restricts tall species with high biomass production.

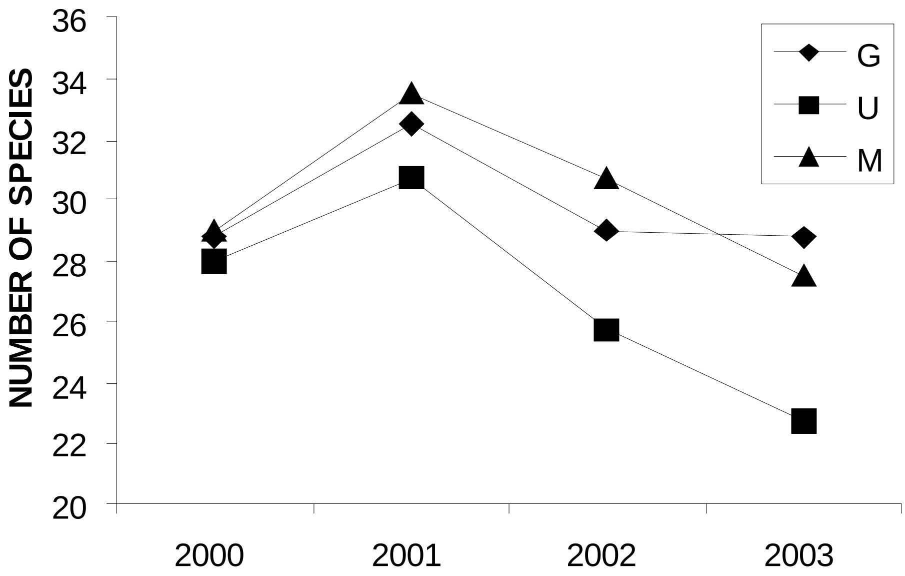

Figure 2. Number of plant species as a function of management (G = grazed, U = unmanaged, M = mown plots).

Conclusions

Although low intensity grazing combined with mulching of non-grazed vegetation does not remove nutrients from the site, this management is able to prevent the degradation of mountain grasslands because of the restriction of tall species. Mowing similarly to grazing is able to stop succession of shrubs and trees. Low intensity grazing is an acceptable management alternative for mesic and dry meadows in the Giant Mountains.

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Maintaining biodiversity and increasing the production of dry matter on mountain meadows

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Abstract

In the Apusieni Mountains, Romania, there is a large area of meadows (360000 ha), on which no mineral fertilisers are used, with *Festuca rubra* meadows being the most prevalent. Both the quality and production of fodder are poor. In this experiment our aim was to improve the fodder production and quality by using mineral fertilisers. We used different rates of fertiliser application and identified the level at which the yield was acceptable from the standpoint of quantity, with a valuable floral composition, without a dramatic reduction in the number of species. A compound fertiliser was used: 20:10:10 in the following quantities (1-4): Control (unfertilised), 50N $25P_2O_5$ $25K_2O$, 100N $50P_2O_5$ $50K_2O$ and 150N $75P_2O_5$ $75K_2O$. The 50N $25P_2O_5$ $25K_2O$ treatment was the most suitable to provide a reasonable increase in dry matter production (from 2.029 up to 2.805 t ha^{-1}) without significantly reducing biodiversity compared with the unfertilised control.

Keywords: natural meadow, biodiversity, mineral fertilisation, dry matter harvest

Introduction

The production of meadow ecosystems of Apuseni Mountains (Romania) is poor but it has a high diversity of species. Our aim is to find a balance between production and biodiversity (Schläpfer and Schmid, 1999) by means of using mineral fertilisers, and finding the application rate of fertiliser which produces acceptable yields but does not trigger a considerable reduction in biodiversity (Briemle, 1997).

Materials and methods

The experiment was set up in 2001, on the Ghetari Calineasa Plateau in the Apuseni Mountains, in Ghețari village, commune of Gârda, district of Alba, at an altitude of 1150 m, on a meadow of *Festuca rubra* (at the boreal level). The annual average temperature is 4 °C, the annual rainfall is 1200 mm, and the soil is Terra rossa. The experiment comprised the following treatments (1-4): Unfertilised control; 50N $25P_2O_5$ $25K_2O$; 100N $50P_2O_5$ $50K_2O$; 150N $75P_2O_5$ $75K_2O$. The experiment was of randomized block design with 4 treatments in 4 replicates. The plots were 10 m^2. Dry matter production and changes in botanical composition of the sward (Braun-Blanquet method) were measured. Fertiliser was applied to the plots in the early spring before the start of the growing season and the plots were harvested by mowing.

Results and discussion

Throughout the three years of study the greatest yield increase compared to the control was recorded in the 150N $75P_2O_5$ $75K_2O$ treatmentwhile the lowest yield increase was obtained from application of 50N $25P_2O_5$ $25K_2O$ (over 200 %) (Table 1). In the 100N $50P_2O_5$ $50K_2O$ treatment, increase in production in the three years of the study varied between 283.5 % and 456.8 %. The increase in dry matter in the first year was greater than in the two following years, due to more rain falling in 2001 than in the other years and so *utilis*ation efficiency of the fertilisers was increased. The use of mineral fertilisers significantly changed the botanical composition of the sward (Table 2).

Table 1. The influence of mineral fertilisation on dry matter production.

year	Treatment	DM t ha^{-1}	%	Difference	Limit difference	
2001	1	0.76	100	0	DL (p 5 %)	0.79
	2	2.13	280.5	1.37	DL (p 1 %)	2.70
	3	3.46	456.8	2.70	DL (p 0.1 %)	3.72
	4	4.47	590.4	3.72		
2002	1	2.58	100	0	DL (p 5 %)	0.93
	2	5.23	202.9	2.65	DL (p 1 %)	1.33
	3	7.31	283.5	4.73	DL (p 0.1 %)	1.96
	4	7.89	306.2	5.31		
2003	1	1.58	100	0	DL (p 5 %)	1.08
	2	3.44	217.7	1.86	DL (p 1 %)	1.56
	3	4.93	311.8	3.35	DL (p 0.1 %)	2.29
	4	5.42	342.5	3.84		

In the case of 150N $75P_2O_5$ $75K_2O$ biodiversity was considerably reduced compared to the control (9 species less), while in the 50N $25P_2O_5$ $25K_2O$ treatment the loss of species was minimal. Applying 100N $50P_2O_5$ $50K_2O$ led to a loss of four species compared to the control whileone species less was lost when 50N $25P_2O_5$ $25K_2O$ was applied. Species which disappeared from 50N $25P_2O_5$ $25K_2O$ included *Carlina acaulis, Potentilla erecta, Thymus dacicus* and *Euphorbia carniolica* disappeared at 100N $50P_2O_5$ $50K_2O$, while the greatest loss occurred from the use of 150N $75P_2O_5$ $75K_2O$ with *Vicia cracca, Arnica montana, Galium verum, Gentiana precox* and *Trollius europaeus* additionally no longer being present.The species present in the sward were, in general, those which arenitrophilic (e.g., *Festuca pratensis, Rumex acetosa*) The percentage of gramineae declined in the 50N $25P_2O_5$ $25K_2O$ treatment butincreased proportionally with the rate of application of fertiliser up to 75.4 %, at the maximum dose. The percentage of *Phabaceae* was greater in the case of 50N $25P_2O_5$ $25K_2O$ (14.9 %) after which it dropped to 3.1 %. The total contribution of plants from other families was similar to that of the *Phabaceae*.

Conclusions

Using 150N $75P_2O_5$ $75K_2O$ resulted in the greatest production increase (from 306.2 % up to 590.4 %) during the three years of the study. The number of species (specific biodiversity) diminished proportionally with the rise in fertiliser application. Using 50N $25P_2O_5$ $25K_2O$ led to an increase in production and an acceptable reduction of the number of species.

Acknowledgements

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Table 2. The influence of mineral fertilisers on floristic composition.

Treatment	1	2	3	4
Covering %	86.5	95.8	97.5	100.0
Total height (cm)	40.0	52.5	62.5	75.0
Species %				
POACEAE	*41.0*	*33.9*	*46.5*	*75.4*
Festuca rubra	8.1	7.4	5.4	0.5
Anthoxanthum odoratum	6.6	4.3	1.6	0.5
Trisetum flavescens	0.5	5.4	15.1	23.3
Cynosurus cristatus	0.5	0.5	0.5	0.5
Festuca pratensis	0.0	0.1 +	0.4 +	0.5 +
Briza media	0.4	0.3	0.0	0.1
Agrostis capilaris	24.9	15.8	23.4	50.0
CYPERACEAE	*0.5*	*0.5*	*0.5*	*0.5*
Luzula campestris	0.5	0.5	0.5	0.5
FABACEAE	*3.8*	*14.9*	*7.1*	*3.1*
Lathyrus pratensis	2.2	11.2	1.6	0.5
Lotus corniculatus	0.5	0.5	0.5	0.5
Trifolium montanum	0.5	2.8	4.3	1.6
Trifolium pratense	0.5	0.5	0.5	0.5
Vicia cracca	0.1	0.5	0.1	0.0 *
OTHER BOTANICAL FAMILIES	*45.1*	*48.0*	*40.4*	*21.1*
Alchemilla vulgaris	25.0	25.9	19.4	2.8
Arnica montana	0.3	0.1	0.4	0.0 *
Campanula patula	0.5	0.5	0.5	0.5
Carlina acaulis	0.4	0.0 *	0.0 *	0.0 *
Carum carvi	0.0	0.1 +	0.4 +	0.0
Centaurea austriaca	1.1	1.6	2.8	1.6
Colchichum autumnale	1.6	2.2	0.5	0.5
Crepis biennis	0.5	0.5	1.6	0.5
Crysanthemum leucantheum	0.5	0.5	0.5	0.5
Euphorbia carniolica	0.1	0.1	0.0 *	0.0 *
Galium verum	0.5	0.5	0.1	0.0 *
Gentiana praecox	0.1	0.0	0.1	0.0 *
Gymnadenia conopsea	0.4	0.3	0.1	0.4
Heracleum sphondylium	1.6	0.5	0.5	0.5
Hieracium aurantiacum	0.0	0.0	0.0	0.0
Pimpinella major	0.5	5.9	1.6	1.6
Plantago lanceolata	0.0	0.0	0.0	0.0
Plantago media	1.1	0.5	0.5	0.5
Polygala vulgaris	0.5	0.5	0.5	0.5
Potentilla erecta	0.3	0.0 *	0.0 *	0.0 *
Prunella vulgaris	5.4	1.6	0.5	0.5
Ranunculus acris	0.5	0.5	0.5	0.5
Ranunculus bulbosus	0.5	0.5	0.5	0.5
Rhinanthus minor	0.3	0.5	0.1	0.3
Rumex acetosa	0.0	0.5 +	0.5 +	0.5 +
Scabiosa columbaria	0.4	0.5	0.4	0.3
Stellaria graminea	0.5	1.6	2.8	1.6
Taraxacum officinale	0.5	0.5	3.9	5.4
Tragopogon orientalis	0.5	0.5	0.5	0.5
Trollius europaeus	0.1	0.1	0.1	0.0 *
Thymus dacicus	0.1	0.0 *	0.0 *	0.0 *
Veronica chamaedrys	0.4	0.5	0.5	0.5
Viola declinata	0.5	0.5	0.5	0.5
Total cover	90.4		97.3	
Species number	42		39	

* Plants that were lost from the sward after fertilisation
+ Plants that apeared in the sward after fertilisation

Conversion into natural grassland of infertile and abandoned agricultural land in Lithuania

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Abstract

Historically Lithuania has been famous for its fertile natural meadows and pastures. An increasingly intensive management results in a decline in the diversity of biotopes suitable for flora and fauna. Furthermore, there are very few natural meadows. Almost 20 % of the plant species and as many as 53 communities of the total 220 plant communities found in Lithuania are in a difficult situation. Some 210 plant species (12 %) have been included in the Lithuanian Red Book. The presently grown cultivated swards usually consist of 3-5 species of grasses. Grasslands degrade not only due to intensive, but also due to over extensive use.

There are approximately 360,000 ha of unfertile soils in Lithuania, which account for nearly 11 % of the total agricultural land. Temporarily not used or abandoned land accounts for nearly the same percentage. The currently applied practice, namely, when the fields are left idle after cereals or row crops, cannot be justified either from social, economic, or environmental points of view. Such lands should be converted into natural grasslands or planted with trees.

Some experimental data suggest that phytocenoses of sown meadows approach phytocenoses of natural meadows after 30-35 years on the basis of the number of vascular plant species. Unfortunately, during the expeditions around the neighbouring Königsberg region we failed to find phytocenoses of natural grasslands or forest even in the fields abandoned 50 years ago. *Agrostis canina* L., *A. capillaris* L., *Solidago canadiensis* L., *Tanacetum vulgare* L., *Calamagrostis canescens* (Weber) Roth., *C. epigeios* (L.) Roth. and other low-value grasses prevailed almost everywhere. Much richer grass phytocenoses were found in Estonian islands, where sown swards were abandoned 12-15 years ago.

Keywords: phytocenoses, grasslands, plant species, unfertile and abandoned land

Introduction

About 1,800 plant species grow in the territory of Lithuania, of which 400 species are cultivated plants. However, only a small part of them are used in practice. With increasing intensity of anthropogenic effects, the diversity of biotypes and biotopes suitable for flora and fauna declines. About 20 % of the country's plant species and as many as 53 plant communities (forest: 4, meadow: 14, swamp: 10, water bodies: 20, sand: 3 and cultivated fields: 2) of the total 220 plant communities are in a difficult state now (Pakalnis, 1997; Balevičienė *et al*., 1998). The number of endangered plant species has increased recently. This can be demonstrated by the fact that the Red Book in 1992 included 210 plant species, while in the year 2000 the list included as many as 357 plant species (Balevičienė *et al*., 2000). Such figures are a great concern to anyone who is concerned with nature, which is our 'home', since each wildlife species has found its niche in the course of evolution and is important for the sustainability of ecosystems. The aim of this article is once more to attract attention of all European society (especially of EU candidates) to the importance of rational use of infertile and abandoned agricultural lands for environment.

Role of grassland in Lithuania

Grasslands and pastures are of special importance for the conservation of species diversity. Some 550 vascular plant species can be found in the grasslands of Lithuania. It was determined that up to 60 plant species, including medicinal plants, can grow per 1 m^2 of a natural pasture. This is very important for various insects and herbivorous animals. Historically grassland swards covering nearly half of the country's territory have been a significant element of Lithuania's landscape, especially in the hilly regions. Of all cultivated plants perennial grasses are best for using solar energy from early spring to late autumn under the climatic conditions of the Baltic countries. They also protect the soils from water and wind erosion and are the basis for the production of valuable, cheap and ecological forage.

Present-day cultivated grasslands in Lithuania and the neighbouring countries consist of only 3-5 grass species. This has a negative effect on milk and meat quality. The grasslands deteriorate if they are underused or overused. The negative effect of intensive grazing is especially obvious after droughty summers when the swards are significantly overgrazed due to the shortage of herbage. After such grazing most of the valuable plant species start wintering unprepared, which has a negative impact on their productivity and even persistence in the following year. Neglected or extensively used grasslands also degrade: their species diversity declines and aggressive low-value species of herbs or even shrubs invade.

In Lithuania the area of unproductive land amounts to about 360,000 ha. This accounts for nearly 11 % of the total agricultural land. There is almost the same area of unused or temporarily (mainly due to long and tightened land reform) abandoned land.

Observations on grassland successions

The current practice in our country, when the fields are left idle after cereals or row crops, cannot be justified either from the economic, social or environmental points of view. The following perennial weeds rapidly spread in such areas: *Elytrigia repens* (L.) Nevski, *Chenopodium album* L., *Cirsium arvense* (L.) Scop., *Artemisia vulgaris* L. etc. They deplete the soil and contaminate the adjacent fields. In West European countries (Germany, Switzerland, Austria and some other countries) it is recommended that unused areas be sown with species mixtures that are most similar to the biocenoses of natural grasslands or pastures. Seed cultivation of meadow flowers and other valuable plant species has become a profitable business in such countries. Imports of such seed mixtures have already been started in Lithuania, however, the price is too high (about 100 USD per kg) and the biotypes are not well-adapted to our agroclimatic conditions. This confirms the general truth that perennial plants, including perennial grasses, have to be bred and multiplied in the agroclimatic conditions in which they will be cultivated.

Application and use of grassland swards have been considerably expanded in recent years. Development of rural tourism creates the need for ornamental and nature conservation swards. Ecological farms with elements of natural grasslands and pastures have become increasingly popular. Integration in the European Union, where payments are given for well-managed natural grasslands and meadows, will promote development of natural grasslands.

Investigation on the structure of perennial grasslands and phytocenoses succession process and on changes in perennial meadows and pastures is relevant not only from the economic but also from the scientific point of view. In Lithuania there is little research concerning the structure of sown grasslands and variations of above-ground phytomass during the naturalisation process. It is known that rationally used sown swards can be productive for many years. Observations of abandoned or temporarily not used areas have been started recently. It was observed that after 10-30 years sown meadows have a similar structure and floristic composition as natural meadows. Therefore it is possible to include them into the hierarchic classification for natural meadows. Long-term succession process (several decades) influences the structure of sown meadow phytocenoses: floristic composition of vascular plants varies, their diversity increases, phytocenotic role changes and phytocenotic diversity manifests itself in mosaics (Sendžikaitė, 2002). However, we had sufficient grounds for doubting this during our expedition in the Königsberg region in 2000 where we did not find any single phytocenose similar to natural grassland or forest in the fields abandoned 10-60 years ago. The following species thrived in almost all areas, especially those not used for a longer time: *Agrostis canina* L. and *Agrostis capillaris* L., *Tanasetum vulgare* L., *Solidago canadiensis* L. *Calamagrostis canescens* (Weber) Roth. and *C. epigeios* (L.) Roth. We observed also other low-value grasses and small bushes, but we hardly found any legumes. This could be the reason why we did not see any bumble-bees there. The members of the expedition were of the opinion that the abandoned fields of the neighbouring country could serve as a basis for the monitoring of abandoned and unused fields phytocenoses.

The expeditions carried out in 2002 and 2003 to 10 Estonian islands gave much more optimistic results. Some 12-15 years ago animal production was developed on these islands, partial land reclamation was done (stones were collected, bushes removed and the surface was levelled) and the fields were sown with various mixtures of perennial grasses. After the collapse of collective farms there were no longer sheep and cows and the unused areas have persisted well up to now. The grasslands are full of lucerne, clover, forbs and even thyme. We were impressed by the 20 ha field in Vormsi island sown with lucerne cv 'Jegeva 118' 13 years ago. This area was intended for sheep pasture. The lucerne has perfectly persisted till now and produces quite a good yield annually. Since there is no need and possibilities to use those lands for fodder and seeds, the majority of lucerne and other plant species plants are maturing and shattering seeds and in this way are resowing and remains a good pasture for wild herbivorous animals and for local and migrating birds. Thus Estonian experience shows that when meadows and pastures are left idle, they renaturalise much better than after cereals or row crops. Natural grasslands are a very important part of the ecosystem. Therefore it is indispensable to use the data of scientific research and foreign experience to find how to conserve or to use rationally unproductive and abandoned areas not only in Lithuania, but also in the neighbouring countries.

Conclusions

- It is necessary to make an inventory of unproductive or temporarily abandoned areas and to foresee their further development.
- Temporarily abandoned land should be sown with simple and cheap grass mixtures and cut 1-2 times annually or mulched. Complex mixtures, similar to those growing on natural grasslands, should be used for long-term land conservation.
- The state should encourage the owners to renaturalise land areas by covering the costs of sowing and management.
- Seed production of the plants of natural grasslands, flowers or other herbaceous plants should be organised and well-adapted local biotypes should be used.

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Influence of cutting and fertilising management on the botanical composition of Ljubljana marsh grasslands

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Abstract

The effects of grassland management on herbage botanical characteristics were investigated in two 5-year field trials, in split-plot design with 4 replications. The trials were established in the *Arrhenatherion* (T1) and *Molinion* (T2) alliances in the Ljubljana marsh in 1999. Treatment factors were cutting regime, i) 2 cuts - with standard and delayed first cut; ii) 3 cuts and iii) 4 cuts per year as the main plots, and fertiliser regime, i) zero fertiliser - control, ii) PK and iii) NPK with 2 N rates as sub-plots. After five years, the appearance of both swards was significantly altered, by the application of fertiliser and to a lesser extent, by the cutting regime. Compared to the control, applying fertiliser positively increased the proportion of grasses to the detriment of herbs in T1 and *vice versa* in T2. Cutting positively affected the proportion of grasses within the unfertilised and PK + high N plots in T1. Applying PK increased the legume content within the 2-cut systems in T2 only. Applying fertiliser considerably reduced the proportion of *Equisetum palustre* in T1 (max. 25 %, min. 1 %). This effect was most pronounced within 3 and 4 cut regimes. The Shannon diversity index measured in T1 was positively affected by cutting (with moderate fertiliser) and negatively affected by fertiliser and 2 cuts with the first cut delayed. The index ranged from 1.42 to 2.35.

Keywords: cutting, fertilising, botanical composition, diversity index, marsh grasslands

Introduction

The Slovene grasslands, which predominantly consist of semi-natural vegetation, cover 60 % of agricultural land (5000 km^2). In addition, over the last fifty years, approximately 2700 km^2 of abandoned grasslands have been subject to uninterrupted plant succession, culminating in forest vegetation. On the managed grasslands, the management system that prevails consists of two to three cuts on *mesotrophic*, and one cut on *oligotrophic karst* and wet grasslands. In recent decades, intensive cutting and grazing systems have also been introduced on many farms. As a result of this development and the abandonment of herbage production in marginal grassland areas, many species-rich meadows and mountain pastures are endangered. Undesired plant succession is occurring in many parts of the Ljubljana marsh, an area that can be described as an environmentally sensitive one. Approximately 75 % of the surface area (160 km^2) is covered by semi-natural grasslands where an *Arrhenatherion* type of vegetation prevails. There is little grassland with *Molinion*, *Filipendulion*, *Magnocaricion*, *Caricion davallianae* and *Fragmition comunis* types of vegetation. The objective of this work was to develop management strategies for ecologically sustainable grassland production in the Ljubljana marsh area. Research was conducted to investigate the effects of cutting and fertiliser treatments on herbage production and the botanical composition of *Arrhenatherum elatius* and *Molinia caerulea* grasslands.

Materials and methods

In March 1999, two field trials were established on the semi-natural grassland of the Ljubljana marsh (lat. 45°58’ N, long. 14°28’ E, alt. 295 m). T1 comprised an

Arrenatherum elatius grassland, and T2 a *Molinia caerulea* dominated fen meadow. Both trials were arranged in split-plot design with four replications. Three cutting regimes were allocated as the main plots and four fertiliser treatments as sub-plots. The cutting regimes for T1 were: 2 cuts with a delayed first cut, 3 cuts, and 4 cuts per year. For T2 the cutting regimes were: 2 cuts with a 'normal' and delayed first cut and 3 cuts per year. Fertiliser treatments comprised: 0 NPK (= zero); PK (= 35 kg P + 133 kg K $ha^{-1}y^{-1}$); $N_{(1)}$PK (= 50 kg N $ha^{-1}cut^{-1}$ applied to cut one only, + 35 kg P and 133 kg K ha^{-1} y^{-1}); $N_{(c)}$PK (= 50 kg N ha^{-1} cut^{-1} applied to each of 2, 3 or 4 cuts, + 35 kg P and 133 kg K ha^{-1} y^{-1}). Sub-plots comprised 2.5 × 4 m (T1), and 2 × 4 m (T2). In year four, the soil in T1 was pH neutral (7.2), with a low P and K content (ammonium lactate extraction; P = 0.9–2.2 mg, K = 7.7–9.0 mg per 100 g of dry soil). In T2 the soil was moderately acidic (pH = 4.9–5.2) with low to moderate P and moderate to high K content (P = 1.9–5.5 mg, K = 10.6–29.5 mg per 100 g of dry soil). Applying PK fertiliser in previous years only had a positive effect on soil nutrient content in T2. The results presented are from cut one, year five (May 11 to June 25, 2003) and comprise the proportion of the botanical groups (and *Equisetum palustre*) found in the herbage (Table 1), and the Shannon index of floristic diversity (Table 2), (Magurran, 1988). The analyses were performed by hand separation of the fresh herbage samples into plant botanical groups or species fractions, which were then weighted. The size of the sample area was 0.5 × 0.8 m. Statistical analyses of the data were done by ANOVA and Duncan's test. Data in proportions were transformed using the equation $Y = 2*\text{arcsine}\sqrt{x}$.

Results and discussion

The grassland community at each trial site consisted of more than 30 plant species with *Equisetum palustre* and *Arrhenatherum elatius* prevailing at T1 and *Molinia caerulea* and *Filipendula ulmaria* prevailing at T2. Due to appearance and the presence of rare species, both communities are the subject of considerable conservation interest. After fertiliser use in year one, both trials exhibited a change in sward stratification to taller and more even vegetation. The ratio of botanical groups, measured in year five, cut one, was affected less by cutting (three $P < 0.003$) than fertiliser application (five $P < 0.001$). In T1, compared to control plots, the proportion of grasses in all fertilised swards increased. This was most pronounced under the four cut regime (Table 1).

Table 1. The proportion of botanical groups and *Equisetum palustre* (% of fresh matter herbage) in the *Arrhenatherum elatius* grassland (T1) and in the *Molinia caerulea* fen meadow (T2) in year five, cut 1, with respect to cutting regime and fertiliser application.

		T1				T2		
Fertiliser	Cutting regime	grasses	legumes	herbs†	*E. pal.*	grasses	legumes	herbs
Zero	2 cuts (delayed)	55.8	0.5	43.7	26.4	82.1	0.0	17.9
Zero	3/2 cuts‡	75.7	0.6	23.7	14.8	78.2	0.1	21.7
Zero	4/3 cuts‡	73.0	0.3	26.7	10.3	88.2	0.2	11.6
PK	2 cuts (delayed)	75.5	1.9	22.6	7.6	46.7	4.0	49.3
PK	3/2 cuts	83.3	3.3	13.4	4.0	59.0	13.6	27.4
PK	4/3 cuts	82.3	0.5	17.2	2.5	62.7	1.2	36.1
$N_{(1)}$PK§	2 cuts (delayed)	85.2	1.9	12.9	6.6	58.0	1.6	40.4
$N_{(1)}$PK	3/2 cuts	86.9	0.4	12.7	3.8	61.3	0.8	37.9
$N_{(1)}$PK	4/3 cuts	87.5	0.6	11.9	1.4	82.8	0.4	16.8
$N_{(c)}$PK#	2 cuts (delayed)	82.3	0.7	17.0	7.5	49.5	0.7	49.8
$N_{(c)}$PK	3/2 cuts	86.3	0.7	13.0	3.1	53.8	0.3	45.9
$N_{(c)}$PK	4/3 cuts	92.9	0.0	7.1	1.6	63.4	0.4	36.2

†Herbs include *Equisetum palustre* (= *E. pal.*). ‡3/2 cuts = 3 cuts in T1 and 2 cuts in T2; 4/3 cuts = 4 cuts in T1 and 3 cuts in T2, §$N_{(1)}$PK = 50 kg N (only to the first cut) + 35 kg P + 133 kg K ha^{-1} y^{-1}, #$N_{(c)}$PK = 50 kg N (applied to each cut) + 35 kg P + 133 kg K ha^{-1} y^{-1}

Such responses in grasslands are well recognised (Tallowin *et al*., 1994). The opposite effects were noticed in herbs, with the proportion of legumes being negligible in all treatments. In T2 the initially grassy sward responded to fertiliser, by increasing the proportion of herbs to the detriment of grasses, when compared with the unfertilised control. There was no consistency in comparisons between different fertiliser treatments. In the extensive *Arrhenatherum* grassland in the Ljubljana marsh, *Equisetum palustre* can dominate in herbage, and in the simulated conditions imposed in T1, reached 25 % of the herbage mass. However, this was successfully reduced by the combination of cutting and fertilising to 1.5 % - the minimum realised level (P = 0.005 for cutting and P < 0.001 for fertilising).

Against expectations, the intensification adopted in the trial did not negatively affect sward plant diversity in T1 (Table 2), which was relatively high and stable within 3 cuts, and highest within 4 cuts (except at 200 kg annual N rate). Compared to the control, applying fertiliser decreased diversity in all treatments within 2 cuts (cut one delayed), and in 200 kg annual rate within 4 cuts. These findings are partially in contrast to those in the literature where negative relationships between fertiliser treatments and plant diversity are reported (Zechmeister *et al*., 2003).

Table 2. The Shannon diversity index and species number in the *Arrhenatherum elatius* grassland (T1) in year five, cut 1, with respect to cutting regime and fertiliser.

	Shannon diversity index†					Species richness‡				
	zero	PK	$N_{(1)}$PK	$N_{(c)}$PK	average	zero	PK	$N_{(1)}$PK	$N_{(c)}$PK	average
2 cuts (delayed)	1.92	1.42	1.43	1.52	1.57a§	19	15	14	15	16a
3 cuts	2.11	2.06	1.94	1.80	1.98b	22	26	21	20	22b
4 cuts	2.35	2.16	2.18	1.70	2.10b	23	21	23	20	22b
Average	2.13b§	1.88a	1.85a	1.67a	1.88	21a	21a	19a	18a	20

† P= 0.006 for cutting; P = 0.003 for fertilising; no cutting × fertilising interaction

‡ P = 0.001 for cutting; P = 0.138 for fertilising; no cutting × fertilising interaction

§ Means within a column or row followed by the same letter are not significantly different at P = 0.05 according to Duncan's multiple range test.

Conclusions

With respect to botanical composition, increasing the frequency of cutting, and the use of inorganic fertiliser (within the range of the study) improved the agronomic value of both plant communities. It also maintained plant diversity in the *Arrhenatherum* grassland on the level of the extensively used sward, but acted as a strong modifying factor in the plant succession of the *Molinion* fen meadow to a more productive grassland community.

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Water buffalo (*Bubalus bubalis)* grazing and summer cutting as methods of restoring wet meadows at Lake Mikri Prespa, Greece

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Abstract

The effects of water buffalo grazing and summer cutting on the vegetation of the littoral zone of Lake Mikri Prespa were examined. Four vegetation zones were identified along an elevation gradient and paired plots (control and grazing) were located in each one of them. Additional plots in which summer cutting was applied once every summer were located in the two lower zones, where helophytes, mainly reeds (*Phragmites australis*), were dominant. Grazing was effective in controlling high emergent helophytes and increased the proportion of bare soil, though cutting once in the summer did not reduce reed cover. These results are very important for the implementation of management regimes to restore wet meadows in the littoral zone, a habitat of great value for aquatic wildlife, including spawning carp (*Cyprinus carpio*) and rare bird species.

Keywords: grazing, cutting, wet meadows, *Phragmites australis*, conservation

Introduction

Lake Mikri Prespa is a Wetland of International Importance located on the frontiers of Greece and Albania. Its surface area in Greece is 43.5 km^2 (47.4 km^2 in total), of which 6 km^2 are covered by reedbeds dominated by reeds (*Phragmites australis*) with *Typha angustifolia* (Kazoglou *et al*., 2001). During recent decades, lack of traditional management, such as grazing, cutting and burning in the littoral zone, has led to the expansion of the reedbeds towards the wet meadow areas of the lakeshore. These are meadows covered by low-growing herbaceous plant species on soils which are periodically flooded or saturated with water for part of the year. Wet meadows play an important role in the lake ecosystem because they are used as spawning grounds for phytophilous and litho-phytophilous fish species (Crivelli *et al*., 1997), as feeding grounds by water birds, support large numbers of invertebrate organisms and are utilised by amphibians, reptiles and mammals (Benstead *et al*., 1997). Their existence depends on the frequency, timing and type of management of the littoral vegetation and on the management of water levels. The total wet meadow area at Lake Mikri Prespa radically decreased from 129 ha in 1945 to 89 ha in 1989 (Pyrovetsi and Karteris, 1986) and was down to only 33 ha in 2000 (Kazoglou *et al*., 2001). The aim of the present work is to examine if water buffalo grazing and summer reed cutting can be used as management techniques to restore wet meadows on presently reed-dominated sites.

Materials and methods

The experiment was located on 6 ha which were available for grazing on a communal littoral site, totalling 18 ha and largely covered by reeds. The site was fenced and five adult water buffaloes were introduced in late May 1997. Four plant communities were identified in the study area representative of the zonation pattern observed on the shores of Lake Mikri Prespa with a low elevation gradient. From the topographically higher parts of the area to the lower ones, the following vegetation zones were distinguished: 1) a dry meadow, 2) a narrow temporarily flooded zone, 3) the fringe of the reedbed, dominated by *Phragmites australis*, and other shorter helophytes such as *Carex pseudocyperus*, *Mentha aquatica* and *Iris pseudacorus*, 4) the reedbed proper, dominated by *Phragmites australis*. In the present paper, treatment effects on the vegetation are presented only for zones 3 and 4, which are of greatest importance in the restoration of wet meadows at Lake Mikri Prespa because of their large total area and favourable water level regime. Three permanent 5 m × 4 m plots were established in each of these two zones, of which two were fenced: 'ungrazed and uncut (control)' and 'ungrazed and cut (cut)'. The other plot was uncut and freely grazed the whole year round with a mean stocking rate of 0.83 buffalo ha^{-1}. The vegetation inside the 'cut' plots was cut once each summer in July or August (1997, 1998 and 1999) using a portable brush-cutter and the mown biomass removed. In each plot, three transects of 4 m were laid down to measure cover and species composition. 50 recordings (first plant touching the needle) were taken at intervals of 8 cm along each transect in mid-June 1997 and 2000 (Cook and Stubbendieck, 1986). Plant species were separated into three groups: perennial grasses, perennial forbs and helophytes (including reeds). The effects of water buffalo grazing and of cutting are presented by comparison of the vegetation cover (%) between 'control' and 'grazed' or 'cut' plots in year 1 (1997) and in year 4 (2000) of the experiment. Statistical comparison of the two treatments was carried out using the t-test with the 3 transects as replicates.

Results and discussion

Comparison between the plots in 1997 showed no significant differences between treatments, a result that was expected since vegetation measurements took place only two weeks after the introduction of grazers to the experimental area. Only plant litter was significantly higher in the grazed plot of the reedbed fringe (Table 1), a fact which is attributed to trampling. On the other hand, a significant accumulation of litter was found in the control plots in 2000. This thick litter layer prevented the growth of dominant helophytes in the reedbed proper. Grazing caused a significant increase of bare soil in both zones and an apparent reduction of helophytes (mainly reeds). Reeds are very palatable to livestock and sensitive to trampling, particularly in sites which are flooded almost continuously (Mesléard and Perennou, 1996).

Table 1. Cover scores (%) of various plant groups in the grazed and control treatments of the two littoral zones in 1997 and 2000.

Plant groups	Reedbed fringe				Reedbed proper			
	1997		2000		1997		2000	
	grazed	control	grazed	control	grazed	control	grazed	control
Perennial grasses	10.1	11.3	9.3	0.0	0.0	0.0	0.0	0.0
Perennial forbs	17.3	11.3	0.0	0.0	0.0	0.0	0.0	0.0
Helophytes	55.3	76.7	50.7	62.0	64.0	65.3	28.0	40.0
Litter	15.3*	0.7	18.7	38.0*	28.7	26.7	40.0	60.0*
Bare soil	2.0	0.0	21.3*	0.0	7.3	8.0	32.0*	0.0

* Significantly higher than the paired value at the 0.05 level

Cutting once every summer favoured helophyte cover in the reedbed fringe, reduced litter in both zones, and increased bare soil in the reedbed proper, a fact which is attributed to trampling by the operator of the cutting machine (Table 2). It did not reduce reed cover in the reedbed proper, but we have evidence (not reported here) that annual cutting twice every summer could significantly reduce reed cover. This result has also been obtained in similar experiments in European wetlands (Hawke and José, 1996).

Table 2. Cover scores (%) of various plant groups in the cut and control treatments of the two littoral zones in 1997 and 2000.

Plant groups	Reedbed fringe				Reedbed proper			
	1997		2000		1997		2000	
	cut	control	cut	control	cut	control	cut	control
Perennial grasses	9.3	11.3	5.3	0.0	0.0	0.0	0.0	0.0
Perennial forbs	12.7	11.3	2.0	0.0	0.0	0.0	0.0	0.0
Helophytes	75.3	76.7	80.0*	62.0	62.0	65.3	51.3	40.0
Litter	2.7	0.7	12.7	38.0*	31.3	26.7	35.3	60.0*
Bare soil	0.0	0.0	0.0	0.0	6.7	8.0	13.4*	0.0

* Significantly higher than the paired value at the 0.05 level

The opening of the dense reedbed vegetation by the grazers and the existence of patches with bare soil or mud in the reedbed created a mosaic of habitats which is very important for a range of wildlife (Hawke and José, 1996). Throughout the course of the present experiment, the grazed parts of the experimental site were regularly used as feeding grounds by many bird species including *Pelecanus crispus*, *Phalacrocorax pygmeus*, *Ardeola ralloides*, *Egretta alba*, *Egretta garzetta*, *Ardea cinerea*, *Ardea purpurea*, *Ciconia ciconia*, *Anas platyrhynchos*, *Anas strepera* and *Fulica atra*, while carp spawning was observed in April 1999 and 2000 (Society for the Protection of Prespa, 1999).

Conclusions

Water buffalo grazing and annual summer cutting can both be used as methods of restoration of wet meadows and for their long-term management.

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Advantages and Risks of Grassland Stands from the Viewpoint of Flood Occurrence

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Abstract

The occurrence and course of runoff from grassland stands and other types of agricultural crops were followed within the period of years 1965-2003. It was found that within the growing season grassland stands could effectively reduce runoff. On the other side, in early spring, the runoff from grassland stands is usually higher than from arable land. This is the result of quicker thawing of snow on grassland stand and a slower disappearance of pedoglacial horizon. As far as the retardation of the runoff was concerned, the best results were recorded on extensively used grassland (cut only once per year in July).
In years 1978-2003, the average winter runoff coefficient φ on grassland stands, cut three times per year, was 0.359 mm mm^{-1} while on a field with winter wheat it was only 0.230 mm mm^{-1} (64.1 %). Within the growing season, the runoff capacity of a rainfall is measured as the so-called rain forcibility F_R, which is expressed as a product of rainfall intensity (in millimetres per minute) and the radix of rainfall duration (min). At F_R values ranging from 1.0 to 4.4, the percentages of runoff from grassland and bare soil (maize stand without canopy) were 0-2.0 % and 8.0-67.5 %, respectively.

Keywords: runoff, grassland, floods

Introduction

Grasslands do not fulfil only productional functions, but also very important non-productional functions. One of them is their capacity to prevent and/or reduce surface runoff, which is an undesirable phenomenon in practically all territories. Surface runoff is the main cause of local floods and of water erosion. Results presented in this paper document an extraordinary capacity of grassland to eliminate the occurrence of surface runoff after downpour rainfalls in the summer season. Unfortunately, this capacity can be significantly reduced and/or even lost in cold periods with negative temperatures, especially during the snow thawing in the spring.
The objective of this study is to demonstrate that the grass stands can eliminate surface runoffs (i.e., local floods) in the course of the growing season. In winter, however, they can increase the risk of as well as the intensity of flooding.

Materials and methods

Presented results were obtained on the basis and analysis of data about precipitation recorded within the period of 1966-2003 on six experimental plots (20 m^2, with loamy soil, altitude 215 m) exposed southward in the locality Brno–Kníničky, Czech Republic. Plots were adapted to measure the extent and course of surface runoff. Experimental plots were covered with several agricultural crops including grassland stands. In this paper, altogether nineteen cases are analysed (vegetation period), which meet the following requirements: (1) the downpour rain had to cause runoff on bare soil; (2) prior to the downpour rain the soil surface had to be very wet; (3) bare (by vegetation non-protected) soil had to have a crust on the surface; (4) the grassland stand was 2-4 years old and (5) the height of the sward had to be above 10 cm at the moment of measuring. The magnitude of downpour rain was expressed as $F_{R;}$ this value was derived from ombrograms. It was named 'rainfall forcibility' and expressed as the equation

$F_R = i_s.t_D^{0.5}$, where i_s = rainfall intensity (in mm min^{-1}) and t_D = rain duration (in minutes). As far as the occurrence of surface runoff and water erosion were concerned, rainfalls with intensity higher than 0.05 mm min^{-1} were taken into account as the so-called effective rain. The coefficient φ was used as the indicator of the forcibility of surface runoff. This parameter is defined as the equation: $\varphi = H_o/H_s$, where H_o = height (sum) of runoff (in mm) and H_s = height (sum) of rainfall (also in mm). In winter, the following parameters were continuously recorded: air and soil profile temperatures, type and sum of precipitation, height and water equivalents of snow cover (Kasprzak *et al.*, 1999). Evaporation of the snow surface was measured seasonally. During periods of snow thawing and/or rainfalls the volume and the time course of surface runoff was measured. The coefficient of surface runoff φ (mm mm^{-1}) was defined by the equation $\varphi = H_o/H_s$, similarly as in case of downpour rains.

Results and discussion

As shown in figure 1, during the growing season, surface runoffs caused by downpour rains occurred with F_R above 0.66 on wet plots with bare soil (maize) saturated with water from preceding rainfalls. On the other hand, on the grassland plots such a runoff occurred on days with F_R values above 1.2. On the bare plots, the average value of surface runoff coefficient φ was 0.417 while on plots with grassland stand it was only 0.011, i.e., 37.9 times lower.

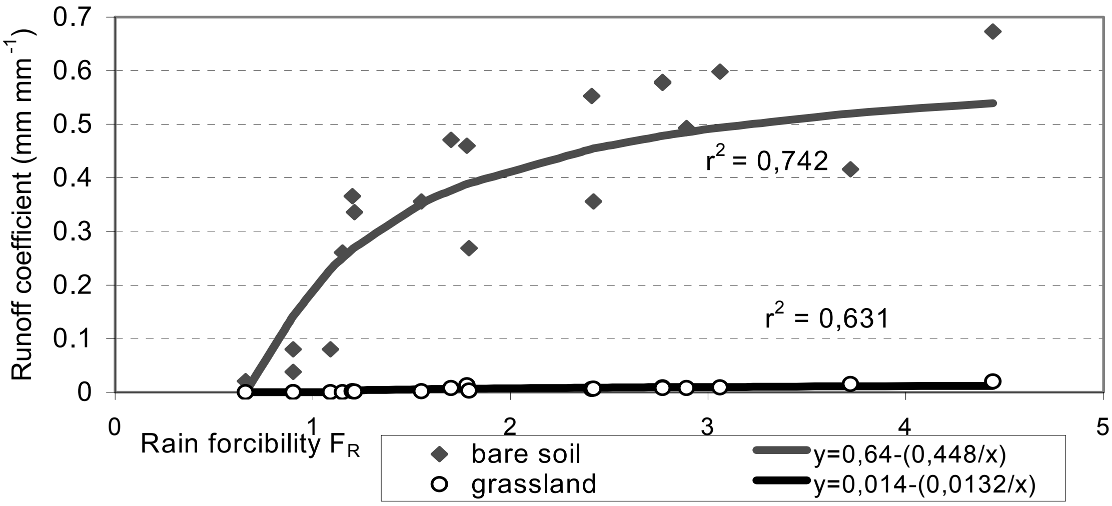

Figure 1. Runoff coefficient as a function of rain forcibility and type of stand.

Table 1. Source data for figure 1.

Rain forcibility F_R	*0.66*	*0.9*	*0.9*	*1.09*	*1.15*	*1.2*	*1.21*	*1.55*	*1.7*	*1.78*
	Runoff coefficient (mm mm^{-1})									
Grassland	0.000	0.000	0.000	0.000	0.000	0.002	0.001	0.002	0.008	0.013
Bare soil	0.021	0.038	0.080	0.080	0.261	0.366	0.336	0.356	0.471	0.460

Rain forcibility F_R	*1.79*	*2.41*	*2.42*	*2.77*	*2.77*	*2.89*	*3.06*	*3.72*	*4.44*
	Runoff coefficient (mm mm^{-1})								
Grassland	0.003	0.006	0.007	0.009	0.008	0.008	0.009	0.015	0.020
Bare soil	0.269	0.553	0.356	0.577	0.579	0.493	0.598	0.416	0.673

Tables 2 and 3 indicate that, within the winter season, a regularly cut grassland stand showed mostly a higher susceptibility to formation of surface runoff than winter wheat after ploughing. In grassland stands, a higher surface runoff was caused by quicker thawing of snow cover 'hanging' of the grass stubble and slower melting of soil (i.e., of pedoglacial horizon). On winter wheat plots, the runoff occurs usually in the period when the runoff from grassland stand had already culminated or was finished. However, if the winter was hard, long and rich in precipitation and/or frequent snow melting, the runoff from stands of winter wheat may be the same or even higher than that from grassland stands. The randomness and a considerable variability of the character of winter weather considerably complicate the research of these phenomena. Although there were no statistically significant differences between φ coefficients of grass and winter stands (significance level 0.248), the maximum parameters of runoff in grassland stands were always higher (Table 3).

Table 2. Winter period runoff coefficient φ of grassland stands and winter wheat after tillage.

Soil cover	Winter period										
	1978-9	1982-3	1983-4	1984-5	1985-6	1997-8	1998-9	1999-0	2000-1	2001-2	2002-03
	Winter period runoff coefficient φ (m^3 m^{-3})										
Grassland	0.538	0.000	0.525	0.767	0.771	0.027	0.400	0.553	0.010	0.002	0.355
Wheat	0.480	0.000	0.196	0.421	0.321	0.045	0.159	0.414	0.050	0.000	0.446

Table 3. Characteristics of surface runoff in the winter period (1978-2003).

Soil cover	Average φ	$φ_{max}$	Max. global volume of winter runoff (m^3 ha^{-1})	Max. daily runoff (m^3 ha^{-1})	Max. runoff intensity (dm^3 s^{-1} ha^{-1})
Grassland	0.359	0.771	648.8	273.9	13.70
Wheat	0.230	0.480	579.5	114.6	9.62

Conclusions

When comparing average coefficients of the surface runoff from grassland in the course of the year, it is possible to see that in winter this coefficient is 32.6 times higher than in the growing period. In extreme cases these differences are even higher: the maximum value of φ in the growing period was only 0.020 while in winter it reached 0.771 (i.e., 38.6 times more). The presented results corroborate a high protective function of grassland stand against floods caused by downpour rains. This capacity results from dissipation of kinetic energy of rain drops and also from a higher infiltration capacity of soil covered with grassland.

On the other hand, a high percentage of intensively managed grassland stands in a landscape may increase the risk of winter floods. These intensive and dangerous runoffs may occur in late winter and/or early spring when snow melting is combined with rainfalls. In general, it can be said that the longer the period of negative temperatures, the higher the surface runoff coefficient. A lower risk of winter and spring floods exists in a landscape, which is partly covered with forests, grassland stands and arable land because the culmination of runoffs is separated in time in these cultures. An extensive meadow stand (cut once a year in July) proved to be the most efficient in the prevention of surface runoff, because the reduced movement of agricultural machinery and a favourable microclimate promote an intensive proliferation of edaphon (loosening of soil).

Acknowledgement

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Role of domestic grazing in the preservation of forage resources for wild ungulates

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Abstract

To understand the role of range management in preserving environments favourable to wild ungulates, the interactions between grazing animals (cattle and sheep) and chamois (*Rupricapra rupricapra*) were studied in an area of Gran Paradiso National Park (NW Italy), during 1999-2001. The grazing land composition and changes of available forage quality were determined. Foraging areas of domestic animals and wild ungulates were obtained by direct observations. Wild ungulates seemed to prefer areas where vegetation was improved by cattle, but avoided those where cattle presence was intrusive. A mosaic of improved areas, interspersed with less exploited areas could improve the faunal value of a territory, by increasing the supply of good quality forage to chamois, especially in spring and autumn when domestic animals were away from the pasture.

Keywords: interactions, grazing management, pastures, ungulates, wildlife

Introduction

In recent years Alpine rangelands have been progressively abandoned in NW Italy, with a decreasing number of herds being led to summer pastures. Despite a reduction of their productive role, the importance of summer pastures as habitats suitable for wild animals has increased. In fact, an effect of the reduction of the presence of humans and herds has been the expansion of the habitat of wild herbivores that, more and more frequently, interact with the domestic ones.

Overlapping, in space and in time, of trophic niches between wild and domestic ungulates is of great importance especially in protected areas where excursionists are willing to meet wildlife (Lapeyronie *et al.*, 2002). The effects of the interactions in the exploitation of the grazing land and the consequences for the diversity of alpine rangelands have seldom been studied in Italy (Bassano *et al.*, 1998; Aceto *et al.*, 2002; Mattiello *et al.*, 2002). The results of a study on the role of domestic grazing to preserve foraging resources for wild ungulates in protected areas are presented in this paper.

Materials and methods

The study was carried out in a sub-alpine summer pasture located in Gran Paradiso National Park (Piemonte, NW Italy). The area (215 ha) was exploited by both domestic (sheep and cattle) and wild ungulates (chamois - *Rupicapra rupicapra*), during 1999-2001.

The vegetation composition was surveyed with Daget-Poissonet's method (1971). Vegetation types were recognized by cluster analysis and, for every type, the pastoral value (VP) based on vegetation composition was calculated. Cattle and sheep grazing efficiency was determined by difference between the herbage mass cut inside and outside exclosure cages (31 samples, surface of single try: 1 m^2). Stocking rate was determined by splitting the grazing land into sectors and recording the presence of domestic animals in each sector. Cattle exploited the pasture by rotational grazing, while sheep were driven along a grazing circuit by a shepherd. The use of space by chamois was monitored twice a week, during the vegetative season, locating the position of animals on a 125 × 125 m grid. Chamois were observed in the

morning (from 0600 h to 0900 h) and in the evening (from 1800 h to 2100 h), when they generally graze. The use of space was obtained by overlapping the seasonal distribution of chamois and vegetation maps.
To determine the digestibility of organic matter (DOM), forage samples for the different vegetation types were collected at the main phenological stages of dominant species until the beginning of the exploitation by domestic animals, then at an interval of 15 days until the end of the growing season.

Results and discussion

Four vegetation types were identified (Table 1), with VP gradually decreasing from areas intensively exploited by domestic herbivores to areas more extensively or not exploited. The percentage of herbage removed by domestic animals reached 50-60 % in the types more intensively grazed by them. Grazing pressure was always lower than carrying-capacity. Grazing efficiency decreased proportionally to stocking rate, being almost zero in the more extensively grazed areas. Hence, a sufficient quantity of forage was always left on the ground for wild ungulates.
Chamois seemed to prefer zones where the vegetation was improved by cattle or sheep, at least in some period of the year and at a well determined vegetation stage (Figure 1). They avoided those areas where cattle or sheep presence was intrusive, regardless of their forage values. The number of observations of chamois was higher (4.74 chamois ha^{-1} y^{-1}) for low forage value types (F3 and R1), than for better quality types (2.69 chamois ha^{-1} y^{-1} for F1 and F2). Even if F3 and R1 were core areas of chamois home-range, F1 and F2 were exploited especially in late spring when they had higher DOM values. In fact, domestic animals exploited F1 and F2 only after fructification (when DOM lowered, affecting animal performances), ensuring good quality forage to chamois for a longer period. High altitude pastures (F2), with short grazing season (60-90 days), had limited range of variation in DOM (Δ = 18 %; Figure 1), providing a reserve of high quality food during mid-summer period.
Although F1 and F2 took up only 24 % of the surface, they accounted for about 36 % of total chamois observations.

Table 1. Description of the vegetation types in the studied area.

Vegetation type	dominant species (%)	surface (% of total surface)	pastoral value (VP)	domestic stocking-rates (LU ha^{-1} year^{-1})	description
F1	*Poa pratensis* (9.9) *Agrostis tenuis* (9.7) *Festuca gr. ovina* (7.3)	15.2	42	0.17	High quality grasslands
F2	*Phleum alpinum (14.0)* Agrostis tenuis *(6.4)*	8.8	34	0.13	High altitude grasslands
F3	*Festuca gr. ovina* (14.0) *Agrostis tenuis* (6.4) *Carex sempervirens* (6.3)	14.1	21	0.02	Encroaching grasslands
R1	*Festuca varia* (37.8) *Carex sempervirens* (10.8)	61.9	6	0.01	Poor grasslands at highest slopes

Conclusions

A vegetation of high quality is generally preserved and improved by suitable pastoral practices. Such a vegetation is available for chamois especially when domestic animals are away from the pasture (above all in spring and autumn), as cattle or sheep might disturb wild ungulates.

A mosaic of improved areas, interspersed with less exploited areas (i.e., steep and rocky slopes) could improve the faunal value of a territory, because of the its capacity to supply high quality forage to wild ungulates. Therefore i) proper grazing management, ii) definition of suitable stocking-rates to balance the pressure by domestic and wild animals, iii) accurate choice of areas for intensive exploitation by domestic ungulates, are fundamental to preserve foraging resources for wild ungulates.

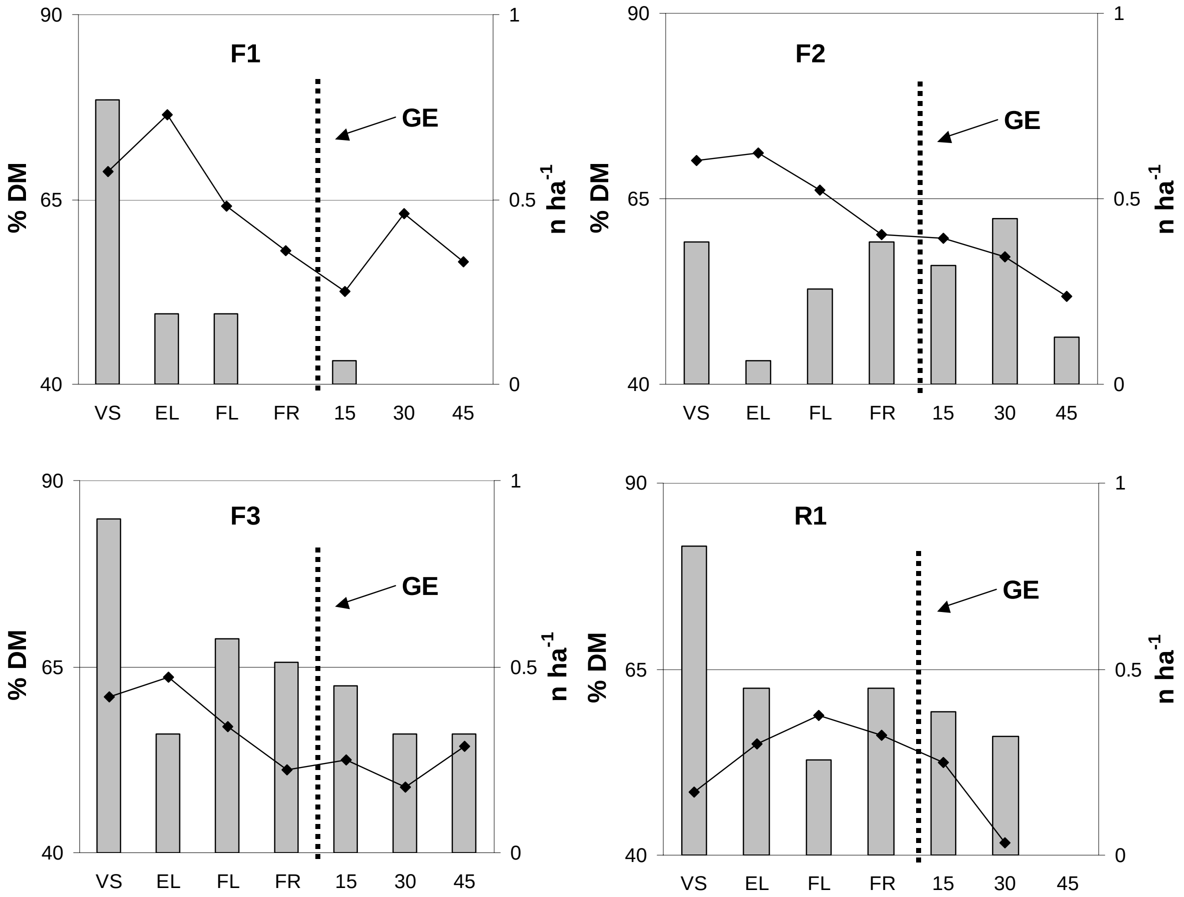

Figure 1. DOM values (continuous line, left *y* axis) and observation of chamois (grey columns, right *y* axis) as functions of vegetation phenology (VS: vegetation stage, EL: elongation, FL: flowering, FR: fructification) until the grazing event (GE) by domestic animals, then as functions of the number of days after exploitation, for the 4 vegetation types.

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Threatened grasshopper species profit from ecological compensation areas

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Abstract

A programme to reverse the species decline of grasshopper and bush-cricket species was implemented by the Swiss government in 1993. To compare the situation before and after the introduction of ecological compensation areas (ECA) a repeated survey of the grasshopper and bush-cricket species was made in the municipalities of Schönenberg and Glattfelden (canton Zurich, Switzerland) both in 1990 and 2000. Schönenberg has important populations of threatened grasshoppers inhabiting wet grassland, whereas Glattfelden has important ones for dry grassland. In both municipalities the number of grasshopper species increased more on ecological compensation areas than on Non-ECA sites. The same was true for the number of species, cited in the red list to be threatened or endangered. The vicinity of ECA to already existing legally protected species rich areas and the time since the implementation of the programme are important factors. The survey underlines the importance of nature conservation areas as a source of threatened species and the success of the agri-environmental programme.

Keywords: Ecological compensation, grassland, grasshopper, nature conservation

Introduction

Increasing biodiversity in the agricultural landscape is one of the goals of the Swiss Federal constitution and one of the tasks of our multifunctional agriculture. Therefore in 1993 area based subsidies for ecological compensation areas (ECA) were a part of the Swiss agri-environmental programme. To qualify for the programme the farmers had to manage at least 7 % of their agricultural land according to the programme rules. Out of 15 defined types of ECA, extensively used meadows, low input meadows and litter meadows were the most important grasslands involved in the programme (Walter *et al.*, 2004). Thus policy needed information about the efficiency of the programme. The objective of this study was to show the effect of ECA's on the species richness of grasshoppers. Therefore the following hypotheses were tested:
1. Between 1990 and 2000 the distribution area of grasshopper species increased due to ECA's. 2. The species number of ECA's increased with the proportion of adjacent species rich areas. 3. The species richness of ECA's increased with the time since the farmer started the contract with the ECA-programme.

Methods and study area

To measure the effect of the programme grasshoppers species richness and relative species density were measured at the site in 1990 and in 2000. Grasshoppers were chosen as indicators, because good field data over a short time period before the introduction of the ECA-programme were available. It is easy to observe them in the field, they react quickly to land-use changes and more than 80 % of the grasshopper species in Switzerland can inhabit grassland (Schneider and Walter, 2001).

The two study areas were selected due to available data of the grasshopper inventory of the canton Zürich (Walter, 1990). One study site Glattfelden was characterized as dry and semidry grassland whereas Schönenberg was characterized as wet grassland. In order to analyse the effect of ECA the sites in the study area were divided in the categories; ECA in the year 2000, nature protection area in 2000 and remaining agricultural area. The grasshoppers were mapped using the same methods in 1990 and in 2000. The results of the two years have been compared (Hunziker, 2001; Peter and Walter, 2001). The effect of source populations was measured by the proportion of the common border of each site with an already species rich site. This measure was correlated with the species richness in Glattfelden. To measure the effect of the duration of the programme the years since the site was under contract were taken into account.

Table 1. Grasshopper species profiting of ECA in two municipalities of the canton Zurich.

Species name	Glattfelden	Schönenberg
**Phaneroptera falcata* (Poda, 1761)	0	
**Conocephalus fuscus* (Fabricius, 1793)		0
**Decticus verrucivorus* (Linnée, 1758)		++
**Platycleis a. albopunctata* (Goeze, 1778))	++	
**Metrioptera bicolor* (Philippi, 1830)	++	
Metrioptera roeselii (Hagenbach, 1822)	0	0
Pholidoptera griseoaptera (DeGeer, 17773)	++	++
**Stethophyma grossum* (Linnée, 1758)		++
**Mecostethus parapleurus* (Hagenbach, 1822)	++	
**Omocestus rufipes* (Zetterstedt, 1821)	0	
Omocestus viridulus (Linnée, 1758)		++
Stenobothrus lineatus (Panzer, [1758])	0	
Gomphocerippus rufus (Linnée, 1758)	++	0
Chorthippus brunneus (Thunberg, 1815)	0	
Chorthippus biguttulus (Linnée, 1758)	++	++
**Chorthippus m. mollis* (Charpentier, 1825)	0	
Chorthippus dorsatus (Zetterstedt, 1821)	++	++
Chorthippus parallelus (Zetterstedt, 1821)	0	0
**Chorthippus montanus* (Carpentier, 1825)		0
**Chrysochraon dispar* (Germar, [1834])	0	++

* are species cited in the Red List to be threatened
++ larger distribution area in 2000 than in 1990, due to ECA
0 distribution area did not change between 1990 and 2000 due to ECA
* Threatened species due to Thorens and Nadig (1994)

Results

Table 1 shows the grasshopper species which have profited of the introduction of ECA. Out of 20 grasshopper species 11 increased their distribution area in one or both municipalities. 6 of these species were threatened according to Thorens and Nadig (1994). None of them had a smaller distribution area in 2000 than in 1990.
The major driving factors for these successes were the ECA-adjoining species rich areas such as nature conservation areas and the time since the farmer started by contract with the programme (Figure 1).

Conclusions

Grasshoppers can react very quickly to land use changes. ECA-measures can be very effective in increasing grasshopper populations in areas with existing source populations. Their species richness increased with time over the duration of the programme. Therefore to be more efficient we need a network of ECA's starting from species rich areas leading to the species poor areas. We also need patience until the success will be visible.

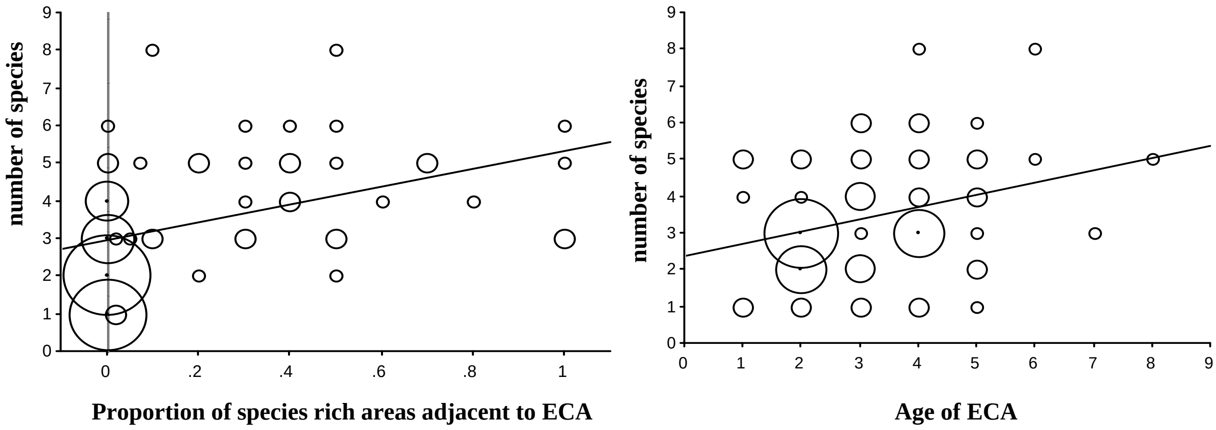

Figure 1. The relationship between proportion of ECA-adjoining species-rich area and the age of the ECA and the species richness.

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Impact of low input meadows on arthropod diversity at habitat and landscape scale

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Abstract

In Switzerland, in order to preserve and enhance arthropod diversity in grassland ecosystems (among others), farmers had to convert at least 7 % of their land to ecological compensation areas – ECA. Major ECA are low input grasslands, traditional orchards, hedges and wild flower strips. In this paper the difference in species assemblages of 3 arthropod groups, namely spiders, carabid beetles and butterflies between intensively managed and low input meadows is investigated by means of multivariate statistics. On one hand, the consequences of these differences are analysed at the habitat level to promote good practices for arthropod diversity in grassland ecosystems. On the other hand, the contribution of each meadow type to the regional diversity is investigated to widen the analysis to the landscape level.

Keywords: agri-environmental scheme, arthropods, biodiversity, low input meadows, multivariate statistics

Introduction

By their variety and abundance in terrestrial ecosystems, arthropods are of particular importance from the biodiversity conservation and economical point of view. In grassland ecosystems, arthropods are responsible for very important ecological functions: they are grass consumers (herbivores), integrate the organic matter in soil (decomposers), help plants to reproduce (pollinators) and feed on other organisms that may be pests (predators). In this context, management operations influencing arthropod diversity may alter these basic ecological functions, as it has been demonstrated in several studies (Curry, 1994). Some operations like mowing have a direct impact on invertebrates by killing individuals or removing them from the habitat. Indirect effects may also occur through changing the habitat, by altering the vegetation (species composition and structure) and consequently by affecting micro-climatic conditions. In Switzerland, efforts have been made to reduce the negative impact of intensive management in grassland ecosystems on biodiversity by introducing an ecological compensation area (ECA) scheme. The management of ECAs is regulated in order to achieve environmental goals: restrictions in fertilisation, pesticide use, prescribed dates for mowing (Walter *et al.*, 2004). This paper aims to compare species richness and species composition of spider, carabid beetle and butterfly communities in extensively and intensively used meadows in two regions of the Swiss plateau. Furthermore, the variability in species richness and species composition due to the management intensity and the region is tested on a comparative basis.

Regions and sampling methods

The study was carried out in 2 regions of the central Swiss Plateau: region 1, Nuvilly, 30 km W of Fribourg, altitude 580-720 m and region 2, Ruswil, 20 km NW of Lucerne, altitude 650-800 m.

Region 1 comprises a total surface of 515 hectares, consisting of grassland (37 %), arable land (55 %), and forests (6 %). Three grassland ECA types, usually small areas of approx. 400 m^2, can be found on the perimeter, namely extensively used meadows (EUM, no fertilisation, late mowing), low intensity meadows (LIM, restricted fertilisation, late mowing), and meadows in traditional orchards with standard fruit trees (TO). As meadows in traditional orchards are usually intensively used (fertilisation and mowing not restricted), they are further associated with intensively used meadows (IUM).
Region 2 comprises a total surface of 885 hectares, mainly consisting of grassland (59 %), arable land (15 %) and forests (17 %). In region 2, the same ECA types occur.
Spiders, carabid beetles in 1999 and butterflies in 1998 were recorded in 21 EUM, 2 LIM, 7 TO and 5 IUM in region 1, and in 14 EUM, 7 LIM, 8 TO and 5 IUM in region 2. Details about spider and carabid beetle collections, and butterfly observations are presented in Jeanneret *et al.* (2003). For analysis of the management intensity impact, EUM and LIM were grouped under extensively used meadows, and TO and IUM under intensively used meadows.
To test the effect of the management intensity and the region on the species richness, ANOVA was performed. Testing was carried out on the species assemblages with redundancy analysis (RDA) and a partial RDA (Ter Braak, 1996). In RDA, the significance of a particular environmental variable can be assessed by Monte Carlo testing (bootstrapping). Partitioning of variation was then performed through partial RDA (Borcard *et al.*, 1992) to differentiate between 'pure' management intensity variation from variation due to the region.

Results and discussion

Altogether 26,674 spiders and 20,150 carabid beetles belonging to 96 and 92 species respectively were collected from the 69 sites. Spider species richness was not dependant on management intensity (extensively used vs. intensively used meadows) in either region (ANOVA, $P = 0.08$). To the contrary, carabid species richness was significantly influenced by the management intensity in both regions (ANOVA, $P < 0.05$).
Altogether, 2636 butterflies belonging to 30 species were observed on the 68 sites. Butterfly species richness was significantly higher in the extensively used than in the intensively used meadows and significantly higher in region 1 than in region 2 (ANOVA, management intensity $P < 0.05$, region $P < 0.05$).

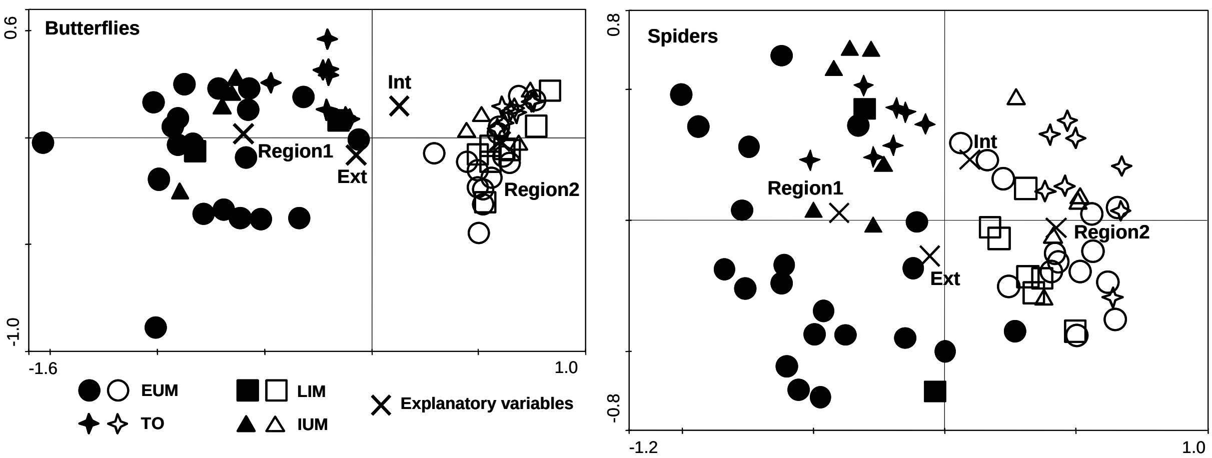

Figure 1. RDA ordination diagram of the sites based on butterfly and spider assemblages with management intensity and region variables displaying 21 % of the variance for spiders and 38 % for butterflies (first and second axes). Filled symbols: region 1; empty symbols: region 2. Ext = extensively used, Int = intensively used. See text for further explanation of meadow types.

The RDA ordination diagram of the sites based on spider assemblages differentiated region 1 from 2 and extensively used (EUM+LIM) from intensive meadows (IUM+TO) (Figure 1). On the whole, management intensity and region explained a significant part of variation in spider assemblages (Monte Carlo permutation test: $P < 0.05$). The canonical coefficients which allow inference about the relative importance of explanatory variables (Ter Braak, 1996) showed that first axis is a ‘region gradient’ and second axis a ‘management intensity gradient’. Therefore, spider assemblages are first influenced by the region and second by the management intensity. Furthemore, the question was whether there is still a difference in spider assemblages among management type after accounting for the effect of the region. This was investigated by specifying the region as covariable in a partial RDA. The partial test (partial RDA) gave a F-ratio of 3.0 and $P < 0.05$. In conclusion, there remains a systematic difference in spider assemblages among management intensity after accounting for the region effect.

Ordination of the sites based on carabid beetle assemblages showed a very similar picture and is therefore not presented. Furthermore, as was the casewith spiders, management intensity and region explained a significant part of the variation ($P < 0.05$). First axis represented a ‘region gradient’ and second axis a ‘management intensity gradient’. Management intensity remained significant after accounting for the effect of the region (partial RDA, F-ratio 12.96, $P < 0.05$).

For butterfly assemblages, sites of the same region were grouped together showing a substantially higher variation among the meadows of region 1 compared with region 2 (Figure 1). This difference was due to the larger species richness in region 1 (29 species altogether) in comparison to the poor species richness of region 2 (15 species altogether). Nevertheless, butterfly assemblages significantly differentiated extensively used from intensively used meadows independently of the region effect (partial RDA, F-ratio 2.2, $P < 0.05$).

Conclusions

Over the two studied regions, management intensity significantly affected the arthropod assemblages showing that extensification enhanced diversity at a regional scale, although species richness may not be affected in all cases. Region 1 and region 2 had their own specific pool of spider, carabid and butterfly species. As explanatory variable, region stressed not only two different biogeographic situations but also summarised regional abiotic factors. Among abiotic factors, landscape features such as habitat variability and heterogeneity, arrangement of cultures, percentage of semi-natural habitats, and their influence on arthropods might be analysed to better understand the differences between regions.

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Extensively managed meadows on the Swiss plateau – floristic composition, vegetation structure and effect on avifauna

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Abstract

In 1993, an agro-environmental programme was incorporated into Swiss Agricultural legislation. An important objective of this scheme was the preservation of natural biodiversity as well as to promote stabilisation and spread of endangered species. In order to achieve these goals, farmers have to convert at least 7 % of their land to 'Ecological Compensation Areas' (ECA) on which the management is regulated for conservation purposes. The share of grassland in the programme had reached a total of 101245 hectares (BLW, 2003). During the period 1998 to 2001 both plant composition and vegetation structure were investigated in 53 study areas on the Swiss plateau. Their effects on breeding birds were studied in 23 of these areas. The results show that the majority of ECA meadows had recently been extensified. 18-25 % of the meadows contained a minimum set of characteristic plants of species rich meadows corresponding to traditionally managed grasslands types. With respect to the appeal of ECA grasslands to breeding birds, 15-17 % of the extensively used meadows and 70 % of the litter meadows had the complex vertical structure required for nesting and feeding. Whereas wetland birds were significantly more frequent on or near litter meadow ECAs (57 % more territories observed than expected), no effects could be found for other grassland birds.

Keywords: Ecological compensation, vegetation ecology, grassland, litter meadows, birds

Species rich ECA meadows are rare

The vegetation composition of extensively managed meadows (late cut, no fertiliser, for detailed management rules see Walter *et al.*, this volume) was assessed according to a typology proposed by Dietl (1995), based on the presence of indicator species for levels of grassland management intensity. We classified the relevés and differentiated between seven classes: (1) Wetland habitats (*Caricetum davallianae*), (2) litter meadows (*Molinion, Calthion*), (3) *Arrhenatheretum s.l.* (typical traditional fertile hay meadows of the lowlands, (4) *Arrhenatheretum* fragments (plant communities containing some but not all indicator species of traditional hay meadows), (5) moderately intensive meadows (*Dactylis glomerata* meadow type), (6) modern, intensively managed meadow types (*Lolium spp.* and *Alopecurus pratensis* meadow types) and (7) a category consisting of tall herb and ruderal vegetation types. The first three classes represented the targeted vegetation types, which contribute to the preservation and promotion of grassland biodiversity in the rural landscape.
Wetland meadows occurred mainly in 'grassland dominated' regions, whereas in the regions which were dominated by other land use practices this vegetation type was marginal (Figure 1). The share of typical, formerly widespread traditionally managed fertile meadows (i.e., *Arrhenatheretum* types from dry to wet performance) was highest in regions dominated by arable land use; whilst in the other regions it made up around 18 %. In every region we also identified *Arrhenatheretum* fragments which, provided extensive management as ECA continues, may evolve towards restored *Arrhenatheretum* meadow types. There was a noticeable dominance (56-64 %) of high intensity type meadows throughout all agricultural

land use regions. Since all ECA meadows are now extensively managed, they will have achieved ECA status only recently.

Birds need structured vegetation

With respect to the appeal of ECA grasslands to breeding birds the vegetation structure was grouped into three classes (monotonous, mediocre or diverse). Additionally, the presence of lookouts for birds was noted and the share of gaps in vegetation structure was estimated. Depending on the dominance of land use practice, 15-17 % of the extensively used meadows and 72 % of the litter meadows showed the complex vertical structure required for nesting and feeding (Figure 2). Lookouts which are needed by birds for prey catching and as singing posts occurred in 38-48 % of the meadows. However, sufficient gaps for nesting (> 10 %) were only available in 7.5-12 % of the meadows. Far more litter meadows provided diverse vegetation structures and supplementary lookouts for birds.

Do birds favour ECA meadows as habitat?

We tested whether the centres of bird territories were more frequent in or near ECA by comparing their actual distribution with a hypothetical random distribution of bird territories. The species were grouped according to their ecological requirements. Openland birds, such as the Skylark (*Alauda arvensis*), were significantly less frequent in or near ECA. This was due to the fact that ECA grasslands were often located as narrow strips along vertical structures such as hedges or forest edges, which openland birds tend to avoid. Also, the structure and botanical quality of most ECA grasslands (except the litter meadows) was hardly different from conventionally managed grasslands (Figure 1). Late herbage cuts were not sufficient to make these usually dense stands suitable for bird nesting. On the other hand, wetland birds, namely Reed (*Acrocephalus scirpaceus*) and Marsh Warbler *(Acrocephalus palustris)*, were more frequent on or near ECA, particularly on litter meadows which were generally of better floristic quality (*Caricetum davallianae*, *Calthion*, *Molinion*). In the grassland-dominated regions, the average density of bird territories was low compared to arable and mixed agricultural regions (Spiess *et al.*, 2002).

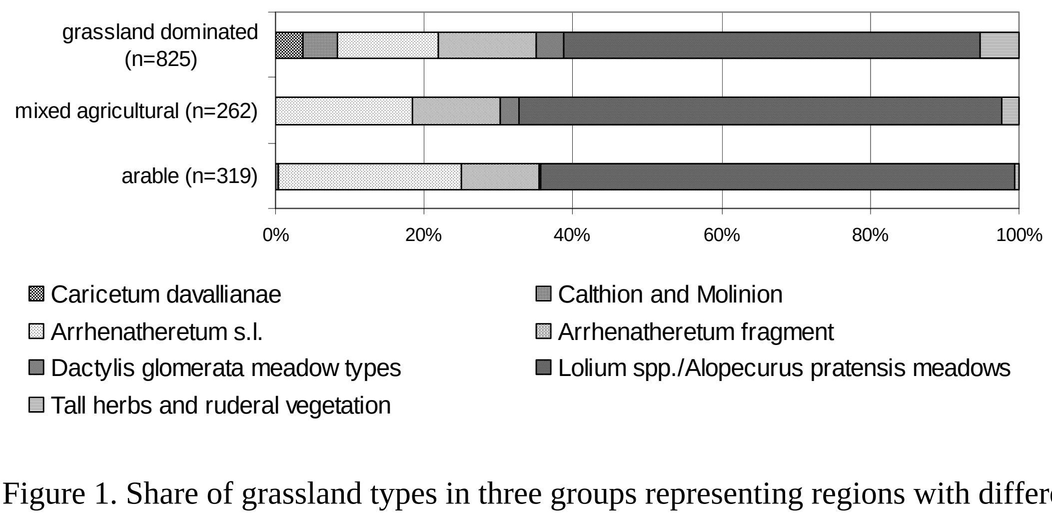

Figure 1. Share of grassland types in three groups representing regions with different dominance of land use practice.

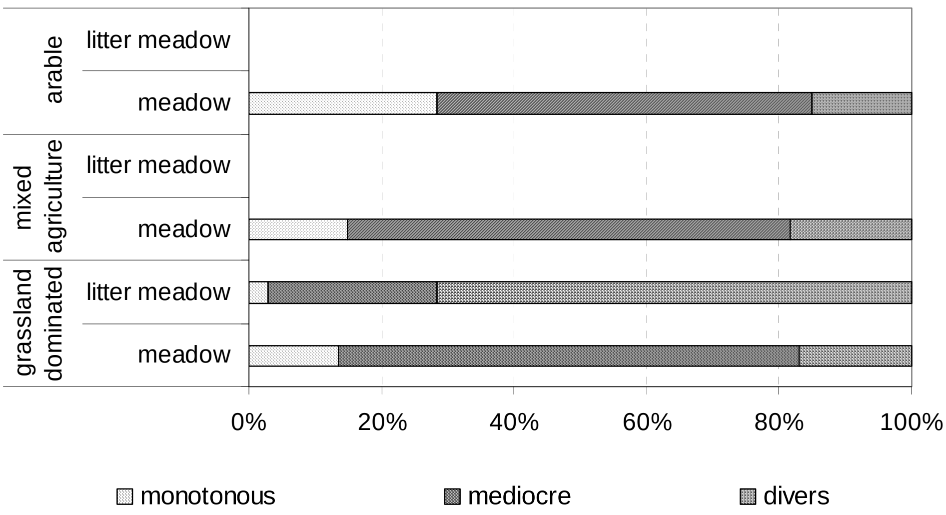

Figure 2. Share of structure types observed in meadows and litter meadows in three groups representing regions with different dominance of land use practice.

Conclusions

Most ECA grasslands (except litter meadows) still reflect former intensive management regimes. The quality of the vegetation of 65-70 % of the ECA meadows (depending on dominance of agricultural land use) did not correspond to traditional hay meadows and their vegetation structure did not generally enhance meadow birds. About 10-13 % of the ECA meadows had the potential to be restored to traditional hay-meadow composition, provided farmers are sufficiently encouraged to engage in long-term extensive management.

The vegetation of 8 % of ECA meadows (in grassland dominated region) corresponded to the target vegetation composition of litter meadows (*Caricetum davallianae*, *Calthion*, *Molinion*). They represented meadow types of the desired quality with rich vegetation structure and adequate provision of lookouts. This explains why wetland breeding birds take advantage of the existence of ECA litter meadows.

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Establishment of experimentally introduced plant species in a hay meadow

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Abstract

Semi-natural, species-rich hay meadows have declined drastically in recent years. Seed spread deliberately into an *Arrhenatherum elatius*-stand was used to examine the impact of management measures on sward structure and the resulting establishment success. The tested factors comprised irrigation, cutting and harrowing, which were orthogonally combined in a split-plot design with 4 replications. Seeds of 6 wildflower and 2 grass species were spread over the sward and emergence and survival of seedlings were recorded. Seedling emergence varied between 3 % for *Lychnis flos-cuculi* and 18 % for *Plantago lanceolata*. Frequent cutting was the most important factor for a high seedling emergence. On average, twice as many seedlings emerged in cut swards than in uncut swards. Harrowing before spreading seeds enhanced seedling emergence of two species, regular irregation of one species. Survival of emerged seedlings in cut swards was higher than in uncut ones, irrigation and harrowing of the sward were of minor importance. It is concluded that for the diversification of productive grassland by oversowing, in the beginning, frequent cutting of the sward is necessary for successful seedling establishment.

Keywords: hay meadow, seed addition, species establishment, grassland management, sward structure

Introduction

Plant species diversity in grassland has been reduced considerably during the last decades. This is true not only for species rich grassland on marginal sites but particularly the more abundant, intensively managed grasslands on fertile sites. Efforts to re-establish higher species diversity by reducing management intensity do not automatically ensure the reversal of this process (Bakker and Berendse, 1999). Apart from a sufficient availability of seeds, the demands of the plant species concerning appropriate microsites for germination of seeds and establishment of seedlings in a competitive grassland sward have to be met (Foster, 2001; Muller *et al*., 1998). Thus the influence of suitable management measures (irrigation, cutting and harrowing) on the sward structure and on the resulting establishment success of spread seeds were investigated in a field experiment,.

Materials and methods

The experiment was set up in a split plot design with four replications on a pure *Arrhenatherum elatius*-stand in Goettingen (E 9°56´, N 51°31´, 150 m asl, annual rainfall 635 mm, annual average temperature 8.5 °C). Sward structure was varied by an orthogonal combination of the factors irrigation (no irrigation or irrigation of 2 mm d^{-1}), which was the main treatment, and cutting (no cutting or frequent cutting down to a stubble height of 6 cm as soon as a sward height of 15 cm was reached) and artificial disturbance of the sward (undisturbed or disturbance by slight harrowing before spreading the seeds), which were the subtreatments. In early spring (19^{th} of March), after-ripened seeds of eight grassland species, including five forb species of local provenance (*Centaurea jacea = Ceja*, *Lychnis flos-cuculi = Lyfl*, *Plantago lanceolata = Plla*, *Salvia pratensis = Sapr*, *Tragopogon pratensis = Trapr*, *Trifolium pratense = Tripr*) and two grass species of commercial cultivars (*Lolium perenne =*

Lope, *Poa pratensis* = *Popr*), were spread over subplots (0.5 by 0.5 m), each with a density of 200 seeds m^{-2}. Seedling emergence and survival were recorded continuously by marking seedlings until the end of the vegetation period. In order to compare the environmental conditions in the different treatments, features of sward structure (sward height, tiller density and proportion of gaps in the sward) and microclimate (light transmission and soil water content of the upper 2 cm) were determined regularly.

Results and discussion

Seedling emergence varied species-specifically between 3 % for *L. flos-cuculi* and 18 % for *P. lanceolata* (average over treatments). Frequent cutting was the most important factor for a high seedling emergence (Table 1).

Table 1. Cumulative seedling emergence (in % seeds) six month after spreading seeds.

Irrigat	Cutting	Disturb.	*Ceja*	*Lope*	*Lyfl*	*Plla*	*Popr*	*Sapr*	*Trapr*	*Tripr*
-	-	-	8.0	8.5	0.0	3.0	2.5	1.0	9.5	5.5
-	-	+	14.0	17.5	0.0	2.0	21.5	7.5	6.0	9.5
-	+	-	13.0	16.0	3.0	12.0	15.5	6.0	20.5	1.0
-	+	+	10.0	26.0	1.0	15.0	31.5	10.5	13.5	7.0
+	-	-	2.5	8.5	1.0	2.0	4.5	1.5	1.5	1.5
+	-	+	6.0	17.5	5.0	5.0	17.5	2.0	3.0	1.5
+	+	-	10.0	16.0	8.5	5.5	19.0	9.0	9.5	1.0
+	+	+	11.0	26.5	8.5	12.0	37.0	5.5	7.0	1.5
ANOVA-summary, significance of F-value										
Irrigation (I)			0.576	0.880	**0.013**	0.831	0.487	0.620	0.192	0.492
Cut (C)			**0.049**	**0.012**	**0.005**	<**0.001**	**0.001**	**<0.001**	**0.002**	0.297
Disturbance (D)			0.356	**0.001**	0.610	<**0.001**	0.118	0.252	0.174	0.231
I x C			0.340	0.718	0.710	0.467	0.243	0.850	0.620	0.362
I x D			0.871	0.652	0.159	0.888	0.220	**0.020**	0.471	0.610
C x D			0.128	0.910	0.274	0.236	0.523	0.227	0.614	0.470
I x C x D			0.516	0.935	0.860	0.586	0.745	0.888	0.714	0.556

Of the investigated species, on average twice as many seedlings emerged in the cut swards as in the uncut sward. In the cut swards, with light transmission values of 60 %, the light availability was twice as high as in the uncut swards (Figure 1). Obviously, the enhanced light quantity and, even more, the changed light quality with a higher red-far red ratio resulted in a significantly higher germination rate. For *L. perenne* and *P. lanceolata*, seedling emergence was further enhanced by an increased proportion of bare ground in the harrowing treatment. The reason why there was no significant relationship between disturbance treatment and seedling emergence for the other tested species might be put down to the initially already low sward density in the undisturbed *Arrhenatherum*-sward with 2500 tillers m^{-2} (data not shown) and light transmissions above 20 % in mid April in the undisturbed and uncut swards. In a further seed addition experiment on a moderately species rich hay meadow with a density of 6400 tillers m^{-2} in the undisturbed and uncut swards at the sowing date, seven of eight tested species showed a significantly increased emergence under the disturbance treatment (Hofmann and Isselstein, 2000). Regular irrigation increased seedling emergence of *L. flos-cuculi*, but had no impact on the other species. This can be explained by periodical rainfall in the first five weeks after spreading seeds which kept the soil water content in the non irrigated plots between 15 and 20 % (w / w) and therefore similar to the irrigated plots. In contrast to the other tested species with the main period of seedling emergence within two months after spreading seeds, *L. flos-cuculi* started to emerge later in summer, when the water stress in the non irrigated plots became more severe and affected seed germination. *T. pratense* was the only species which emerged regardless of the sward treatment.

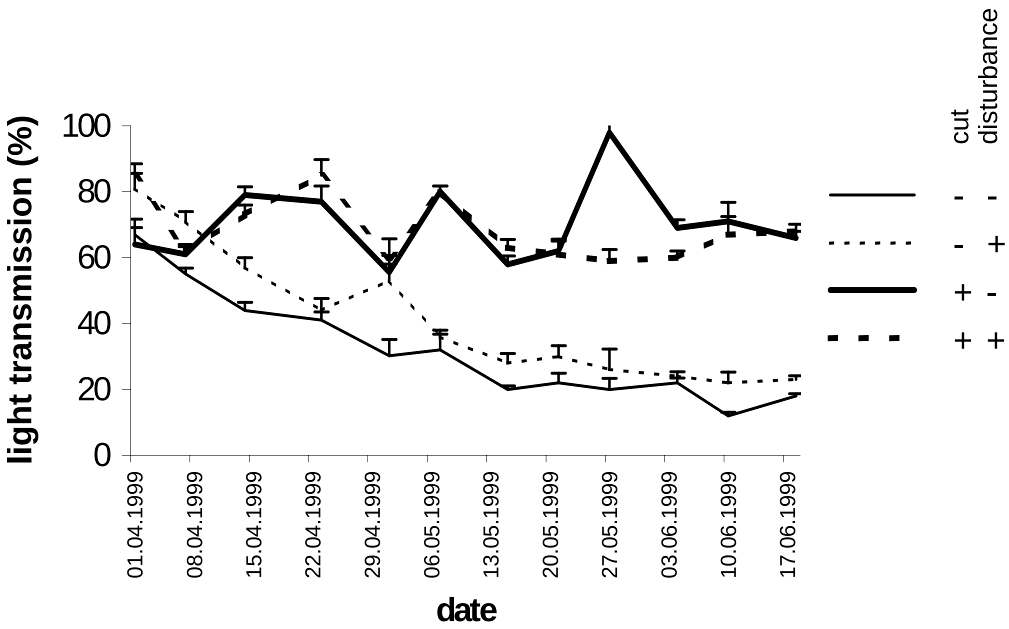

Figure 1: Light transmission (in %, PAR) at soil surface in the differently treated swards (average on irrigation).

The survival rate of the emerged seedlings was calculated six months after spreading seeds. For *L. perenne* and *T. pratense* it was significantly higher in the cut swards than in the uncut ones, for the other tested species the difference was less marked. The effects of irrigation and harrowing of the sward were of minor importance for short term survival. The comparatively weak effect of treatment on seedling survival in this experiment might be due to the relatively open sward even in the undisturbed treatment with light transmission values never dropping below 15 %. Under more competitive conditions in more species rich and denser vegetation, repeated defoliation has been proven to be highly effective in enhancing seedling establishment (Kowarsch *et al*., 2001; Hofmann and Isselstein, 2000; Jones and Hayes, 1999).

Conclusions

To diversify hay meadows by deliberately spreading wildflower seeds over the existing sward, in the beginning, frequent cutting of the sward is necessary to provide suitable microsites for high seedling recruitment.

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Reintroduction of grassland species

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Abstract

Intensification of grassland management during the last 50 years has resulted in the loss of many plant species. Guidelines for management and restoration appeared often inadequate for a successful restoration of former species-rich grasslands. Viable seeds of many species are no longer present in the soil and the natural influx of seeds is lacking. Therefore reintroduction of seeds seems a logical step to regenerate species-rich grasslands.
At the Veenkampen area near Wageningen three introduction experiments were carried out. Seeds of twelve former common grassland species were sown. Germination and establishment were monitored. After 8 years six species (*Achillea ptarmica, Centaurea jacea, Cirsium dissectum, Molinia caerulea, Prunella vulgaris, Succisa pratensis*) established successfully and started to colonise the surrounding grassland. Four species (*Briza media, Carex hostiana, Danthonia decumbens, Filipendula ulmaria*) were present in limited numbers. Two species (*Gentiana pneumonanthe, Rhinanthus angustifolius*) were not successful. We conclude that topsoil removal is a necessary step before the reintroduction of seeds.

Keywords: reintroduction, grassland management, restoration management

Introduction

Intensification of agricultural grassland management during the last 50 years has resulted in a dramatic negative effect on biodiversity. Due to increased fertiliser input and optimization of land use, productivity of many types of grasslands increased from approx. 5,000 kg DM ha^{-1} in the 1930's to 10,000-12,000 in the 1970's (Oomes *et al.*, 1996). Simultaneously with this increase in productivity, species richness greatly declined.
In order to restore biodiversity on these intensively used grasslands many new management tools have been developed over the last 20 years (Benstead *et al.*, 1999). It is assumed that topsoil removal in combination with increased ground water levels and cessation of fertiliser input is one of the most powerful tools. This strategy was also applied in the Veenkampen area in the Netherlands (Oomes *et al.*, 1996). Even though this strategy resulted in an impressive increase in species richness after several years, many species typical for the *Juncon Molinion* grasslands that were present in the 1930's at the same location did not re-establish (Geerts *et al.*, 1996). This suggests that seeds of these species were either absent in the seed bank or not viable anymore (Bekker *et al.*, 1998). Furthermore, input from surroundings may be limited (Strykstra *et al.*, 1998). Introduction of seeds may be one of the options to re-introduce these 'missing' species. Here we report on the success and failure of re-introduction in relation to several treatments.

Materials and methods

Three types of grassland in the Veenkampen area were used and experiments started in the period 1995-1996. Experiment I and II started in the autumn of 1995 and were laid out on a hayfield that had not received fertiliser since 1978 and on a grazed heavily fertilised grassland, respectively. Experiment III started in the autumn of 1996 on a hayfield, unfertilised since 1978 but with an increased groundwater table from 1985 onwards. Each experiment consisted of four treatments:

- C: control; maintaining existing sward without introduction
- Si: an existing sward, sprayed with herbicide to kill the vegetation in a 20 cm width strip, followed by rotovation of the strip and introduction of seeds
- Rw: 10 cm topsoil removal without introduction
- Ri: 10 cm topsoil removal and introduction of seeds.

Seeds of 12 'missing' grassland species were collected in the summers of 1995 and 1996 in a nature reserve 'De Bennekomse Meent'in the vicinity of the Veenkampen area. Species were: *Briza media, Danthonia decumbens, Molinea caerulea, Carex hostiana, Achillea ptarmica, Centaurea jacea, Cirsium dissectum, Filipendula ulmaria, Gentiana pneumonanthe, Prunella vulgaris, Rhinanthus angustifolius, Succisa pratensis*. Treatments were replicated six times in experiment I and II and four times in experiment III. Plot size was 24 m^2. Within each plot four rows of seeds were sown. In every row each species was sown at a rate of 50 viable seeds per 35 cm length (sub-plot). Seed germination percentage was *analys*ed in a preliminary experiment. Germination and establishment of both introduced and naturally germinated species were scored.

Results and discussion

The first spring after introduction the germination in experiment I and II was much lower for all species than in experiment III. This was probably due to the cold and dry winter of 1995 / 1996. The number of species per treatment (total and introduced) in the second year after introduction and in 2000 is presented in table 1. Topsoil removal (treatments Rw and Ri) resulted in significantly more species than in treatments C and Si. Reintroduction after topsoil removal (Ri) was more successful than reintroduction in a small strip (Si). Some of the introduced species also established in treatment Rw (increase between 1997 / 8 and 2000), and this was probably due to input of seeds of introduced species from the surrounding plots.

Table 1. Total number of species and number of introduced species $plot^{-1}$ in second year (1997 in experiment I and II or 1998 in experiment III) after introduction and in 2000.

Year	1997 or 1998					2000				
Treatment	C	Si	Rw	Ri	LSD ($P \leq 0.05$)	C	Si	Rw	Ri	LSD ($P \leq 0.05$)
				Total number of species						
Experiment I	12.2 a[1)]	17.3 b	22.2 c	30.2 d	2.6	9.0 a	12.2 b	29.3 c	34.5 d	2.1
II	10.3 a	17.2 b	19.7 b	27.0 c	4.2	11.8 a	16.2 b	27.0 c	31.2 d	4.0
III	15.0 a	22.0 b	30.8 c	38.3 d	3.8	19.8 a	28.3 b	29.3 b	36.3 c	3.7
				Introduced species						
Experiment I	0.0 a	5.0 c	1.2 b	8.0 d	1.1	0.0 a	3.7 c	2.3 b	8.2 d	1.2
II	0.0 a	4.3 b	0.8 a	7.7 c	1.1	0.2 a	3.5 b	2.8 b	8.5 c	1.4
III	0.3 a	8.0 c	2.5 b	11.5 d	2.0	0.0 a	7.8 c	2.8 b	10.5 d	1.6

[1]Same letters within an experiment and year: species numbers are not significantly different $P \leq 0.05$

The introduced species performed best in experiment III, both after topsoil removal (IIIRi) and introduction in small strips (IIISi). Results of IIISi are comparable with IRi and IIRi. An explanation could be that the higher groundwater table and the wetter weather conditions in winter 1996 / 1997 gave favourite conditions for germination in experiment III compared to I and II.

The development of the introduced species was recorded every year till 2001 and again in 2003. In table 2 the average number of individual plants per sub-plot is grouped into five categories for the years 2000 and 2003. The introduced species established after topsoil removal (Ri) much more successfully than after introduction in a small strip (Si). Topsoil removal (Ri and Rw) reduced herbage production in the first year to about a third of the production of the existing sward (Si and C). In 2001 however the grass production on all treatments was comparable with approx. 5,000 kg DM ha^{-1}, but species diversity on Ri was not much affected. This suggests that the initial conditions are of paramount importance for the establishment of the species. Presumably, sod removal (treatment Ri) reduces the competitive effect of the dominant grass species in the existing sward more and for a longer period than rotary cultivation of strips (treatment Si). Also Hopkins *et al.*, (1999) reported greatest effect on increasing botanical diversity of topsoil removal compared with strip-seeded treatments. Between 2000 and 2003 plant numbers for the introduced species tended to decline, but 8 years after the introduction on treatment Ri most species were still present.

Table 2. Recorded average numbers per introduced species per sub-plot for treatment Si and Ri. Code 1: 1-10, 2: 11-25, 3: 26-50; 4: 51-100; 5: 101-500 individual plants.

	Si. Introduction in 20 cm width strip						Ri. Introduction after top soil removal					
	Expt. I		Expt. II		Expt. I		Expt. II		Expt. I		Expt. II	
Species	2000	2003	2000	2003	2000	2003	2000	2003	2000	2003	2000	2003
Briza					1		1		1	1	3	1
Danthonia					1	1	1		1	1	4	1
Molinea					1	1	1	1	1	2	3	4
Carex					1	1	1	1	1	1	1	1
Achillea	1		4		2		5	5	4	1	2	
Centauria	2	1	4	1	2	1	2	3	5	4	3	2
Cirsium					1		1	1	4	3	1	
Filipendula					1	1		1	1	1	1	1
Gentiana									1		1	
Prunella	1		2		3		4	3	4	2	5	3
Rhinanthus							1	1				
Succisa	1	1	1		3	2	3	5	3	3	4	4

Conclusions

After 8 years, six species (*Molinia caerulea, Achillea ptarmica, Centaurea jacea, Cirsium dissectum, Prunella vulgaris, Succisa pratensis*) had established successfully and started to colonise the surrounding grassland. Four species (*Briza media, Danthonia decumbens*, *Carex hostiana, Filipendula ulmaria*) were present in limited numbers. Two species (*Gentiana pneumonanthe, Rhinanthus angustifolius*) were not successful. Topsoil removal was a necessary step before reintroduction of seeds, but rate of success depended possibly on weather and initial growing conditions.

Acknowledgements

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Wild flower seed yields in northern Finland

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Abstract

The characteristics of different wild flowers in cultivation were studied at the Lapland Research Station of MTT Agrifood Research Finland in Rovaniemi during 1996-1999. The main aim of the study was to clarify the opportunities for commercial production of wild flower seeds in northern Finland. In the experimental fields the winterhardiness, seed yield and germination of 16 different wild plant species were observed.
On the uncovered experimental plots the mean seed yields were 1.9-67.6 g m^{-2} and 13,400-364,400 seeds m^{-2}. On the plots covered by black plastic sheeting corresponding yields were 1.8-93.7 g m^{-2} and 10,700-798,800 seeds m^{-2}. The seed yield by weight was high in *Ranunculus acris*, *Rumex acetocella* and *Solidago virgaurea*. The largest numbers of seeds were produced by *Lychnis viscaria*, *Campanula rotundifolia* and *Rumex acetocella*. The seed yield of *Silene dioica* declined in the third production year. On average, *Erysimum strictum*, *Antennaria dioica*, *Ranunculus acris*, *Lychnis viscaria*, *Knautia arvensis* and *Campanula rotundifolia* had the best germination.
The results showed that seed production of early flowering and ripening wild plants is possible in the short growing season of northern Finland. Wild flower seeds of this northern origin can be available for landscape maintenance and the promotion of biodiversity in cultivated grassland.

Keywords: wild flowers, winterhardiness, seed production, seed germination

Introduction

There is a growing need for wild flower seeds of Finnish origin, but to date these have mostly been gathered in the wild. The most important wild flower seeds need to be produced in such quantities that Finnish seed material can be used also in large-scale green area creation. Such quantities can be supplied only by cultivation. For both cultivation and landscape management purposes it is important that the plants have good germination and winterhardiness, that the seeds are easy to harvest and clean, and that the flowers and foliage are beautiful (Kaunisto *et al*., 1997). A further aim of this study was to ascertain the opportunities for increasing the plant diversity in cultivated grasslands. In the selection of dicotyledons for this purpose, the herbage yields and sanitary effects of the plants must be taken into account. Also ecological factors, landscape maintenance and adaptability to common cultivation techniques for grassland plants must be considered.
The main aim of the study was to clarify the opportunities for commercial wild flower seed production in northern Finland.

Materials and methods

The characteristics of different wild flowers in cultivation were studied at the Lapland Research Station of MTT Agrifood Research Finland in Rovaniemi during 1996-1999. In the experimental field, 16 different species were planted. The most common wild plants thriving in northern conditions were selected. The soil used was fine sandy till with low content of organic matter, pH 6.3, Ca 698, P 7.7, K 118, Mg 194 and NH_4-N 4.2 mg l^{-1}. No fertilisation and irrigation were used during the trial years.

The seed production trials were set up with seedlings pre-grown in greenhouse. Both uncovered plots and plots covered by black plastic sheeting were used. Also parallel experimental plots were established by seeding in order to observe the rate of development of those plants compared to those of pre-grown and transplanted seedlings.
Winterhardiness, growth rate, ornamental character, covering, flowering, seed yield and germination were observed. The development of the plants, their flowering and seed production were monitored weekly. Seeds were collected by hand and cleaned using different methods adapted to various plant species.
During the experimental years the growing period (daily mean temperature above +5 ^{o}C) averaged 138 days, the effective growing degree days (base +5 ^{o}C) 899 ^{o}C and the precipitation during May-September 271 mm. In all the winters, the soil froze before the formation of a permanent snow cover. The average number of days with snow cover was 189.

Results and discussion

The most winter damage was suffered by *Lychnis viscaria*. *Galium verum*, *Campanula rotundifolia*, *Solidago virgaurea*, *Achillea ptarmica*, *Leucanthemum vulgare*, *Veronica longifolia, Knautia arvensis* and *Erysimum strictum* were the most winterhardy species.
Rhodiola rosea and Silene dioica began to flower already at the end of June. The flowering of *Galium verum* at the end of July was the latest among the species. *Lychnis viscaria* had a very short flowering period. *Ranunculus acris*, *Rumex acetocella*, *Galium verum*, *Veronica longifolia*, *Dianthus deltoides* and *Silene dioica* had a long flowering period.
The seeds of *Lychnis viscaria*, *Silene dioica*, *Rhodiola rosea* and *Ranunculus acris* began to ripen at the end of July. *Galium verum* was the latest, setting seeds at the end of September.
On the uncovered experimental plots the mean seed yields were 1.9-67.6 g m^{-2} and 13,400-364,400 seeds m^{-2} (Table 1). On the plots covered by black plastic sheeting the corresponding values were 1.8-93.7 g m^{-2} and 10,700-798,800 seeds m^{-2}. The seed yield by weight was high in *Ranunculus acris*, *Rumex acetocella* and *Solidago virgaurea*. The largest numbers of seeds were produced by *Lychnis viscaria*, *Campanula rotundifolia* and *Rumex acetocella*. The seed yield of *Silene dioica* declined in the third production year.
On average, *Erysimum strictum* (91 %), *Antennaria dioica* (72 %), *Ranunculus acris* (70 %), *Lychnis viscaria* (68 %), *Knautia arvensis* (58 %) and *Campanula rotundifolia* (55 %) had the best germination values.

Table 1. Mean seed yields of wild flowers (g m^{-2} and seeds m^{-2}) in 1997-1999.

Species	Mean seed yields			
	Uncovered		Black plastic sheeting	
	g m^{-2}	seeds m^{-2}	g m^{-2}	seeds m^{-2}
Ranunculus acris L.	67.6	48,600	56.7	48,600
Rumex acetocella L.	63.5	227,600	93.7	321,400
Solidago virgaurea L.	59.6	103,400	81.1	157,300
Galium verum L.	26.6	71,300	29.5	84,700
Silene dioica (L.) Clairv.	20.5	26,800	41.3	56,000
Dianthus deltoides L.	18.0	74,900	6.8	39,400
Dianthus superbus L.	17.6	22,900	17.9	24,600
Campanula rotundifolia L.	12.4	294,100	19.8	513,600
Antennaria dioica (L.) Gaertner	8.6	140,800		
Lychnis viscaria L.	6.4	364,400	48.7	798,900
Achillea ptarmica L.	51.2	300,800		
Rhodiola rosea L.	1.9	13,400	1.8	10,700
Leucanthemum vulgare Lam.	48.5	112,400		
Veronica longifolia L.	7.1	88,800	18.2	224,200
Erysimum strictum	21.9	52,000		
Knautia arvensis (L.) Coulter	82.4	14,800		

The effect of the trial site on the seed yields of plant is hard to assess. In natural habitats, too, the seed yields of wild plants vary greatly depending on the availability of water and nutrients. In the present trials, no fertilisation was used. However, cultivated plants are tall, they produce many seeds and thus there is an increased need for fertilisation. Phosphorus and potassium are especially important. Most wild plants are very winterhardy and winter damage is not a problem in northern seed production. However, the seed yields of the different plant species varied greatly between the trial years. Species of northern origin seemed to be the most certain in production. In conditions of short growing period and low temperature sum early flowering plants and species which produce most of their seed yields in August must be selected. In the present study the main seed yields were gathered when the accumulated effective temperature sum was 600-800 ^{o}C. Use of pre-grown plants in establishing plant stands speeds up the seed production and seems to be advantageous in northern growing conditions. In nature, very many factors such as dormancy of seed, temperature, light, size of seed and chemical conditions in the soil affect germination, and different plant species behave in different ways. However, in germination tests performed in the greenhouse the seeds germinated fast, in 5-10 days. There was also only a slight variation in seed germination between different experimental years.

Conclusions

The results showed that seed production of early flowering and ripening wild plants is possible in the short growing season of northern Finland. Wild flower seed of this northern origin can be available for landscape maintenance and the promotion of biodiversity in cultivated grassland.

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Longevity and vertical distribution of dandelion (*Taraxacum officinale* F. Weber.) seeds in meadow soil

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Abstract

The longevity and vertical distribution of dandelion seeds were studied in two experiments. In Experiment I dandelion seeds were collected on semi-natural meadows in June 2000 and air dry stored for two months. The seed germination was determined before we buried seeds 5 and 10 cm below the soil surface (in August 2000) and after 1, 4, 7, 10 and 22 months of burial. The germination rate of dandelion seeds buried at 5 cm depth decreased constantly from 73 % in December 2000 to 19 % in June 2002, while at 10 cm decrease from 70 % in December 2000 to 38 % in June 2002. On both depths the percentage of seeds that germinated after 10 months of burial was significantly lower (60.5 %) than the pre-burial percentage (82.7 %). After almost 2 years of burial the germination percentage further decreased (28.5 %). In Experiment II soil cores were collected on semi natural grassland in April 2000 from three different depths (0-5, 5-10 and 10-15 cm). The highest average number of emerged dandelion plants was obtained in the top 5 cm of soil (180 plants m^{-2}). In other two layers the number of emerged dandelion plants was lower (132 plants m^{-2}).

Keywords: Dandelion, germination, seed longevity, depth distribution, soil seed bank, grassland

Introduction

Modern grassland management strives for sward exploitation that results in a stable and qualitative yield and at the same time assures suitable plant diversity. An optimal botanical composition of permanent grassland recommended by Buchgraber *et al.* (1994) contains 50-60 % of grasses, 10-30 % of clovers and 10-30 % of other herbage plants. Among the latter we find plants which, in small percentage, increase the forage quality, but in a large portion decrease it. Dandelion (*Taraxacum officinale* F. Weber.) belongs to these species. The feed value of dandelion is high (Falkowski *et al.*, 1989) and the plant can contain as much protein as white clover (Bockholt *et al.*, 1995). On the one hand, it is a valuable feed, based on its fat and carbohydrate content (Spatz *et al.*, 1990). On the other hand, it is an aesthetic problem during flowering and seed production, it reducing yields of agricultural crops (Hartwig, 1989) and it especially causes slower drying of hay (Isselstein and Ridder, 1993).
The presence of dandelion in a sward mostly depends upon the quantity of produced seed, seed longevity and its allocation in the meadow soil. The aim of the present study was to investigate the vertical distribution of dandelion seeds in the soil and the longevity and size of its soil seed bank.

Materials and methods

In Experiment I dandelion (*Taraxacum officinale* F. Weber.) seeds were collected on semi-natural meadows in June 2000. Air dried seeds were stored at external temperature for two months. In August 2000 we buried dandelion seeds in 10 netlike bags (each contained 100 seeds with 10 cm^3 soil) at 5 cm and in 10 netlike bags at 10 cm depth. The seed germination rate was determined before the burial and after 1, 4, 7, 10, 16 and 22 months of burial. In appointed time we dig up 2 bags with the buried dandelion seeds, one from 5 cm and one from 10 cm depth. The germination tests were carried out in petri dishes where 50 seeds were sown on filter paper moistened with distilled water. Petri dishes of both treatments in two replicates were placed in a growth chamber with 16 hours day-length. The temperature was 25 °C during the day, 15 °C at night. Germinated seeds were counted and removed after seven and fourteen days. Means of the percentage germination are given with the standard error of the mean (SE) and differences between time and depth of burial was tested by Tukey HSD test ($P < 0.05$). Experiment II was carried out on semi-natural grassland at Rače near Maribor (46°26'15" N, 15°32'46" E, 262 m asl), in north-east Slovenia. Before the trial, the sward was used for four cuts annually. The viable seed bank was sampled within this meadow, as detailed below. Seed bank samples were taken in April 2000, before seed dispersal had begun. 150 soil cores were collected at three different depths 0–5 cm, 5–10 cm and 10–15 cm using a soil corer with a diameter of 5 cm. This produced samples corresponding to a soil surface of about 3000 cm^2 and to a soil volume of 15 litres. The soil samples were concentrated using the bulk reduction method. By doing so, rhizomes and roots were eliminated from the samples. The samples in two replicates were spread in separate trays into layers with a thickness of 1 cm, overlying a layer of sterilized sand with a thickness of 5 cm. At the end of April 2000, the samples were placed in a safe place to protect them against the wind and rain and to prevent them from contamination by wind-borne seeds. The place allowed natural daily temperature fluctuations to promote germination. The trays were watered regularly and checked for seedlings on a weekly basis. If a seedling was not identifiable, it was transplanted into separate flowerpot and grown until identification was possible. The experiment was terminated in April 2001, after no new seedlings emerged.

One-factorial analysis of variances was performed to assess the effect of soil depth on the mean number of dandelion seeds.

Results and discussion

The dandelion seeds showed pre-burial germination rates varying from 74 % to more than 82 %, in accordance with Falkowski *et al.* (1989), who reported a germination rate of 80 to 90 %. The germination percentage of dandelion seeds buried at 5 cm was not significantly different from those at 10 cm. At 5 cm depth the germination rate decreased from 73 % in December 2000 (after 4 months) to 19 % in June 2002 (22 months) while at 10 cm decrease from 70 % in December 2000 to 38 % in June 2002 (Figure 1).

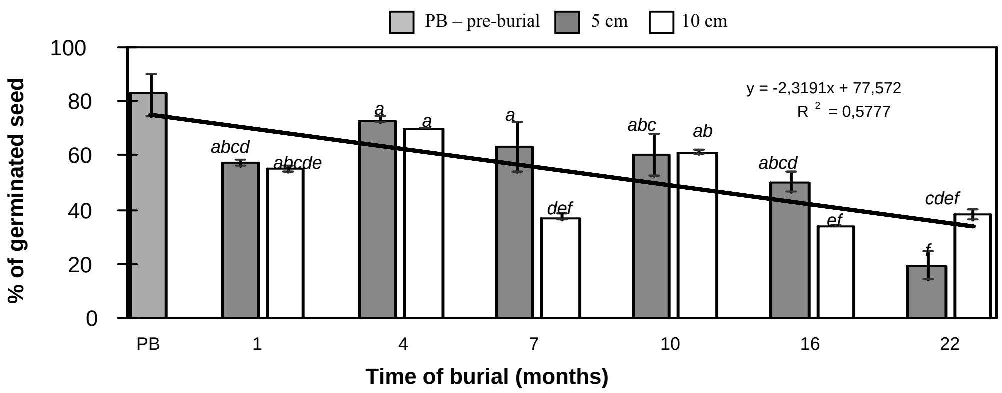

Figure 1. Germination rate of dandelion seeds (*Taraxacum officinale* F. Weber.) after several months of burial 5 or 10 cm below the soil surface. Means followed by the same letter are not significantly different ($P < 0.05$). Vertical lines on columns signify the standard error.

Combination of depth and time of burial (interaction between those two factors) had strong effect on the germination rate (Figure 1). A simple regression of germination rate against the time of burial revealed a negative slope with $R^2 = 0.58$ (Figure 1). At both depths the percentage of seeds germinated after several months of burial was significantly lower than the pre-burial percentage. In our experiment, after almost two years of burial, the germination percentage was low (28.5 %). There are varying reports on the viability of dandelion seeds after burial (Roberts and Nielson, 1981; Burnside *et al.*, 1996). But in the present study it is clear that the dandelion seeds could be classified as short-term persistent seeds. This statement is similar to that in the Thompson *et al.* (1997) database.

The total number of seedlings of all present seeds and the number of emerged dandelion seeds from the soil samples and per m^2 are given in table 1. The highest average number of emerged dandelion plants from soil samples was obtained in the top 5 cm of soil (180 plants m^{-2}). In two other layers the lower number (132 plants m^{-2}) of emerged dandelion plants was established. Patterns for dandelion seed density per m^2 were similar to those for seed per pooled sample and did not significantly differ between depths. The vertical distribution of dandelion seeds in the meadow soil suggested that dandelion seed bank is slightly greater in the upper soil layer what is comparable to the results of Champness and Morris (1948).

Table 1. Total number of seeds and number of seeds of dandelion (*Taraxacum officinale* F. Weber.) at the three different depths (mean ± standard deviation).

	Depth (cm)			Significance
	0-5	5-10	10-15	
Total number of seeds (m^{-2})	16098 ± 51	13092 ± 68	14394 ± 61	n.s.
Total number of seeds per soil sample	671 ± 10	546 ± 14	600 ± 12	n.s.
Number of dandelion seeds (m^{-2})	180 ± 11	132 ± 6	132 ± 10	n.s.
Number of dandelion seeds per soil sample	8 ± 2	6 ± 1	6 ± 2	n.s.

n.s.: not significant

Conclusions

After almost two years of study we can conclude that the viability of dandelion seeds buried at different depths in sward decreases with the time of burial. There is also a tendency that the seeds of dandelion keep the higher germination rate for the longest time if they are buried deeper in the meadow soil. The vertical distribution of dandelion seeds in the meadow soil suggests that dandelion seed bank is greater in the upper soil layer.

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Seed banks of native pastures of the Ragusa Plateau in relation to crop rotation

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Abstract

The native pastures of the Ragusa Plateau (Sicily, southern Italy) play a major role in the animal husbandry economy of the country. The present paper aims to explore the relationships between the seed banks and the vegetative cover of the native pasture. In two representative pastures of the Ragusa Plateau with a different previous crops (pasture after grain in Canalicci, two years pasture in Castiglione) the following characteristics were evaluated: seed banks, number and type of appearing plants, vegetative cover. Compared to Canalicci, Castiglione showed a more relevant seed bank and an interesting correlation between the number of appearing plants and the quantity of seeds in the soil for some of the main studied families. Analysis of the vegetative cover of the main families showed a constant ratio between the different families in Canalicci and a large increase in *graminaceae* in Castiglione during the vegetative season.

Keywords: native pasture, Ragusa Plateau, seed banks, vegetative cover, crop rotation

Introduction

The Ragusa plateau is characterized by a Mediterranean climate, an average altitude of 450 m asl and shallow soil depth (less than 50 cm). The native pasture on this plateau makes a substantial contribution to forage supply for animal husbandry. In rotation with winter grain and forage crops, the pastures are characterized by a grassy surface in which herbs (mainly consisting of annual species) grow spontaneously (Gresta *et al.*, 2003). These pastures are subjected to a high rate of utilisation, because of intensive grazing of livestock (Foti, 1973). The aim of the present research was to study the quantity of seed in the seed banks and its relationship with the appearing plants under different rotations, in order to develop efficient methods of identifying appropriate crop managements and crop sequences.

Materials and methods

The trials were carried out in two representative sites of the Ragusa native pasture at an altitude of 600 m asl: Canalicci (pasture after grain) and Castiglione (two years pasture). The seed banks present at three depths in the soil (0-5, 5-10, 10-15 cm) were assessed. The soil samples were replicated six times and mixed in order to satisfy the minimum value of 500-600 cm^3 stipulated by Hayashi and Numata (1971). The soil samples were sieved through a steel net with a pore size of 250 μm and rinsed with a water jet. The seeds were separated and identified following Benvenuti *et al.* (2001). During the vegetative season, the number of appearing plants was counted, separately for each plant family, on an area of 1 m^2 replicated four times. In addition, the floristic composition was determined following the Braun-Blanquet (1964) method to evaluate the vegetative cover of the pasture.

Results and discussion

The seed bank per m^2 was higher in Castiglione than in Canalicci in total (20,065 m^{-2} compared to 12,609 m^{-2}) and at 0-5 cm soil depth (Table 1).

Table 1. Seed banks (seeds per m^2) in the two sites at three soil depths.

	Canalicci				Castiglione			
Families	0-5cm	6-10 cm	11-15 cm	Total	0-5cm	6-10cm	11-15cm	Total
Leguminosae	650	100	150	900	550	50	100	700
Graminaceae	100	50	0	150	4,403	0	0	4,403
Compositae	300	250	0	550	900	50	0	950
Cruciferae	200	250	200	650	4,803	150	0	4,953
Other families	4,553	4,103	1,701	10,357	6,104	1,601	1,351	9,056
TOTAL	5,804	4,753	2,051	12,609	16,762	1,851	1,451	20,065

Generally, the most representative species in the seed banks at both sites could be categorised as ‘other families’ (10,357 in Canalicci and 9,056 in Castiglione). *Leguminosae* were higher in Canalicci than in Castiglione (900 and 700, respectively), while *graminaceae* and *cruciferae* were much more prevalent in Castiglione. At both sites, the quantity of seeds in the soil decreased with depth. In particular, *graminaceae* and *compositae* seeds decreased to zero at the greatest depth (11-15 cm) in both sites. The seed bank values of first depth (0-5 cm) were not correlated with the number of plants appearing in the pasture after grain (Canalicci), whereas a strong relationship was observed in the two years pasture (Castiglione) (Figure 1).

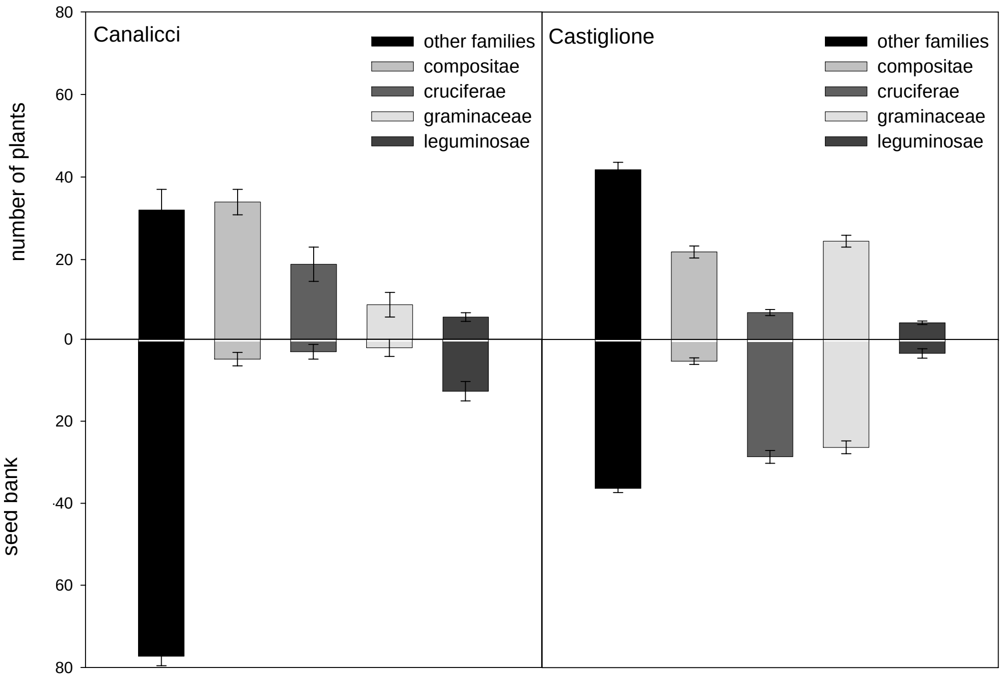

Figure 1. Relative number of plants of the different families in the pasture (%) and of seeds (%) in the first soil depth (0-5 cm) in the two different sites. Vertical bars indicate standard error.

In Canalicci, the relative importance of the ‘other families’ and *leguminosae* was greater in the seed bank than in the pasture (respectively 77.3 % and 32.0 % for the ‘other families’, 12.7 % and 6.1 % for the *leguminosae*), whereas the number of appearing plants in the *compositae*, *cruciferae* and *graminaceae* was underestimated by their presence in the seed bank.

In Castiglione, the seed bank presence of the ‘other families’, *graminaceae* and *leguminosae* was strongly correlated with their appearance in the pasture (36.6 and 41.8 %. 26.3 % and 24.5 %. 3.4 % and 4.7 % respectively). A weaker correlation was observed for the *compositae* and *cruciferae* (5.3 % and 28.6 %. 28.6 % and 7.2 %).

In Canalicci no relevant variations were registered in the ratio of the different families over time (Figure 2). The *compositae* were always predominant compared to the other families, with values between 364 and 407 g kg^{-1}. In Castiglione, the *graminaceae* showed a large increase after the end of February (from 305 to 540 g kg^{-1}), with a simultaneous reduction in the abundance of all the other families.

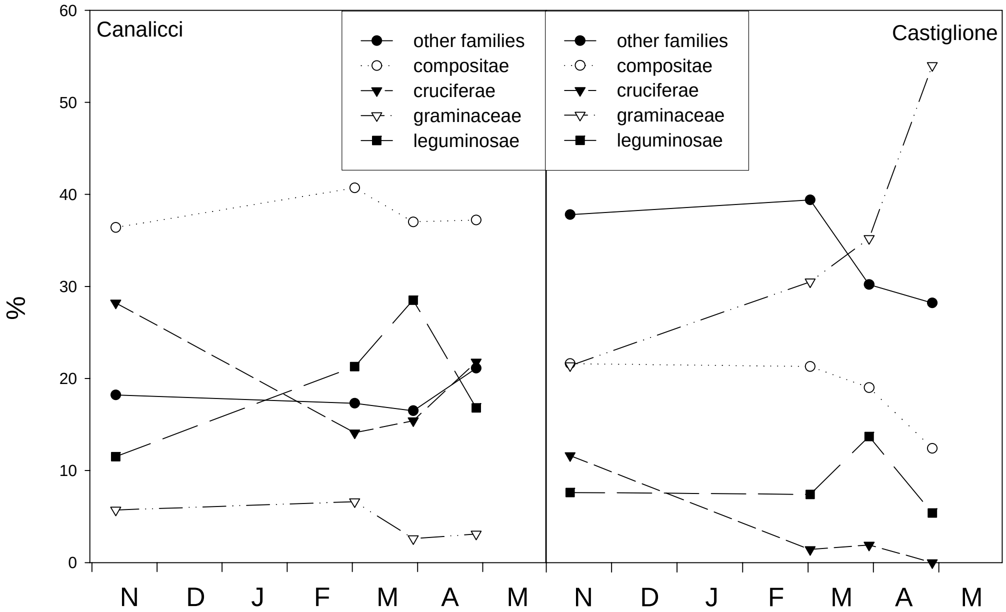

Figure 2. Trend of percentage cover of the main botanical families in the two sites.

Conclusions

The number of seeds in the 'two years pasture' site (Castiglione) was higher and much more correlated with the subsequent appearance of plants than in the 'pasture after grain' site (Canalicci). Annual variation in vegetative cover was comparatively small in Canalicci, whereas Castiglione showed a large increase in *graminaceae* and a corresponding decrease in all the other families. The improvement of evaluation techniques can lead to a better knowledge of the composition of the seed banks and its effects on vegetative cover. Consequently, it could be possible that oversowing of local species could be used to obtain a balanced native pasture.

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Revegetation of a marble quarry with native subalpine grasses in North-East Italy (Venetia)

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Abstract

In 1998, an abandoned excavated area of a white marble quarry was filled with rocky materials, covered with a stratum of local meadow soil and revegetated by sowing seven native grasses and six commercial legumes. Our trial included 15 treatments (3 binary grass-legume associations, 4 multispecies grass-legume mixtures and 8 pure stands) in a randomized complete block design, with 4 replicates. The plot size was 4.5 m^2. On average the 5-year experiment has shown satisfactory results for almost all treatments. There was a high final total ground cover by sown and volunteer species (mean of 90 %, with 75 % of sown species) for grass pure stands, binary associations and mixtures. Weeds and native species started to develop slowly in the plots three years after the seeding. A great number of the treatments provided a high total DM-yield ranging from 35 to 43 t ha^{-1} for the 5 years. The revegetation of such disturbed area proved to be successful due to the good performances of six out of seven native species and of white clover and alfalfa *Amerigraze*.

Keywords: grassland, native grasses, commercial legumes, marble quarry, revegetation

Introduction

The main income of the subalpine Upland of the Seven Communes of Vicenza province, Venetia, is derived from tourism, cheeses, timber and marble. The Upland is an important dairy producing district with over 42,000 ha grassland and many scattered red and white marble quarries at different altitudes. Such excavated areas, according to the Venetian Regional Law no. 44/1982, must be filled, shaped and revegetated after exploitation. A well-adapted vegetation of native species is needed to achieve a permanent grassland cover (Krautzer, 1996; Urbanska, 1997). The objectives of our research work were to create a suitable habitat for rapid establishment of some native grasses, associated with selected commercial legume varieties (Paoletti *et al*., 2000), and then to study the development of the re-established swards.

Materials and methods

A revegetation trial was carried out over a 5-year period at the medium-altitude summer farm of 'Bertiaga' near Asiago (1,001 m, lat. 45°52'N, long. 11°30'E, mean annual rainfall 1,500 mm, sandy loam soil, pH 6.3). Seven native grasses and six commercial legumes were sown (Table 1). The adopted seed rate was 60 kg ha^{-1} for 8 pure stands, except timothy (30 kg), and the same total amount or less, according to species, for the other 7 treatments, i.e., 4 multispecies mixtures and 3 binary associations. The treatments were established (June 1998) in four replicates in a randomized complete block design. The plot size was 1.5 m × 3.0 m, and rows were 12 cm apart. An NPK mineral fertiliser was applied prior to seeding and N was broadcast after each cutting (low rate). During the trial the following data were recorded: plant establishment, ground cover of sown and volunteer species, sward height, heading or flowering time of sown species, dry matter yield (DMY) and change in the botanical composition with time. The main results concerning initial and final ground cover, total DMY and botanical composition are summarized here. The significance of differences in ground cover, after angular transformation, and in DMY was tested by Anova at $P \leq 0.05$.

Table 1. Name, origin and breeder or/and maintainer of the established grasses and legumes.

Species	Populations/ Cultivars	Origin	Breeder or/and Maintainer
a) Grasses[1]			
Dactylis glomerata L.	*dg1*	Alt. 7 Comuni, Asiago (I)	ISCF (Lodi, Italy)
Dactylis glomerata L.	*dg16*	Alt. 7 Comuni, Asiago (I)	ISCF (Lodi, Italy)
Festuca pratensis H.	*fp1*	Alt. 7 Comuni, Asiago (I)	ISCF (Lodi, Italy)
Lolium perenne L.	*lp1*	Alt. 7 Comuni, Asiago (I)	ISCF (Lodi, Italy)
Festuca gr. rubra L.	*fr1*	Alt. 7 Comuni, Asiago (I)	ISCF (Lodi, Italy)
Phleum pratense L.	*pa1*	Alt. 7 Comuni, Asiago (I)	ISCF (Lodi, Italy)
Phleum pratense L.	*pp1*	Alt. 7 Comuni, Asiago (I)	ISCF (Lodi, Italy)
b) Legumes[2]			
Lotus corniculatus L.	*Leo*	Biasion, Bolzano (I)	McDon. (Bellevue, CDN)
Medicago sativa L.	*Amerigraze 401+z*	ABI, Ames (USA)	J.Bouton (Athens, USA)
Medicago sativa L.	*Lodi*	Continental, Traversetolo (I)	ISCF (Lodi, Italy)
Trifolium pratense L.	*Marino*	Ceccato, Tombolo (I)	NPLembke (Holtsee, D)
Trifolium repens L.	*Alice*	Sivam, Casalpusterlengo (I)	IGER (Aberystwyth, UK)
Trifolium repens L.	*Gigante Lodigiano*	CAP, Cuneo (I)	MiPAF (Rome, Italy)

[1] Natural populations from the Upland of the Seven Communes (Asiago, VI, North-East Italy).
[2] Cultivars in table 2: *Leo*=lc, *Amerigraze*=msc1, *Lodi*=msc2, *Marino*=trp, *Alice*=trr1, *Gigante Lodigiano*=trr2.

Results and discussion

Almost all the treatments established well. The initial percent ground cover of sown species was high for most treatments whereas the mean value after five years showed a remarkable decrease in the contribution of sown species from 84 to 75 % (Table 2).

Table 2. Initial (IGC) and Final Ground Cover (F1GC and F2GC)[1] in % for the treatments.

Treatments[2]	IGC	F1GC	F2GC
1 - dg1	95 abc[3]	88 ab	92 a
2 - dg16	97 a	87 ab	90 abcd
3 - fp1	90 abcd	89 ab	91 ab
4 - fr1	23 f	64 f	90 abcd
5 - msc1	76 d	37 g	87 e
6 - msc2	54 e	15 h	88 de
7 - pa1	86 cd	82 de	88 de
8 - pp1	92 abc	80 e	89 cd
9 - dg16/msc1	94 abc	89 a	91 abc
10 - pa1/msc1	88 bcd	64 f	91 ab
11 - pp1/trr1	92 abc	85 bcd	89 bcd
12 - pa1/lc/trr2/trp	95 ab	83 cde	89 bcd
13 - lp/fp1/fr1/lc/msc2	91 abc	87 ab	91 abc
14 - pp1/fr1/lp1/trr1/trp/lc/msc2	94 abc	86 abc	89 bcd
15 - dg16/fr1/lp1/fp1/trr1/trp/lc/msc1	94 abc	89 a	89 cd
Mean	84	75	90

[1] F1GC is meant for seeded species, only, and F2GC both for sown and volunteer species.
[2] The legend of the treatments is indicated in table 1.
[3] Values in the same column not followed by the same letter are significantly different at $P \leq 0.05$.

Among the 15 treatments three grass pure stands, three multispecies mixtures and two binary associations still displayed satisfactory values (F1GC ≥ 85 %). The total ground cover of sown and volunteer species (F2GC) ranged from 87 to 92 % (mean of 90 %). During the trial progressively more species were recorded in the plots. The most frequent volunteer species were *Taraxacum officinale* Weber, *Achillea millefolium* L., *Trifolium repens* L. and *Plantago lanceolata* L. The total DMY of the 15 treatments ranged from 35 to 43 t ha^{-1} over the 5 years (Figure1).

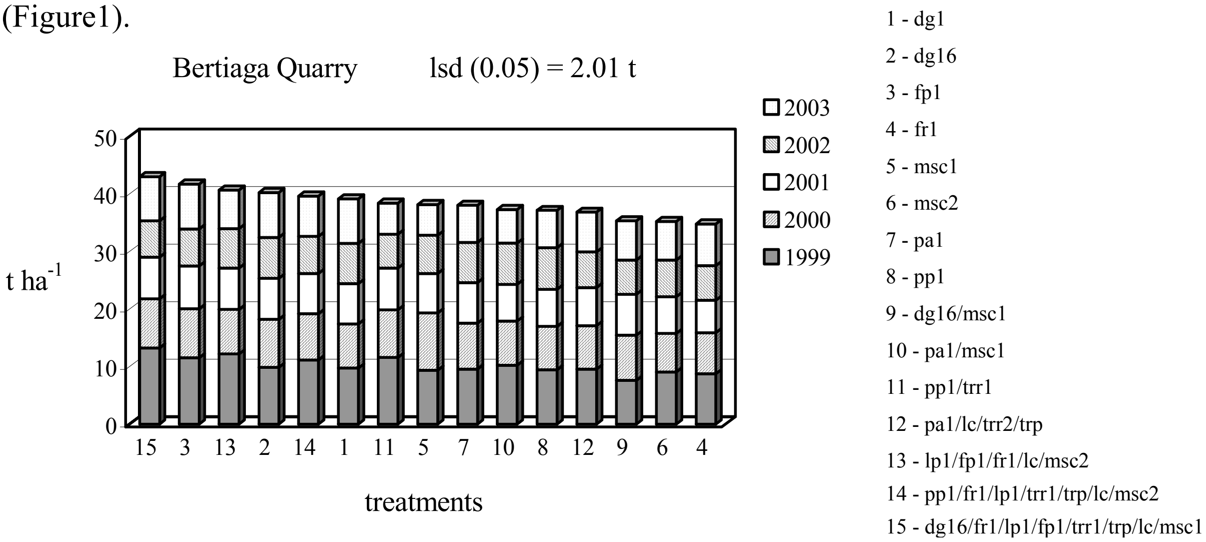

Figure 1. Annual and cumulated 1999-2003 forage DMY (t ha^{-1}) for the 15 treatments (the legend of the treatments is indicated in table 1).

Two of the multispecies mixtures and two pure grass stands provided the highest DMY (> 40 t). The layer of good meadow soil covering the filled quarry top favoured the establishment of both grasses and legumes. The quality of some legume varieties and native subalpine grass seeds was very effective for revegetation purposes. The trial has shown a satisfactory vegetation establishment in almost all the treatments. In particular, five natural grass populations (*fp1*, *pa1*, *pp1*, *dg1* and *dg16*) from the Upland and three legume cultivars (*Amerigraze 401+z*, *Alice* and *Gigante Lodigiano*) performed well with regard to ground cover and/or DMY.

Conclusions

Such results show that it is possible to revegetate any quarry areas and degraded pastureland in our mountain districts successfully. The availability of adequate amounts of seed of suitable native grasses and legume cultivars is at present a fundamental key strategy. In the near future further seed collection, followed by bio-agronomic evaluation and seed development, will provide more native legumes. These species should be very useful for revegetating disturbed areas, to conserve biodiversity and to maintain the original productive functions.

Acknowledgements

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Evolution of anti-erosion revegetation carried out with herbaceous commercial species in North-Eastern Italy

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Abstract

Botanical surveys were carried out in the years 1994, 1995 and 2000 on a landslide and on a former gravel quarry located at about 1,000 m asl on calcareous substrates. Commercial varieties of herbaceous plants had been sown at both sites in the early ninety's. The aim was to evaluate the changes in the artificial plant cover created by the revegetation and the establishment of native species. The growth of the sown species resulted in high vegetation cover, which had an anti-erosion effect. Nevertheless, in the more difficult situations (high slope and southerly aspect), the herbaceous cover decreased progressively, leaving the soil partially uncovered. This apparently negative situation favoured the invasion of native species which were almost completely excluded in the dense and high growing herbaceous stands of other sites (low slope, north aspect).

Keywords: revegetation, commercial seed, native species, erosion

Introduction

In the Alps, seeds of herbaceous forage or turfgrass species are often used for the revegetation of steep, bare areas. This plant material usually possesses good settlement capacity and anti-erosion efficiency but can also lead to environmental problems. For example, it can genetically contaminate the local plant populations or it can form dense artificial stands, which prevent the return of the native species and vegetation (Millar and Libby, 1989). This paper presents the results of a study on the vegetation changes in two revegetated sites.

Materials and methods

The sites were the landslide Gravon and the ex-quarry Celado, which are described in table 1 (more information is available in Scotton *et al*., 2000). The surfaces were revegetated in 1993 (Gravon) and in 1991 (Celado) by the public services of Trento Province. The commercial mixtures of herbaceous plants sown at both sites contained the species shown in table 2, with exception of *Lolium multiflorum*, which was sown only on Gravon. Other sown species, which had nearly disappeared before our botanical surveys, were *Agrostis tenuis*, *Festuca arundinacea*, *F. pratensis*, *Lolium perenne*, *Medicago lupulina*, *Plantago lanceolata*, *Poa compressa*, *P. pratensis*, *Trifolium hybridum*, *T. repens* and, only in Gravon, *T. dubium.* Shrubs and trees were also planted.
Botanical surveys took place during 1994, 1995 and 2000, on respectively 9, 10 and 6 sampling areas of 100 m^2 at Gravon and on 6, 6 and 8 sampling areas at Celado. We estimated visually the cover of the herbaceous, shrub and tree layers and of individual species, coming

Table 1. Main characteristics of the revegetation sites (sand, silt and clay are in % of the soil sieved at 2 mm).

Revegetation	Substrate	Elevation (m asl)	Slope (%)	Aspect	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
Landslide Gravon	Calcareous moraine	1,000-1,070	65	North-Eastern	60	81.5	16.7	1.8
Ex-squarry Celado	Clayey limestone	1,160-1,220	72	South-Western	82	64.9	24.5	10.5

either from sowing and planting or from the surrounding natural vegetations. Species were identified and named according to Pignatti (1982). In this contribution, only data of the herbaceous layer are considered.

Results and discussion

The vegetation cover reached 74 to 97 % on average (Table 2). Considering that erosion evidence was never found, such values appear to be able to guarantee effective soil protection. During the years, the herbaceous cover increased at Gravon and decreased at Celado. In 2000, 6 to 9 years after the revegetation, we can assume that the site characteristics had enough time to influence the growth of the sown species. At this time the cover depended mainly on aspect and slope (Figure 1 and 2), whose joint effect is described by the following regression (obtained using a stepwise model that utilised the pooled observations from Gravon and Celado): % cover = 87.9 + 0.34626 x Aspect - 0.0068 x Slope^2 (significant at $P < 0.01$; $R^2 = 0.84$, n = 14).
(aspect is given in ° of declination from South to East or to West and Slope in %).
The northerly aspect and the lower slope of Gravon (Table 1) are reflected in an higher vegetation cover compared to Celado (Table 2).
At Gravon, the species responsible for the increase in cover are the relatively mesophilous perennial grasses such as *F. rubra* and *D. glomerata* (Table 2). At the same time, the cover of the short-lived grass *L. multiflorum* and of some legumes (*M. sativa* and *T. pratense*) decreased. Among the legumes, only *M. alba*, with its great growing and dissemination

Table 2. Evolution of the herbaceous layer in Gravon and Celado (species and species groups covers are referred to 100 %, + indicate values less than 1 %).

Site	Gravon			Celado		
Year	1994	1995	2000	1994	1995	2000
Vegetation cover (%)	82.3	81.8	96.8	96.0	93.3	74.4
% cover of sown species	92.3	95.2	96.6	84.0	84.6	92.8
% cover of spontaneous native species	7.7	4.8	3.4	16.0	15.4	7.2
Number of sown species	11.4	12.4	10.7	14.2	15.5	11.0
Number of spontaneous native species	4.0	2.2	1.3	4.7	5.2	8.0
Grasses cover (%)	57.4	22.6	61.2	36.0	31.9	79.9
Legumes cover (%)	35.9	71.4	38.7	35.5	42.9	14.7
Other families cover (%)	6.7	6.0	0.1	28.5	25.1	5.4
Medicago sativa	5.2	3.1	2.0	5.6	5.9	+
Lolium multiflorum	32.7	1.8	.	.	.	.
Festuca rubra	18.5	8.4	37.3	2.2	1.8	2.0
Melilotus alba	6.0	35.6	27.6	+	2.6	5.2
Melilotus officinalis	2.5	18.7	+	+	3.6	.
Trifolium pratense	14.3	8.4	+	+	1.0	+
Dactylis glomerata	+	1.9	14.7	+	+	+
Achillea millefolium	+	1.0	+	11.1	9.6	+
Sanguisorba minor	+	0.7	+	5.1	3.9	+
Lotus corniculatus	1.7	1.5	3.0	6.5	7.6	+
Festuca ovina	1.1	3.9	.	4.0	3.7	21.2
Bromus erectus	.	+	+	5.6	5.7	34.1
Festuca ovina duriuscula	.	+	1.2	9.0	8.6	6.4
Bromus inermis	.	.	1.4	7.5	5.3	10.2
Onobrychis viciifolia	.	1.2	+	7.3	6.1	+
Coronilla varia	.	.	.	11.1	11.6	2.9
Anthyllis vulneraria	.	.	+	2.1	2.8	2.1
Other species	16.5	13.4	11.7	21.3	19.6	12.5

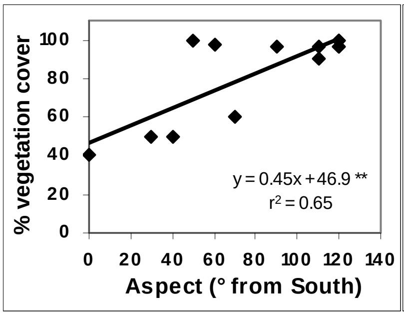

Figure 1. Effect of aspect on herbaceous plant cover in Gravon and Celado (data 2000) (** = significant at the 0.01 level).

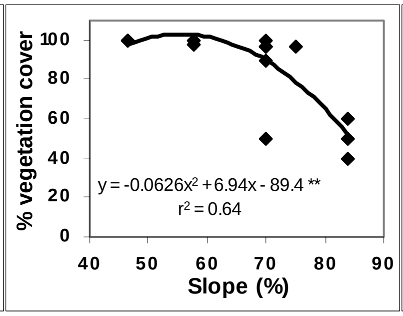

Figure 2. Effect of slope on herbaceous plant cover in Gravon and Celado (data 2000) (**, see Figure 1).

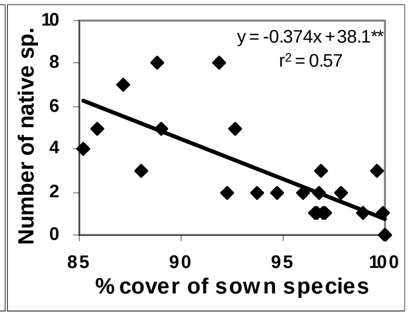

Figure 3. Relation between number of native and cover of sown species in Gravon (data 1994, 1995 and 2000) (**, see Figure 1).

potential, was able to maintain a high cover. At Celado, where the site conditions were more difficult, most legumes decreased during the years. In addition, the most abundant grasses, *Bromus erectus* and *Festuca ovina*, were not able to completely cover the soil, though they showed greater competitiveness on the drier substrates of Celado than in Gravon.

The sown species increased between 1994-1995 and 2000 at both sites. After 6-9 years, they made up 84 to 97 % of the herbaceous cover (Table 2). The number of sown species varied from 10.7 to 15.5. The number of spontaneously spread native species changed differently at the two sites, decreasing at Gravon and increasing at Celado. At Gravon the closing of the canopy by the sown species and their high growth progressively excluded the initially present native species. This hypothesis appears to be confirmed by the negative relationship between the cover of the sown species and the number of spontaneously spread native species (Figure 3). At Celado, the lower cover and growth of the sown species makes possible the ingression of the native species, whose number tends to increase. In this last case, the low competition exerted by the commercial species, which grew less and almost never completely covered the soil, explains why we didn't find results similar to those at Gravon (Figure 3).

Conclusions

At these sites, the use of mixtures of commercial varieties of herbaceous species resulted in relatively high cover, which was able to protect the soil against erosion. In the site characterised by high slope and south aspect (Celado), the vegetation cover tended to decrease with time leaving the soil partially uncovered, as already found by Scotton *et al*. (2000). This apparently negative situation allowed the ingression of native species and evolution toward natural vegetation. In the dense and high-growing herbaceous stands found at the more favourable site (Gravon), native species were clearly stopped.

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Grassland cover on erosion-endangered land

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Abstract

The field trial with eight different treatments was established in spring 1997. The experimental site is situated near Banská Bystrica (Radvan, 460 m asl, slope inclination 6°). The soil is a *cambisol*, clay type. The long-term average of annual rainfall is 819.5 mm (431.5 mm during the growth season) and annual temperature 8.0 °C (14.3 °C during the growth season). A seven component grass/clover mixture sown at full (38 kg ha^{-1}), 50 and 33 % seed rate was compared to grass self-regeneration and harvested in 2-3 cuts or 3-5 cuts. Results confirm that the most erosion endangered soils were those left bare. In the first growth season and during winter sown seed mixture was essential for erosion control. In the first year (1997) treatments at the full seed rate were the most effective in erosion control of arable land. In the second year (1998) there were no significant differences between different seed rates in relation to erosion control. During the following years (1999-2002) the swards became well established and the soil was covered and protected against erosion in all treatments, including grass self-regeneration.

Keywords: erosion, grass/clover mixture, seed rate, grass self-regeneration

Introduction

In some regions of Slovakia there are still some areas of arable lands susceptible to water erosion and their grass self-regeneration is a need from both agricultural and environmental points of view. The aim of this study was to compare the self-regeneration with some grass/clover mixtures at different seed rates for effectiveness in erosion control.

Materials and methods

A field trial including grass self-regeneration and a grass/clover mixture sown at different seed-rates was conducted at two annual cutting regimes at site Radvan (near Banská Bystrica, 460 m asl) from 1997 to 2002. Soil was cambisol, clay type (pH 6.8, humus content 3.75 %). The grass/clover mixture was composed of *Festuca arundinacea* (11 kg ha^{-1}), *Poa pratensis* (8 kg), *Festuca rubra* (3 kg), *Phleum pratense* (4 kg), *Dactylis glomerata* (4 kg), *Trifolium repens* (5 kg) and *Trifolium pratense* (3 kg). Seed rate of 38 kg ha^{-1} (treatments 4 and 8) was reduced to 50 % (treatments 3 and 7) and 33 % (treatments 2 and 6). Grass self-regeneration was represented by treatments 1 and 5. Treatments 1 to 4 were cut 2-3 times per year and treatments 5 to 8 were cut 3-5 times.
Immediately after sowing on 12 May 1997 the deluometers for measuring soil run-off were installed. Soil take-offs were collected, dried and weighed. Samplings of soil (take-off) were taken after the cuts. Botanical analyses were made each spring, summer and autumn from 1997 to 2002. The proportion of grasses, legumes, forbs and bare ground per m^2 were estimated visually. No fertilisers were applied during the first two years.

Results and discussion

Assessment of the soil take-offs (Table 1) showed the impact of both rainfall (Table 2) and self-regeneration on the development of erosion in the first (1997) and partially also in the second year (1998). The highest values were found in the self-regeneration treatments in 1997 and after heavy rainfall in 1998. There were no big differences in soil take-off between different seed rates and no soil take-off was measured in the following years 1999-2002, the sward being then well established, and without bare spots.

Table 1. Effect of seed rate and cutting regimes on soil run-off (t dry weight ha^{-1}) in 1997 and 1998.

Treatment	Samplings 1997				Samplings 1998			
	I.	II.	III.	Sum	I.	II.	III.	Sum
1 – Self-regeneration (2-3 cuts)	2.72	5.68	0.64	9.04	2.83	-	1.01	3.84
2 – 33 % seed rate (2-3 cuts)	1.56	2.88	0.28	4.72	0.35	-	-	0.35
3 – 50 % seed rate (2-3 cuts)	1.28	2.68	0.20	4.16	0.19	-	-	0.19
4 – 1000 % seed rate (2-3 cuts)	0.32	0.60	0.08	1.00	0.09	-	-	0.09
5 – Self-regeneration (3-5 cuts)	2.80	5.52	0.72	9.04	2.37	-	0.92	3.29
6 – 33 % seed rate (3-5 cuts)	1.64	2.76	0.32	4.72	0.27	-	-	0.27
7 – 50 % seed rate (3-5 cuts)	1.36	2.16	0.20	3.72	0.09	-	-	0.09
8 – 100 % seed rate (3-5 cuts)	0.36	0.80	0.08	1.24	0.07	-	-	0.07

Table 2. Rainfall (mm) at the experimental site Radvan in 1997 and 1998.

Year	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Apr.-Sept.	Annual
1997	25.5	48.2	20.4	39.0	47.9	113.2	144.8	44.0	13.9	38.2	181.9	48.8	402.8	765.8
1998	31.8	2.6	33.4	99.2	47:8	65.5	59.7	33.8	188.8	179.8	53.0	34.3	494.8	829.7

Sward botanical composition (Table 3) in the first two years was in accordance with measurements of soil take-offs: the highest percentage of bare spots and forbs was found in the self-regeneration treatments. High proportions of legumes were observed in all ‘sown’ treatments in 1997 (65-85 %) but only in the 2-3 cuts regime in 1998 (70-72 %). In the 3-5 cut system the proportions of legumes was lower (42-57 %) in 1998. Proportion of forbs was low (2-6 % in 1998) in ‘sown’ treatments; the self-regeneration treatments were dominated by *Polygonum aviculare* in 1997 and *Taraxacum officinale* in 1998. *Elymus repens* was a dominant grass weed in grass self-regeneration treatments in both years.

Table 3. Effect of the treatment (see table 1 for the legend) on botanical composition (%) in 1997 and 1998.

Treatment	September 1997				September 1998			
	grasses	legumes	forbs	bare spots	grasses	legumes	forbs	bare spots
1	15	14	41	30	55	20	20	5
2	25	65	4	6	28	70	2	0
3	22	78	+	0	26	72	2	0
4	23	75	2	0	27	71	2	0
5	30	5	33	32	60	20	17	3
6	25	65	5	5	52	42	6	0
7	23	73	1	3	48	50	2	0
8	15	85	0	0	40	57	3	0

Conclusions

Water erosion can be expected on land of inclination 5° and more (Zachar, 1970). Our results show that developing a grass cover, even with a reduced seed rate, can satisfactorily control erosion and create a dense sward of good quality, according to the observations of Michalec *et al*. (2003).

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Comparison of mixtures for revegetation of ski slopes in North Italy

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Abstract

Revegetation of ski slopes is important for technical and environmental reasons. Commercial mixtures composed of forage species are generally used, even if some authors support the use of native or adapted species to enhance the success of restoration. The work reports data obtained from an experimental trial in a ski slope located on a calcareous scree in North Italy (Sappada, eastern Alps) in which three mixtures, differing in seed cost and composition, were tested. A variable amount of two unconventional (introduced) species (*Anthyllis vulneraria* and *Plantago lanceolata*) was added to each mixture, resulting in different seeding rates. Data were collected to evaluate the behaviour of tested mixtures in establishing and maintaining artificial canopies. Results show differences between the mixtures, while no significant effect was found between the seeding rates. Addition of unconventional species to the original mixtures seem to affect the botanical composition but not the total ground cover. Thus, the use of these unconventional species should be well evaluated in advance because of the high cost of their seeds.

Keywords: ski slopes, revegetation, seeding rate, ground cover, native species

Introduction

Revegetation of ski slopes (as well as other areas degraded by human activity) is a very important technique to prevent soil erosion, to refit the slopes back into the original landscape and to reduce the environmental impact of their construction (Argenti *et al.*, 2002). Mixtures of forage species composed mainly of grasses are commonly used (Krautzer, 1996), even if difficulties in their establishment can occur due to unsuitability to severe local conditions (Ruth-Balaganskaya and Myllynen-Malinen, 2000). To reduce these failures and to enhance from the beginning the process of restoring vegetation, the use of unconventional species adapted to local conditions or capable of rapid establishment is recommended. That should lead, in the mid-long term, to a complete integration of revegetated areas into the surrounding environment (Dinger, 1997), even if in these cases some problems can arise due to higher cost of the restoration. In this work some results from a revegetation trial carried out on a ski slope in North Italy concerning mixtures differing in composition and including unconventional species are reported.

Materials and methods

The trial site is located at Sappada (a ski resort in Veneto, North Italy), in a ski slope running on a calcareous scree (altitude about 1,700 m asl, slope 25-30 %) characterised by a high content of gravel and low content of organic matter and nutrients. Three mixtures (M1, M2 and M3) differing in composition (from 3 to 13 species) and seed cost were tested. A variable amount of *Anthyllis vulneraria* and *Plantago lanceolata* (10 kg ha^{-1} or 40 kg ha^{-1} of each species) was added to a constant quantity of each mixture (270 kg ha^{-1}), resulting in two different seeding rate 290 (L) and 350 (H) kg ha^{-1}. Both species were already used in the area and established well in the first years. Experimental design was a completely randomised block with three replications and the plots size was 50 m^2. Stands were established by the so called ‘Schiechtl method’ that consists of sowing into straw previously scattered on the soil (at a rate of about 0.5 kg m^{-2}) followed by distribution of a bituminous solution. Fertilisation was 40, 120 and 120 kg ha^{-1} of N, P and K at sowing and 30, 28 and 45 kg ha^{-1} $year^{-1}$ of N, P and K for the first three years of the trial. Sowing date was on October 1999. Ground cover and botanical composition (according to Daget and Poissonet, 1969) were recorded during four growing seasons (summer 2000 to summer 2003).

Results and discussion

All of the mixtures performed well during the experiment, but M2 (composed mainly of forage species) was the most rapid to establish and always had the highest ground cover values (Table 1). M1 (comprising of only three species) performed similarly to M2 in 2001 and 2002. M3 (the most expensive) performed similarly to M2 only in 2001 but had lower values all other years. The trend of each mixture was almost the same, with increasing ground cover with time attaining particularly high values (more than 70 %) in the last two years. Differences in seeding rate were significant only at the beginning.

Table 1. Average ground cover (%) according to mixture and seeding rate in different years.

Mixture	2000	2001	2002	2003
M 1	59 b	60 a	73 a	73 b
M 2	65 a	63 a	76 a	78 a
M 3	59 b	57 a	70 b	72 b
Seeding rate	2000	2001	2002	2003
L	59 b	59 a	72 a	75 a
H	63 a	62 a	74 a	74 a

Values with the same letter are not significantly different for $P < 0.05$

For each mixture the botanical composition changed markedly during the four years of the trial (Figure 1). At the beginning the composition was similar for all tested mixtures, with a relatively high level of legumes and species belonging to other botanical families, mainly *Plantago lanceolata*. From the second year grasses increased gradually but definitely in M1 and M2, especially *Festuca rubra*, which was a major component in these mixtures. The components in M3 were always more balanced.

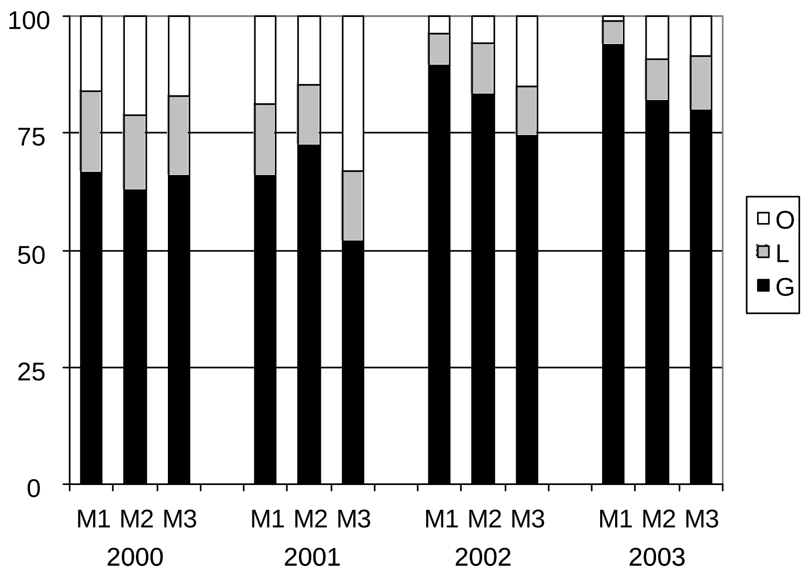

Figure 1. Botanical composition (G = grasses, L = legumes, O = other species) for each mixture in different years (average of the two seeding rates).

The proportions of the two added species (average of the three mixtures) for both seeding rates are presented in figure 2. As expected higher values were always found in H than in L, but differences tended to decrease during the experiment. Both species showed the same trend but with major differences in absolute values. *Anthyllis vulneraria* was more persistent, being recorded in the fourth year of the trial, but reaching a maximum value of about 10 % in the second year. *Plantago lanceolata* established rapidly, attaining a high level in the second year (more than 20 % as a maximum) but then disappeared from all plots.

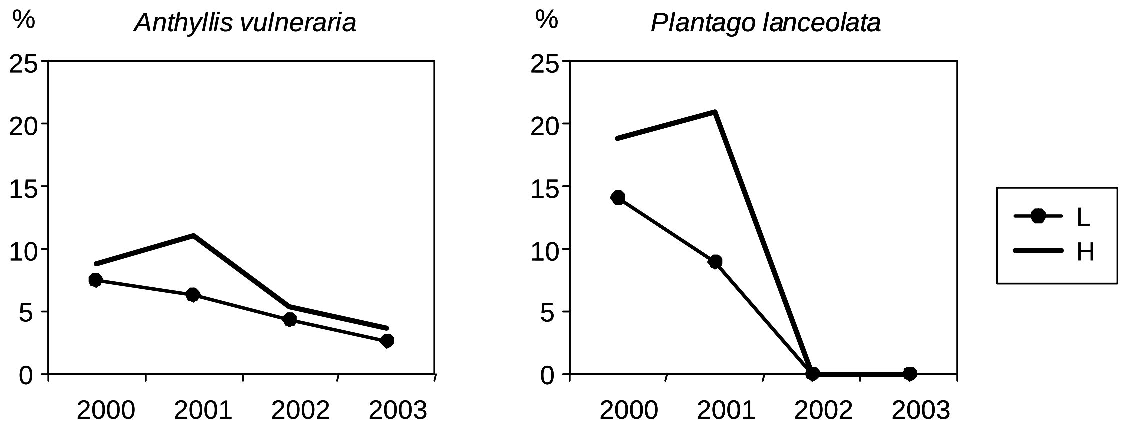

Figure 2. Percentage of added species for low (L) and high (H) seeding rate (average of the three mixtures).

Conclusions

All mixtures produced satisfactory results in the trial. However, differences between mixtures were recorded, economic and simple mixtures producing the highest performances in speed of establishment and ground cover. The most expensive mixture (M3) had the lowest ground cover but produced a better botanical composition. In fact use of very aggressive species (such as *Festuca rubra*, a very common grass in many commercial mixtures for revegetation) can create a canopy dominated by grasses with a strong competitive behaviour against native species. Seeding rate did not seem to affect the ground cover as expected (probably because of the high rates used in the experiment). Use of different amounts of added species to the original mixtures produced effects on botanical composition, but only at the beginning of the observation period. Our results show that the success of restoration, in terms of ground cover, can be achieved with very common forage species, especially under not very severe environmental conditions (i.e., at low altitude as in our case). The use of unconventional species must be well evaluated in advance due to the high cost of their seeds. Thus, the success of revegetation is very difficult to assess if the aims (ground cover, cost, recovery of natural vegetation) are not previously well identified.

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Evaluation of site-specific and commercial seed mixtures for alpine pastures

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Abstract

In most cases commercial seed mixtures containing varieties of lowland species are used for reseeding at high altitudes. However, in recent years, special seed mixtures containing a high percentage of site-specific species have become available on the market. Using data of the EU research project ALPEROS, commercial (SM1) compared to site-specific seed mixtures (SM2) were assessed on three sites at increasing altitude. Their suitability for reseeding alpine pastures was tested from an ecological as well as from an agricultural point of view. The use of site-specific species led to significantly better soil cover. Only the coverage achieved by SM2 could guarantee sufficient protection against erosion. Calculating the average energy yield of harvests in 2001 and 2002, the results showed a significant influence of altitude, but not of the seed mixture, on energy yield. Even though the concentration of metabolizable energy (ME) differed significantly between mixtures, only a slightly better forage quality was achieved by SM1.

Keywords: alpine pasture, seed mixture, restoration, site- specific species, energy yield

Introduction

Thousands of hectares are still machine-graded each year in the Alpine area for intensive road building, torrent and avalanche barriers as well as ski slopes and infrastructural measures. At increasing altitude, successful reseeding becomes increasingly more difficult due to the rapidly worsening climatic conditions. The first target function of restoration or reseeding in high zones is usually the achievement of stable grassland. This is particularly true in Austria, Switzerland and Bavaria, where most of those areas are used as pastures during summertime. For this reason, farmers' expectations for forage quality and yield are also valid for such reseeded areas. In this study, vegetation cover, dry matter yield, metabolizable energy and energy yield were assessed on three re-vegetated ski runs, comparing a widely used commercial seed mixture with site-specific seed mixtures containing species adapted to the prevailing climatic conditions, but also considered suitable for agricultural use (Krautzer *et al*., 2001).

Materials and methods

For four years, an international research project has been carried out by various institutes. At three sites, the pros and cons of site-specific compared to commercial seed mixtures were tested. At the locations Sudelfeld (SU, Bavaria, 1,245 m), Hochwurzen (HW, Styria, 1,830 m) and Gerlos (GE, Tyrol, 2,280 m), similar trials arranged as two factorial split-plot designs with plots of 21 m², replicated three times, were carried out from 1999 to 2002. As factor 1, two application techniques were used (AT1 = hydro seeding, 15 g m^{-2} seeds, AT2 = hydro seeding, with vesicular-arbuscular mycorrhiza inoculum, 15 g m^{-2} seeds). Factor 2 was the seed mixture (SM1 = usual seed mixture; SM2 = site-specific seed mixture, containing site-specific grasses, leguminosae and herbs, see table 1). For more detailed information on locations, application techniques and seed mixtures see *www.alperos.org*. Plots were fertilised only once in the establishment year. Vegetation cover, botanical composition and subsequent yield and forage quality were assessed at the stage of flowering of *Festuca nigrescens*, in order to guarantee comparable conditions. Plots were harvested in 2001 and 2002 (two cuts at Sudelfeld, once a year at the other locations). Digestibility was estimated using the in vitro method of Tilley and Terry (1963). ANOVA was carried out for all comparisons. An F-ratio of $P < 0.05$ was regarded as significant. No significant differences between application techniques were found in 2001 and 2002, so these results are not reported.

Table 1. Composition of seed mixtures.

Grasses	SM 1 SU, HW, GE	SM 2 SU	SM 2 HW	SM 2 GE	Leguminosae and herbs	SM 1 SU, HW, GE	SM 2 SU	SM 2 HW	SM 2 GE
Agrostis capillaris	4,6		4	6	*Anthyllis vulneraria*		3	5	
Avenella flexuosa				6	*Lotus corniculatus*	5	3	3	6
Festuca nigrescens		28	35	22	*Trifolium badium*		1	5	2
Festuca ovina	2,5				*Trifolium hybridum*	2,4			6
Festuca rubra	31				*Trifolium nivale*			7	
Festuca supina				5	*Triolium repens*	4,2	6		6
Lolium perenne	15,7		3		*Vicia sativa*	3,4			
Phleum alpinum		5	10	6	*Achillea millefolium*	0,7		1	2
Phleum hirsutum		10			*Campanula barbarta*			0,22	
Phleum pratense	19,9				*Crepis aurea*		0,1	0,5	
Poa alpina		25	15	27	*Leontodon hispidus*		2	1	1
Poa pratensis	10,6				*Melandrium rubrum*			0,03	
Poa supina		5	5	4	*Plantago lanceolata*		1,9		
Poa violacea		10	5		*Silene vulgaris*			0,25	1

Results and discussion

Alpine ecosystems are characterised by unfavourable climatic conditions, with limiting effects on the growth and biomass production of plants. Such effects increase with altitude. Only sufficient vegetation cover can stabilise the topsoil and minimise soil erosion to an acceptable degree. Results of several assessments indicate that at altitudes between 1,200-2,400 metres, a minimum vegetation cover of 70-80 % is required to avoid erosion (Tasser *et al.*, 2003). Figure 1 shows a comparison of vegetation cover between sites, years and seed mixtures. In general, it was obvious that in high zones, seed mixtures need at least two growing seasons to achieve sufficient vegetation cover. At the Gerlos site, no sufficient cover could be established during the investigation period. Only the vegetation obtained with site- specific seed mixtures enabled sufficient protection against erosion at the Sudelfeld and Hochwurzen sites. A significantly lower mean cover value was obtained for SM1(60.5) than for SM2 (66.8). In accordance with previous results (Gruber *et al.*, 1998), dry matter yield (DMY kg ha^{-1}) decreased significantly with altitude but no differences between mixtures were observed, while the concentration of metabolizable energy (ME) differed significantly between seed mixtures. For SM1, a mean concentration of 9.2 MJ ME kg^{-1} DM was measured, whereas SM2 only achieved 8.6 MJ ME kg^{-1} DM. This can be partly explained by the faster development and growth of site-specific species at high altitudes, and therefore with earlier phenological development of commercial species at the time of cutting. Considering changes in the botanical composition of the trials during the first four years, a decreasing proportion of poorly-adapted, high quality species was observed in the commercial seed mixture. Thus, an adjustment of ME values can be expected at all locations. The energy yield (DMY x MJ ME) is a useful parameter to compare the three locations (Figure 2). As observed for DMY, the energy yield also showed a significant decline with increasing altitude. The highest value was found for SM1 at Sudelfeld (24.9 GJ ha^{-1} y^{-1}) and the lowest for SM2 at Gerlos (2.5 GJ $ha^{-1}y^{-1}$). In contrast to what was found for energy concentration, only slightly higher values, but no significant differences, in energy yield could be found between the different mixture types.

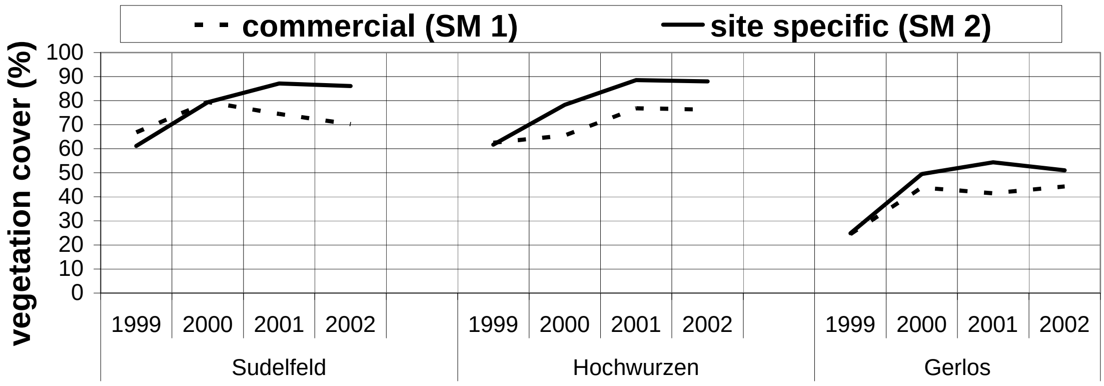

Figure 1. Development of vegetation cover in %, 1999-2002, comparison of three sites.

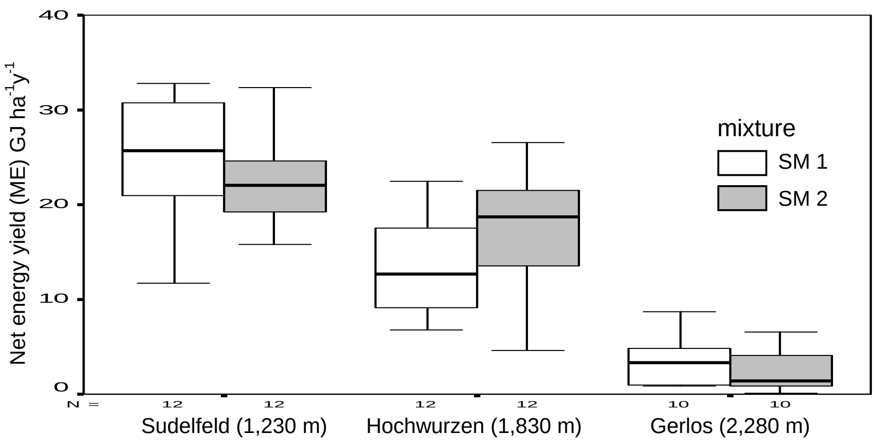

Figure 2. Average Net energy yield (Nel) in GJ ha^{-1} y^{-1} at the experimental sites (∅ 2000, 2001), comparison between commercial (SM1) and site specific (SM 2) seed mixtures.

Conclusions

On soils of low nutrient contents, significantly better vegetation cover and comparable energy yield can be expected if site-specific, instead of commercial seed mixtures, are used.

Acknowledgments

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Forage production in ski runs restored with indigenous seed mixtures

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Abstract

Dry matter yield and potential forage quality (calculated on the basis of specific contribution and Klapp's forage value scores) of plant stands obtained through restoration of ski runs were measured in the course of the EU-research project ALPEROS, in order to investigate the suitability of revegetated areas for agricultural purposes in combination with low fertiliser input. At three different locations, one below the timberline (Sudelfeld, D, 1,245 m asl) and two near or above it (Hochwurzen, A, 1,830 m asl and Gerlos, A, 2,280 m asl), a commercial seed mixture (SM1) with lowland forage varieties bred for agricultural purposes was compared with an indigenous seed mixture (SM2) containing ecotypes of alpine and subalpine species. Dry matter yield decreased with increasing altitude and SM1 yielded higher dry matter levels at the sole location below the timberline in the first harvest year, while better performances of SM2 were initially observed at intermediate altitude. A slightly better potential forage quality was initially achieved by SM1 at two of the three locations, but, starting from the third growing season, differences between seed mixtures were no longer found. Results are discussed in relation to vegetation dynamics and changes of specific contribution through time.

Keywords: restoration, indigenous species, dry matter production, potential forage quality

Introduction

New approaches have been recently developed for the restoration of eroded areas in mountain environments using seed mixtures containing indigenous subalpine and alpine species. In combination with low fertiliser input (only one application at trial establishment), there is evidence that they lead to increased vegetation cover and sward persistence if compared with inexpensive commercial seed mixtures, containing highly productive forage varieties bred for agricultural purposes (Krautzer *et al.*, 2001; Peratoner, 2003). Although protection against erosion can be considered the primary aim of restoration, forage production is often regarded as an important secondary target, as re-vegetated ski runs are often grazed by animals, or the hay obtained through mowing is fed to cattle. In this study, data about dry matter yield and potential forage quality were assessed under the premises described above at three different sites through a four-year observation period, in order to gain information about differences and trends through time depending on the seed mixtures used.

Materials and methods

Experimental fields were established in 1999 on ski runs at three different locations in the Alps (Table 1). Trials were arranged as two-factorial split-plot designs with three replications. Factor 1 was the application technique (AT1 = conventional hydroseed, containing 80 g m^{-2} cellulose, 15 g m^{-2} mineral fertiliser (15N:15P:15K), 5 g m^{-2} Rekuform®, 15 g m^{-2} synthetic binder; AT2 = mycorrhiza hydroseed, containing 65 g m^{-2} vesicular-arbuscular mycorrhiza inoculum, 80 g m^{-2} compost, 65 g m^{-2} Provide verde®, 3.5 g m^{-2} organic binder; AT3 = site-specific technique, being a mycorrhiza hydroseed with 500 g m^{-2} straw mulch at the sites Sudelfeld and Gerlos, and a dry seeding with 1,355 g m^{-2} compost, 15 g m^{-2} Hyperkorn and 7.9 g m^{-2} Nitroform and straw mat at Hochwurzen). Fertilisers were applied only once at trial establishment. Factor 2 (sub-plots) was the seed mixture (SM1 = commercial seed mixture Schwarzenberger type B 3; SM2 = indigenous seed mixture, which contained subalpine and alpine species, and whose composition differed from site to site and was adapted to local conditions). A detailed description of the seed mixtures is available at *www.alperos.org*.

Table 1. Experimental sites, mean air temperature (MAT) during the growing season (July and August, average of 3 years) and soil chemical properties at trial establishment.

Site	Country	Altitude (m); Exposition	MAT (°C)	Soil chemical properties				
				pH $CaCl_2$	humus (g kg^{-1})	N_{tot} (g kg^{-1})	P (CAL) (mg kg^{-1})	K (CAL) (mg kg^{-1})
Sudelfeld	Bavaria, D	1,245; N	14.3	6.9	82	4.4	13	56
Hochwurzen	Styria, A	1,830; SE	11.3	6.6	40	2.1	13	47
Gerlos	Tyrol, A	2,280; S	8.3	4.9	57	2.7	22	31

Starting from the second growing season (from the third one at the location Gerlos), dry matter yield was determined on oven-dried samples (105 °C for 36 hrs), which were obtained through accurate harvest of four randomly placed 1 m² square frames per plot. The potential forage quality was calculated on the basis of the specific contribution measured through linear analyses according to Daget and Poissonet (1971) in 50 sampling points per plot and of Klapp's empirical forage value scores (Klapp *et al.*, 1953), which were integrated as described in Peratoner (2003). All assessments and harvests were performed at the flowering time of *Festuca nigrescens*, in order to ensure comparability between sites and between years. An additional cut at the end of the growing season was performed at the site Sudelfeld starting from the third year. ANOVA was performed separately for each site, because of different composition of SM2 and AT3 between sites. Mean separation was performed by Tukey's HSD. If variance homogeneity could not be achieved, the Mann-Whitney-U test was carried out for planned comparisons. An F-ratio of $P < 0.05$ was regarded as significant.

Results and discussion

As expected because of increasingly unfavourable climatic conditions, dry matter yield considerably decreased with increasing site altitude and peaked at later harvest years at Hochwurzen and Gerlos (Table 2).

Table 2. Mean dry matter yield in kg ha^{-1} at the experimental sites from 2000 to 2002 (n = 9). Within sites and years, different letters indicate significant effect of factor 2 (seed mixture).

Site	2000		2001		2002	
	SM1	SM2	SM1	SM2	SM1	SM2
Sudelfeld	3,053 ^{a}	2,115 ^{b}	2,816	2,872	2,611	2,305
Hochwurzen	327	551	1,703 ^{b}	3,091 ^{a}	1,936	1,939
Gerlos	n.m.	n.m.	200	252	491	360

n.m. not measured because of insufficient biomass production

The use of SM1 proved to be of only short-term advantage at the lowest location, while at intermediate altitude SM2 allowed a biomass production in the second harvest year greater than that of the commercial seed mixture. In the third harvest year no further effect of the seed mixtures on dry matter yield was found. No effect of factor 1 was observed, with exception of the first harvest at Hochwurzen, where AT1 achieved a production about 2 and 4 times higher than that of AT3 and AT2 respectively (760 kg ha^{-1} vs. 415 kg ha^{-1} and 140 kg ha^{-1}). No interaction between factors 1 and 2 was found. A relatively high potential forage quality, similar to that of *Arrhenatherum elatius*-meadows (Klapp *et al.*, 1953) was achieved at all sites in the growing season 2000 (Figure 1). At this stage, with the exception of the highest location, the use of SM1 resulted in higher values because of large proportions of valuable forage species such as *Lolium perenne*, *Phleum pratense* and *Trifolium repens*. However, such an effect of the seed mixture disappeared already in the following growing season, as the specific contribution of the species mentioned above decreased on average from 45.0 % in 2000 to 28.0 % in 2001 at Sudelfeld and from 43.2 % to 19.2 % at Hochwurzen. Irrespective of the seed mixture used, decline of the potential forage quality was observed through time only at the lowest location. Here, substitution of valuable forage species (i.e., *Poa alpina* in SM2) with non sown species (species not included in the seed mixtures) was observed. The specific contribution of the latter rose from 21.2 % in 2000 to 39.9 % in 2002, while it was low and did not change at the other sites (4.5 % at Hochwurzen and 6.1 % at Gerlos, average of 2000 and 2001 data).

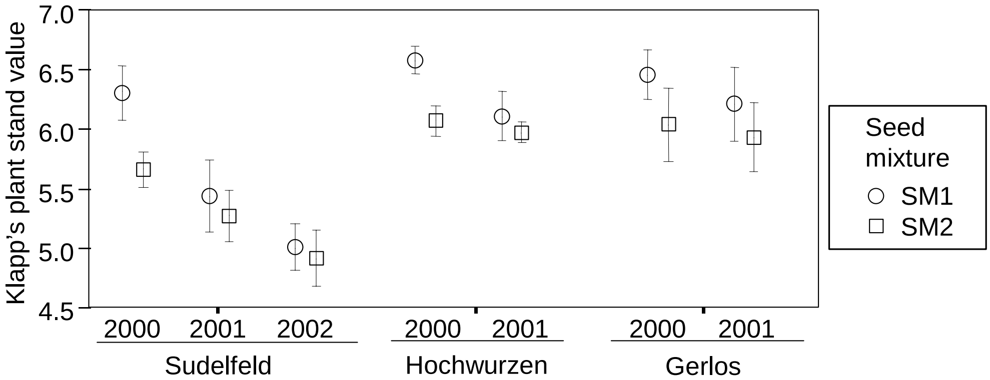

Figure 1. Mean and 95 % confidence interval of the potential forage quality of plant stands at the experimental sites through time (n = 9).

Conclusions

Our results show that under low nutrient input, dry matter yield and potential forage quality of indigenous and commercial seed mixtures are comparable in the medium term, although short-term advantages may initially be achieved by the latter at relatively low altitudes. Under relatively favourable climatic conditions allowing marked vegetation shifts and with adequate biotic resources (i.e., soil seed bank, vegetative propagation units) for the spontaneous re-colonization processes, decreases of forage quality can be expected because of increasing specific contribution of species that are less demanding with respect to climatic and edaphic conditions, but of lower forage value.

Acknowledgements

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Grazing the highlands: food, biodiversity and catchment implications

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Abstract

In the European Alps, montane pastures and periodically grazed alpine vegetation cover about half of the land area between the northern and southern front ranges, which provides protein for about one million people. This land area includes old cultural landscapes as well as some of the last wilderness areas of Europe. The sustainable use of these highlands is endangered in many areas by over-exploitation or abandonment, reducing productivity, biodiversity and catchment value. The Global Mountain Biodiversity Assessment (GMBA) of DIVERSITAS has a focus on the documentation and explanation of the biological richness of these biota and aims at synthesising knowledge about the influence of land use on biodiversity. With these tasks, it will be shown in this overview and the following contributions that land use is not necessarily in conflict with biological richness. Examples from the Alps and the Caucasus will underpin the significance of management for sustainable ecosystem function and biological richness of these biota.

Keywords: alpine grassland, catchment, elevation, productivity, species richness, water

Introduction

Worldwide as well as in Europe the alpine belt alone covers ca. 3 % of the terrestrial land area. This land area fraction hosts 4 % of all terrestrial plant species at the global scale, but accumulates ca. 20 % of the total European terrestrial vascular plant diversity (Körner, 1995; Nagy *et al.*, 2003 p. 454). Much of this falls into the grassland category. These rich biota are under land use pressure worldwide, not only in the alpine belt, but also in the montane belt. A 50 km N-S transect across the central Alps of Austria (the 'Hohe Tauern' region, 650 m to 3800 m of elevation) over a land area of nearly 3000 km^2 revealed that 56 % of this area is under some sort of agricultural use (in large grazing), with the majority of the pastures in the upper montane and the alpine belt (Körner, 1989).

The biodiversity of these open, non-forested biota is exceptionally high. One fifth of the total Swiss vascular plant flora of ca. 2500 species is native to the alpine life zone above treeline, a fraction similar to that for Europe as a whole. Much of this diversity, the abundance of many precious taxa in particular, is associated with many centuries of land use (see Fischer *et al.*, this volume). Managed in a sustainable way, montane and alpine grasslands are ecologically stable, productive and most attractive biota (Körner, 2000a). In this brief account we will first assess principal elevational trends of productivity and diversity, and will then exemplify ecosystem services associated with well managed high elevation grassland.

Productivity and biodiversity

Along elevational gradients productivity and plant species richness gradually decline (Figure 1), which is commonly associated with a climate (temperature) driven, physiology based decline in 'life activity'. However, the land area also declines with elevation (mountains are in essence 'cones'), as does the duration of the growing season (the snow free period). If one relates productivity of high elevation grassland to the duration of the growing season, there is no elevational decline, and alpine grassland is as productive as lowland grassland per month of growing period (Figure 2a). Similarly, if one relates species diversity to the actually available land area per elevation belt, there is no decline in species richness (Figure 1b). This illustrates the significance of space and time as key drivers of life. At a very coarse scale, high elevation biota appear to be as productive and diverse per unit of time and space, respectively, as low elevation biota (Körner, 1998, 2000b).

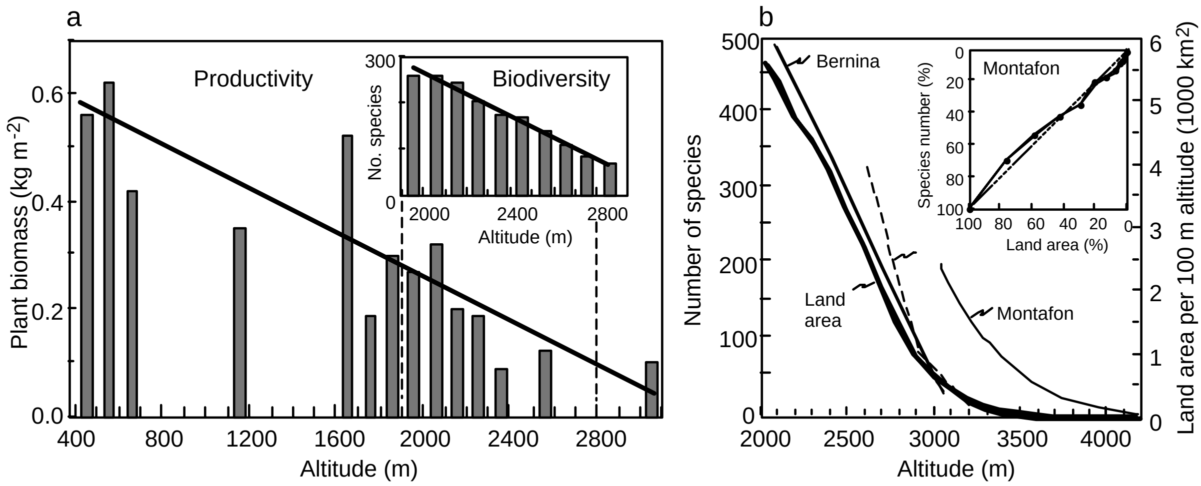

Figure 1. *a*, The elevational reduction of peak season grassland plant biomass (a correlate of productivity) and vascular plant species richness in the Alps. *b*, The elevational trend in land area correlates with that in species richness (data extracted from Körner, 2003).

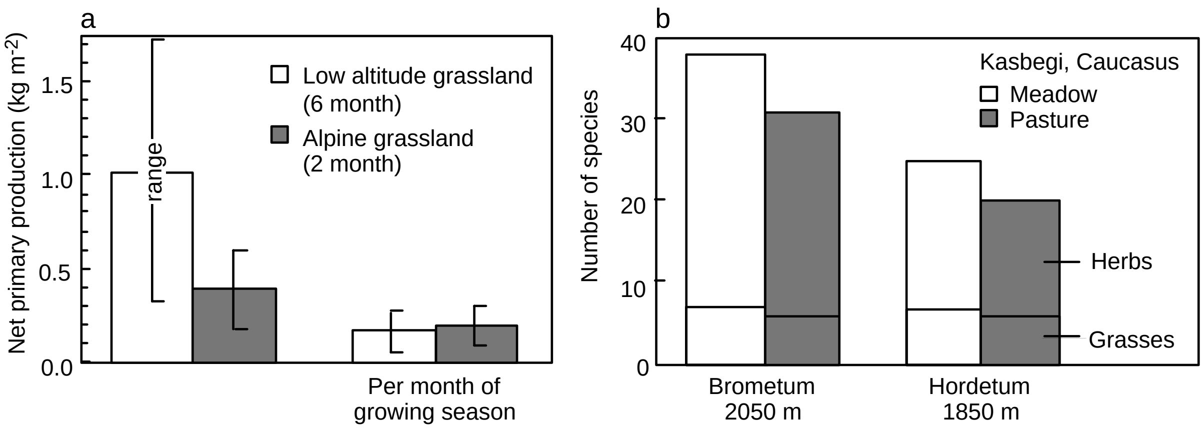

Figure 2. *a*, Low and high altitude grassland production y^{-1} or m^{-1} of growing season. *b*, The influence of mowing versus grazing on high elevation grassland species richness.

Biodiversity and ecosystem functions of high elevation grassland

There are many examples underpinning the fact that sustainable agricultural use of high elevation grassland is associated with high biodiversity, productivity and catchment value, provided flora and fauna is well adapted and land use intensity meets the local carrying capacity. This is true for regions with a long history of selection and micro-evolution under land use, but does not hold for virgin biota (e.g., the mountains of New Zealand and Australia, Mark, 1994; Costin, 1958). Remarkably, disturbance by sheep trampling hardly affects alpine grassland diversity (see Hiltbrunner and Körner, this volume, K. Bandurski unpublished). In fact, a six year cessation of cattle grazing in alpine heath led to a decline in diversity and productivity (Körner, 2000a; cf. Erschbamer *et al.*, 2003). A 33 year fencing trial in the Central Caucasus revealed a slight initial loss in number of forb species, no effect on grasses, and no effect on cover for three decades (Figure 2b).

A remarkable benefit of grazing the highlands is enhanced water yield, provided the ground cover remains intact (no erosion). A short, grazed alpine turf was found to lose less vapour both in the Alps and the Caucasus, thus enhancing run off and catchment yield. For elevations above 2000 m the annual gain in hydroelectric energy from such sustainable land management can reach 150 Euro ha^{-1} of alpine land. Alpine pasture land also resists erosion better than abandoned land with tall shrub encroachment (Tasser *et al*., 2003).

Conclusions

High elevation grasslands – man made in the montane belt, natural in the alpine belt – are well suited for extensive but controlled land use, while bearing high biological diversity and providing – besides clean food – secondary benefits, such as enhanced water yield and touristic attractiveness (cultural heritage). Unfortunately, this successful model can not easily be exported to other parts of the world, the tropics in particular (Körner and Spehn, 2002). The most critical issue is control of evenness and intensity of use, commonly personell intensive and thus expensive. These expenses can, however, be balanced by the quality of products and by commonly unaccounted secondary benefits, both requiring appropriate marketing.

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Impact of soil conditions and agricultural use on the plant species diversity of Alpine pastures

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Abstract

Both agricultural management and site factors may influence the species composition of Alpine pastures. In this study we investigated how these factors are related to plant species diversity at plot scale (1 m^2) and at farm scale through a survey of 200 plots on ten Alpine farms in the north-eastern Swiss Alps. Farm-scale species richness correlated positively with plot-scale species richness (r = 0.85). Both farm-scale and plot-scale richness correlated negatively with the farm area, reflecting the greater altitude of larger farms and the reduced species exchange with surrounding forests. Of the examined management factors, only the proximity to economically important places correlated with farm-scale beta diversity (heterogeneity of the 20 plots). Relationships between small-scale richness and nutrient concentrations in soils or the nutrient indictor value of the vegetation were significantly negative or unimodal but generally weak. They presumably reflect the tendency of certain species from either very nutrient-poor or very nutrient-rich sites to dominate the pasture and reduce species diversity. We conclude that multiple interdependent factors simultaneously influence plant species diversity on Alpine pastures.

Keywords: pasture area, soil nutrients, species richness, stocking density

Introduction

Alpine pastures are characterised by considerable variation in plant species composition at different spatial scales. Both agricultural management and site factors contribute to creating these patterns. In this study we examine how the two factors are related to the species diversity of pasture vegetation. This is relevant to assess possibilities of influencing biodiversity on Alpine pastures through changes in management. It has been argued that small-scale plant species richness depends more on regional than on local factors ('species pool hypothesis'; Zobel, 2001). On Alpine pastures, however, local site factors might have a strong influence on plant species richness because of a large species pool, highly effective species dispersal by the livestock, and strong small-scale variation of site conditions. We therefore expected that small-scale species richness depends on nutrient availability in soil, disturbance by cattle or the presence of particular dominant plant species, whereas the species diversity of entire farms might depend more on farm management.

Methods

We investigated vegetation and soils in a total of 200 plots (1 m^2) on ten Alpine farms in the north-eastern Swiss Alps (47° N, 9° E). The 20 plots per farm were distributed systematically along two transects, a horizontal and a vertical one. In each plot we recorded the cover of all vascular plant species and took a soil core to determine its total C, N and P concentrations and soil pH. We calculated the species richness per plot as well as four indices of species diversity per farm (cf. legend of Table 1). Diversity measures were related to potentially relevant site factors and to variables describing pasture use (cf. Müller, 2003) using linear or quadratic regression models. We also determined relationships between site factors and the 'potential species richness' as defined by Braakhekke and Hooftman (1999).

Table 1. Relationships between plant species diversity (mean species number (S) on 1 m^2, total species number on 20 m^2, the ratio of mean to total species number, and ß diversity, the mean Euclidean distance between the 20 plots) and five variables describing the management and location of ten alpine farms. Data are coefficients of determination (r^2) of linear regression, except for 'type of road', where F-values from Anova are given. Significant relationships ($P < 0.05$) are shown by (+) or (-) signs indicating the sense of the relationships.

	Mean S	Total S	Mean / Total	ß diversity
Stocking density	0.14	0.01	0.28	0.00
Type of road (ease of access)	0.86	0.24	0.30	2.14
Proximity to economically important places[1]	0.39	0.29	0.19	0.56 (+)
Altitude of the farm building	0.24	0.04	0.42	0.11
Pasture area	0.75 (-)	0.49 (-)	0.47 (-)	0.44 (-)

[1]index based on the time needed to reach the next village, the market and the main farm at the valley bottom

Results

The number of vascular plant species per 1-m^2 plot ranged from 3 to 32, with an average of 16.6 species (SD = 6.0). Species richness differed significantly among farms, with farm means between 10.8 and 20.5 species m^{-2}. Farm means were strongly correlated with the total number of species per farm (r = 0.85). Both mean and total species numbers per farm were negatively correlated with the farm area, but unrelated to pasture use (stocking density, grazing system, number of grazing periods per year) or altitude (Table 1). Beta diversity (heterogeneity of the vegetation) decreased with greater proximity of the farm to economically important places, but it was not related to the ease of access as described by the type of road leading to the farm (Table 1). The species richness of the 200 individual plots was negatively correlated to the P concentration of the topsoil (Figure 1a) and positively correlated to the soil pH (not shown); its relationship with the N and C concentrations of the soil and with the average nutrient indicator value of the vegetation (Landolt, 1977) was unimodal (Figure 1b and 1c). The 'potential species richness' showed similar types of relationships with site conditions (Figure 1).

Discussion

The positive correlation found here between the mean and total numbers of species per farm resembles the positive correlation between small-scale species richness and the 'species pool'' described by many other authors (e.g., Pärtel *et al.*, 1996; Zobel and Liira, 1997). The latter has been interpreted as evidence that the species pool determines small-scale species richness more than local factors such as competition (Zobel, 2001) In our study, however, we determined 'species pools' per farm, which are administrative units and not plant communities or geographical regions. The pronounced patterns in plant species composition found within farms indicate that local species assemblages do not reflect a quasi-neutral selection from a farm's species pool but that they respond to small-scale variation in site factors. This does not invalidate the species pool hypothesis but shows that correlations between species numbers at different scales can occur even when local control is strong. Our negative correlations between species diversity and farm area seem to contradict the general tendency for species diversity to increase with habitat size (Pysek *et al.*, 2002). This result probably has two causes: First, some species from the surrounding forests could disperse into the grazed area; they were most frequent close to forest borders and therefore contributed most to the species diversity of small pastures with a large proportion of border areas. Second, the larger farms were on average situated at higher altitude, where low grazing intensity caused the main vegetation type to be species-poor heathland. The lower species richness of the larger farms thus reflected their differing vegetation. There was a clear unimodal

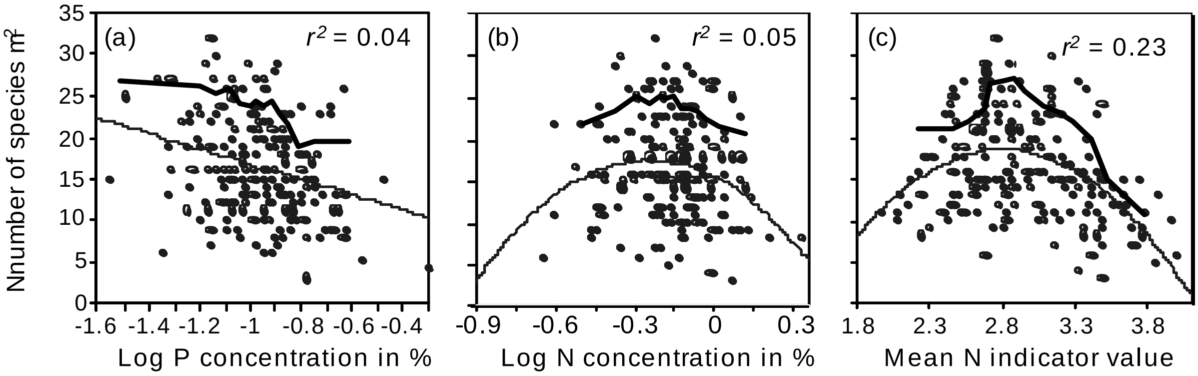

Figure 1. Relation between plant species richness per plot (1 m^2) and some local site factors, i.e., (a) total soil P concentration (b) total soil N concentration, and (c) mean nutrient indicator value of the vegetation (Landolt, 1977). Thin lines show the mean species richness as modelled with linear or quadratic regression (coefficients of determination are given); thick lines the potential species richness (90 % percentiles calculated for 14 classes of plots).

relationship between local species richness and the mean nutrient indicator value of vegetation, as also found in other studies (e.g., Bollens *et al.*, 1998). It would be tempting to regard our result as the demonstration of a unimodal relationship between productivity and species richness (e.g., Zobel and Liira, 1997). However, this needs not be the case, as the causality might as well be inverse: with increasing number of species, the mean nutrient indicator value is more likely to be close to the overall mean (3). This statistical effect arises from the fact that on these Alpine pastures, plant species that typically dominate the most species-poor communities have either high N values (e.g., *Rumex alpinus* or *Senecio alpinus*) or low N values (e.g., *Nardus stricta* or *Calluna vulgaris*). Overall, large variations in plot data resulted in a weak relationship between species richness, soil conditions and management. This indicates that multiple factors simultaneously influence the vegetation on Alpine pastures, which act at various spatial scales and whose effects on species richness are interdependent. These complex effects are largely mediated by the patterns of habitat use by livestock in response to pasture management and local site conditions; indeed, the intensity of grazing, trampling and defaecation determines whether individual species dominate the vegetation or whether many species can coexist within a small area of Alpine pasture.

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Effects of grazing exclusion in alpine grasslands in the Central Alps

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Abstract

In summer 2000 several grazing exclusion areas were established in Obergurgl and Hochgurgl (Ötztal, Tyrol, Austria). The main aim was to establish a long-term project in the alpine zone to monitor changes in alpine grassland ecosystems after grazing cessation. Three exclosures were established on each of three alpine sites (2300 m, 2500 m and 2600 m asl) and one exclosure at the treeline ecotone (1950 m asl), respectively. Within each exclosure, permanent plots of 1 m^2 were established, and compared with control plots outside each fenced area. Frequency counts were made every growing season from 2000 to 2003. In addition, in 2002 and 2003, flower, fruit and seed production were studied.

A higher canopy height and a higher amount of litter was observed in the exclosure plots, compared to the controls. The frequency of the species changed in most of the plots. Some species were positively affected, while others exhibited a lower frequency after four years. The number of seeds and the seed weight of selected species were significantly higher within the exclosures. It can be concluded that the frequency of *Poaceae* and *Cyperaceae* increases within the exclosures, whereas mosses and lichens generally decrease. Species-poor alpine grassland communities will result from long-term cessation of grazing.

Keywords: frequency, exclosure, flowers, permanent plots, seeds

Introduction

Grazing influences plant diversity in many ecosystems (Milchunas and Lauenroth, 1993). In alpine environments the role of grazing in maintaining plant diversity is poorly understood. We know that alpine grasslands of the Central Alps have been grazed by domestic ungulates for approximately 5000 years (Vorren *et al*., 1993; Bortenschlager, 1993, 2000, 2001), and it must be assumed that this has had some impact on community structure. While few detailed analyses and exclusion studies have been conducted in the Alps (Erschbamer *et al*., 2003), in arctic environments (snowbeds) the growth of Graminoids and Polytrichaceae mosses was enhanced by grazing (Virtanen, 2000). In order to test this hypothesis in the Alps, a long-term exclusion study was established in the Central Alps of Austria. Along an altitudinal gradient in a high-montane pasture, exclosures were established in three alpine grassland stands to investigate the general impact of domestic ungulate grazers.

Materials and methods

In summer 2000, several grazing exclusions were established in Obergurgl and Hochgurgl (Ötztal, Tyrol, Austria, Table 1). Frequency counts and cover estimations were made in permanent plots (1 m^2) in the exclosures and in the controls. These observations were made every year, with exception of the Obergurgl site where the observations were made only in 2000 and in 2003. In 2002 and 2003 flower and seed production and seed weight were determined. Data were analysed using the programme CANOCO (detrended correspondence analysis) and the programme SPSS.

Table 1. Study sites and number of the permanent plots (EX = exclosure, CO = control).

Site	altitude (m asl)	no. of permanent plots	community	mean inclination (°)
Obergurgl	1950	3 EX / 3 CO	pasture with *Nardus stricta*	13
Schönwies	2320	9 EX / 9 CO	*Nardus-Carex curvula*	8
Hochgurgl	2500	9 EX / 9 CO	*Carex curvula*	4
Hohe Mut	2600	9 EX / 9 CO	*Carex curvula*	9

Results and discussion

After four years of grazing exclusion, a higher canopy height and a greater amount of litter was found, compared to the control plots. The frequency of the species changed in most of the plots. In general, the frequency of herbs decreased (not significantly), whereas for Poaceae and Cyperaceae, no uniform trends were detectable. Some species were affected positively (*Carex curvula*, *Festuca rubra* and *Homogyne alpina*) showing an increased frequency within the exclosure plots compared to the controls, although, the results were not statistically significant. Several species exhibited a lower frequency in the exclusion plots (*Nardus stricta, Leucanthemopsis alpina, Geum montanum, Potentilla aurea, Ligusticum mutellina, Cetraria islandica*), however, only for *Nardus stricta* were significant differences calculated (P = 0.014). Mosses and lichens decreased (not significantly) within the exclosure plots. The number of seeds and the seed weight of *Nardus stricta* was significantly higher in the exclosures (Figure 1).

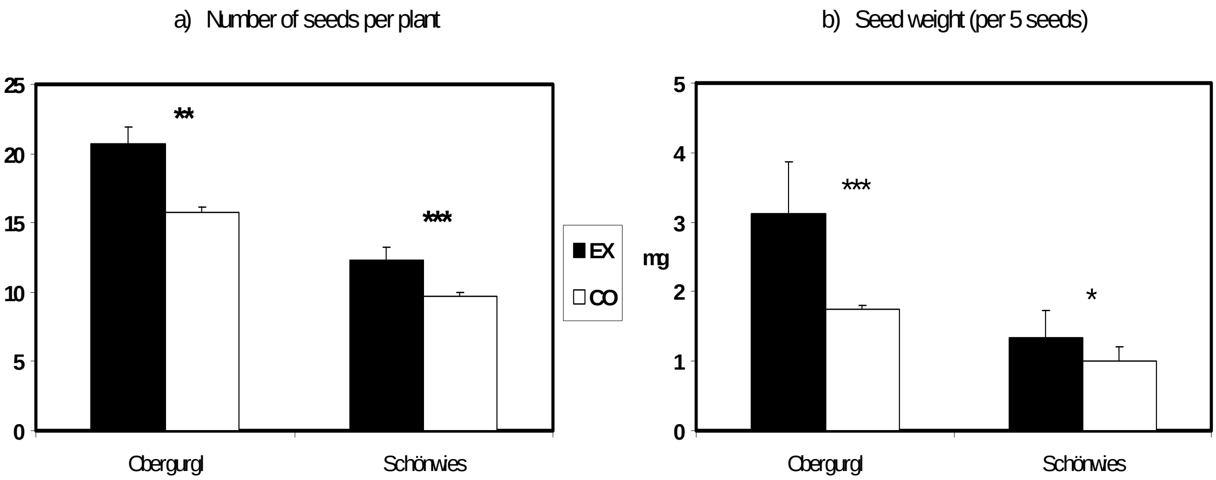

Figure 1. Number of seeds (a) and seed weight (b) of *Nardus stricta* in exclosures (= EX) and in control plots (= CO) at two study sites (Obergurgl = 1950 m asl, Schönwies = 2320 m asl) in 2002; *** = $P < 0.001$, ** = $P < 0.01$.

Responses on the species level depend highly on the initial plant community structure (Stüssi, 1970; Dietl, 1982), on the grazing intensity at the beginning of the exclusion (Andersson and Jonasson, 1986; Moen *et al*., 1993) and on the productivity of the vegetation and the environmental conditions (Moen and Oksanen, 1998). In this study, most decreases or increases in frequences were not statistically significant. This was also reported by other authors (Schneiter, 1997; García-González *et al.*, 1998; Camenisch and Schütz, 2000). However with *Nardus stricta*, a significant decrease was found in the exclosure plots. This would appear to confirm that *Nardus stricta* can be regarded as a good grazing indicator.
The impact of grazing on seed production and seed weight has been little studied (Erschbamer *et al*., 2003). Based on the significantly reduced reproduction of *Nardus stricta* in the grazed

plots, we can deduce that grazing has a strong impact on life history traits of the species, favouring clonally growing species.

Conclusions

Changes in canopy height and amount of litter in alpine grasslands are short-term reactions to grazing exclusion. The reproductive efficiency of species will be significantly lowered within short periods after grazing exclusion. In the long-term, significant changes in the species composition are expected.

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Past and present land use effects on subalpine grassland species and functional diversity

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Abstract

In European mountain regions land use change, characterised by a concentration of activities towards the more productive and accessible areas and the concomitant cessation or extensification of labour-intensive traditional management in subalpine grasslands, threatens the high plant diversity harboured by these man-made habitats. Two sites in the French Alps were selected with contrasting climatic and land use conditions. This enabled us to test the hypothesis that decreases in plant diversity in response to extensification represented changes in functional composition that could be related explicitely to modifications in nutrient availability and disturbance regimes. Floristic changes in fields with known management history, nutrient availability and current disturbance regime were related to whole-plant morphological and leaf trait measurements. Decreases in nutrient availability along extensification gradients dominated response patterns. They were associated with decreased leaf specific area and nitrogen content and increased dry matter content of leaves and stems. We identified three plant strategies for dominant grasses: exploitative competitors in intensively used manured grasslands; stress tolerators in unfertilised mowed grasslands; and conservative competitors in extensive pastures. Within the matrix they formed, forb diversity decreased when mowing was replaced by grazing and evenness was highest at intermediate levels of fertility.

Keywords: subalpine grasslands, land use change, plant diversity, functional response traits

Introduction

In European subalpine grasslands the recent concentration of activities towards the more productive and accessible areas and the concomitant cessation or extensification of labour-intensive traditional management threatens the high plant diversity harboured by these man-made habitats. Plant functional analyses, where vegetation response is expressed as changes in key structural and ecophysiological characters of plant populations, can help to understand the mechanisms underlying these changes, and the consequences on ecosystem functioning (McIntyre *et al.*, 1999, Lavorel and Garnier, 2002). Two sites in the French Alps were selected with contrasting climatic and land use conditions. This enabled us to test the hypothesis that decreases in plant diversity in response to extensification represented changes in functional composition that could be related explicitely to modifications in nutrient availability and disturbance regimes.

Materials and methods

The first site was located on the south aspect of the Lautaret Pass (altitude 1900-2100 m), where the climate was montane with a continental influence. We studied a mosaic of fields with varying past and present intensities of pasture management ('land use trajectories' hereafter) that affect mineral resource availability (mainly manure fertilisation) and disturbance regimes (mainly mowing and seasonal grazing). Based on cadastral data from 1810 onwards, we selected five different historical land use trajectories, with 3 replicate plots each. The second site (Les Saisies) was located in the Beaufortain massif, within two subalpine pastures (altitude 1700-1770 m). The climate was montane with oceanic influence. Seventeen fields representing three levels of manure fertilisation and grazing, and abandonment, were selected to represent a gradient of nutrient availability (Brau Nogué *et al.*, 1994). At both sites management intensity was quantified by soil fertility variables. In addition, at Lautaret, we also noted whether fields had been ploughed in the past. Botanical composition was surveyed using the point quadrat method. Plant functional traits were measured for dominant and subordinate species (cumulated total > 80 % abundance) using standardised protocols (Cornelissen *et al.*, 2003). These included morphological traits describing the aboveground vegetative volume, leaf traits associated with plant resource economy (Garnier and Laurent, 1994), and reproductive traits. For each site we analysed the response of plant functional traits to management variables using the RLQ multivariate technique (Dolédec *et al.*,1996).

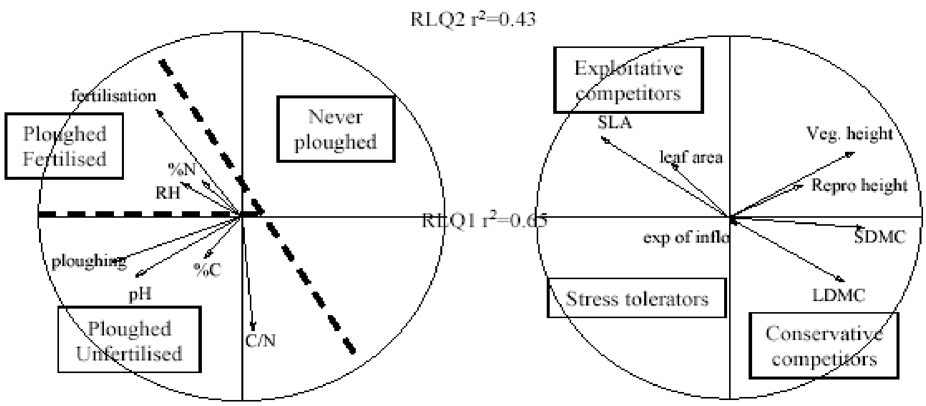

Figure 1. Results from the RLQ analysis for the Lautaret site. Left panel: Correlation plot of the environmental variables in the first two axes, and corresponding projections of land use trajectories. Variables: presence of fertilisation and former ploughing, % carbon and nitrogen content in soils and their ratio, pH, relative humidity in August (RH). Right panel: Correlation plot of the functional traits in the first two axes and delineation of corresponding dominant strategies for dominant grasses. Abbreviations: SLA (specific leaf area), LDMC (leaf dry matter content), SDMC (stem dry matter content), expinflo (exposure of the inflorescence, the difference between reproductive and vegetative heights).

Results and discussion

Significant decreases in nutrient availability along extensification gradients dominated the response patterns at both sites (Figures 1, 2). They were associated with decreased leaf specific area and nitrogen content and increased dry matter content of leaves and stems, and indicated an increasingly conservative nutrient use strategy. A second gradient was associated with plant height (Lautaret) or aboveground biomass (Saisies) and reflected past and present disturbance intensity. These gradients separated three plant strategies for dominant grasses: exploitative competitors in intensively used, manured grasslands (e.g., *Trisetum flavescens, Dactylis glomerata*); stress tolerators in unfertilised mowed or grazed grasslands (e.g., *Sesleria caerulea, Festuca rubra*); and conservative competitors (e.g., *Festuca paniculata, Nardus stricta*) in extensive pastures. Concomitantly, forb diversity decreased with management extensification, especially when mowing was replaced by grazing (Figure 3). Traditionally managed grasslands of our region have been recognised for their high conservation significance. Our results suggested that: 1) extensification of grassland use represents a threat to forb diversity, and most likely to the diversity of other organisms such as insects (Orthopterae and Lepidopterae). 2) as SLA, LDMC and height impact on ecosystem

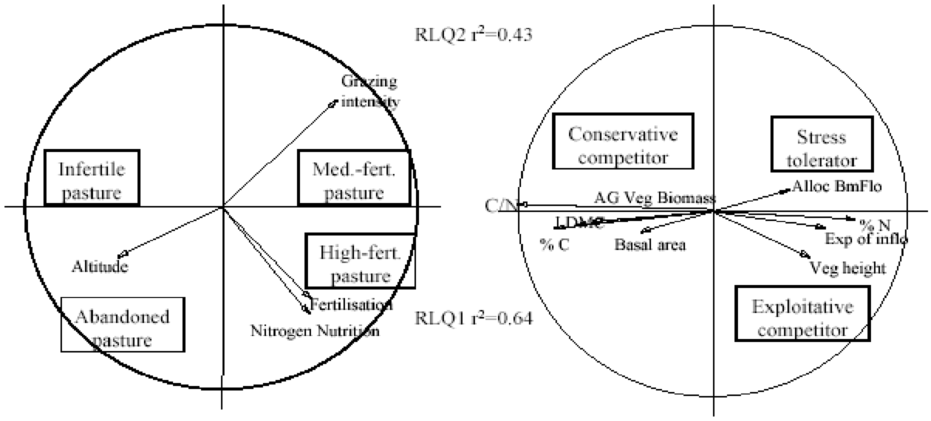

Figure 2. Results from the RLQ analysis for the Saisies site. Details are the same as for figure 1. One additional environmental variable was included: the nitrogen nutrition index (Cruz *et al.*, 2002). Additional traits: aboveground vegetative biomass (AG Veg biomass), allocation to floral biomass (Alloc BmFlo).

functions such as primary productivity and litter decomposition (Lavorel and Garnier, 2002), extensification in subalpine ecosystems is likely to result in a slower turnover in carbon and nutrients. Taken together, these changes in botanical and ecosystem function will also affect the pastoral value (Cruz *et al.*, 2002), along with other ecosystem services provided by subalpine grasslands.

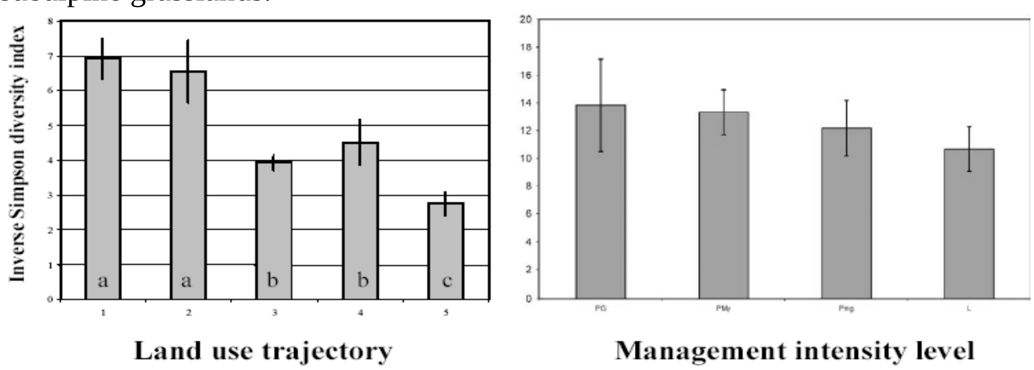

Figure 3. Changes in total plant diversity in response to land use management. Left panel: Lautaret, with five historical land use trajectories ($P < 0.05$). Right panel: Les Saisies, with four levels of management intensity (n.s.).

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Biomass responses of subalpine grasslands in the Pyrenees under warming conditions

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Abstract

We investigated the consequences of warming and drought on productivity, allocation, nutrient dynamics and plant diversity in two transplanting experiments carried out in subalpine grasslands in the Pyrenees. The increased aboveground productivity with warming suggests that these ecosystems are more temperature-limited than water-limited. In spite of the large change in aboveground biomass, belowground biomass did not vary, producing major changes in allocation patterns, opposite to what was expected. Nutrient fertilisation through increased *mineralis*ation is offered as an explanation for these results, confirmed by the decreased labile C with increased temperature and the positive effect of P addition on aboveground biomass in further experiments.

Keywords: plant diversity, labile carbon, climate change, nitrogen, phosphorus, water

Introduction

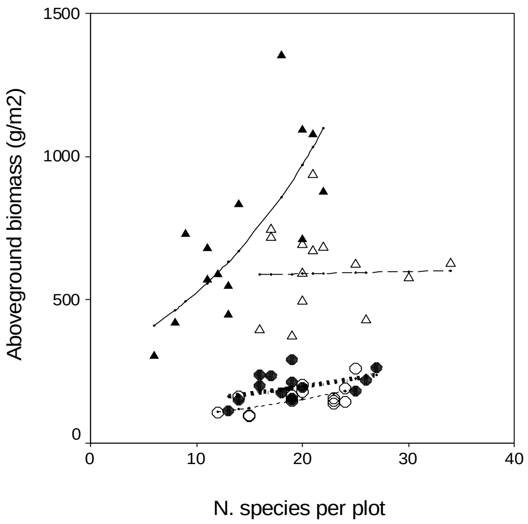
Species and ecosystems are considered to be particularly vulnerable at the edge of their area of distribution. Grasslands have been classified among the most vulnerable ecosystems under climate change conditions (Sala *et al*., 2000). In the Pyrenees, subalpine grasslands share many similarities in flora, vegetation and ecology with grasslands from other cold-temperate regions in Europe (Sebastià, 2004), however, in some years they experience strong Mediterranean influences, with summer drought. Under climate change conditions, temperature is expected to increase, rainfall to decrease, and acute drought periods to occur more frequently in the area. We investigated the consequences of warming and drought on biomass and diversity in two transplanting experiments, in order to assess the vulnerability of these altitudinal grasslands to climate change conditions.

Materials and methods

We carried out two transplanting experiments, in 1999 and 2002, to assess structural and functional changes in subalpine grasslands in the Pyrenees under warming conditions. In both experiments, we cut intact sods of *Festuca nigrescens* grassland communities on limestone (Sebastià, 2004) and fit them inside plastic trays 40 x 40 x 20 cm depth, with bottom holes. Half of the sods were transplanted in a lowland locality and half were placed back in their location of origin in the upland, inside the trays. The first experiment was carried out in Pla de Rus (2000 m, upland) and the campus of the Agronomy School in Lleida (400 m, lowland) and the second experiment in Vall d'Alinyà (2000 m, upland) and Solsona (800 m, lowland). In the second experiment we had four nutrient treatments, obtained from crossing two N (60 kg ha^{-1} ammonium-nitrate added bi-weekly/no N added) by two P (25 kg ha^{-1} of calcium bi-phosphate added bi-weekly/no P added) treatments. In the same experiment, sods were randomly assigned to 5 watering treatments: 2 in the upland (44 and 179 L m^{-2} total water added) and 3 in the lowland (44, 89 and 134 L m^{-2} total water added). We used GLM and step-wise backwards regression to model biomass responses. The explanatory fixed variables were site (S1/S2, as sods from two different areas were sampled in both experiments) and locality (lowland/upland). In the first experiment we also introduced harvest (mid harvest, 31 July/ final harvest in different, undisturbed sods, 9 September) and the number of species per sampled sod. In the second experiment we modelled data from the final harvest (3 October) and introduced N and P fertilisation (added/not added), and total water input (rainfall plus watering). Interactions were also considered, but only appear in the final model if they are significant.

Results and discussion

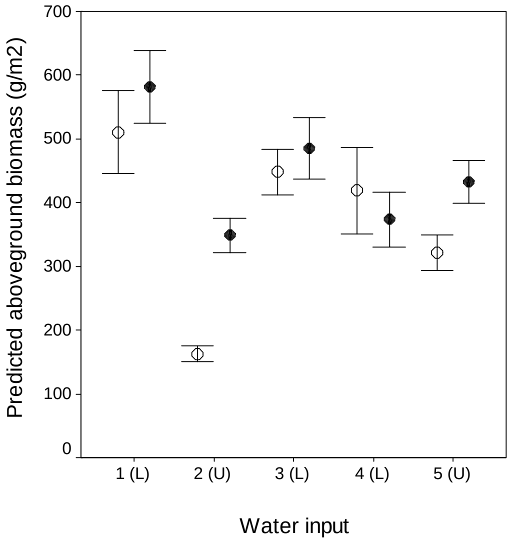
In the first experiment, aboveground biomass showed a large, significant increase in the lowland in contrast to the upland (Figure 1). However, belowground biomass was unchanged, contrary to the prediction of increased belowground allocation to compensate for the reduced water availability. These results suggest that the ecosystem is more temperature-limited, as found in cold ecosystems (Shaver *et al*., 2000), than water-limited, as expected for Mediterranean ecosystems. Note the significant decrease of species richness in the lowland compared to the upland by the end of the experiment (Figure 1).



Variable	P-value
Location	<0.001
Harvest	0.828
No. species	<0.001
Location x Harvest	0.033
Location x No. species	0.802
Harvest x No. species	0.147
Loc. x Harvest x No. species	0.014

Figure 1. Relationship between aboveground biomass and number of species per plot at each treatment in the first experiment. Symbols indicate actual values and lines the value predicted from the model. Actual values: open circles, upland first harvest; solid circles, upland second harvest; open triangles, lowland first harvest; solid triangles, lowland second harvest. Predicted values: dotted fine line, upland first harvest; dotted thick line, upland second harvest; dashed line, lowland first harvest; solid line, lowland second harvest. The table shows the P-values of the variables in the model.

Temperature enhances plant growth through a direct effect, or indirectly through increased *mineralis*ation and the resulting nutrient fertilisation. In the second experiment we explored the relative role of water and nutrients in the enhancement of aboveground biomass. Samples from the upland receiving low levels of watering produced the lowest biomass (Figure 2). Both phosphorus and water addition enhanced aboveground biomass in the upland but not in the lowland (Figure 2). N addition produced no effect on aboveground biomass in any treatment (Figure 2). The positive response of aboveground biomass to P addition in the upland and the lack of response in the lowland support the hypothesis of yield enhancement by increased nutrient availability under warming conditions. P has already been shown to be a critical limiting factor in limestone grasslands in the Alps (Köhler *et al*., 2001). The hypothesis was further sustained by the dynamics of carbon fractions throughout the growing season in an additional experiment, which suggests an increased soil carbon *mineralis*ation in the lowland (data not shown). The productivity enhancement in these short term experiments could be transitory, disappearing once the mobilized nutrients are removed from the system.



Variable	P-value
Site	0.137
Location	<0.001
N	0.186
P	0.010
Water input	<0.001
Location x P	0.001
Location x Water input	0.001
Water input x P	0.042

Figure 2. Mean predicted aboveground biomass and 95 % confidence intervals at five increasing water input levels including rainfall plus watering throughout the experimental period, from mid June to the end of October. Open dots, no P added; solid dots, P added. In the x-axis, U indicates upland (Vall d'Alinyà) and L, lowland (Solsona). Water input level 1: 471 mm; 2: 505 mm; 3: 516 mm; 4: 561 mm; 5: 642 mm. The table shows the *P*-values of the variables introduced in the final model. All main effects and the significant interactions are included in the final model.

Conclusions

Our results indicate that climate change could have critical consequences for subalpine grasslands in the Pyrenees, both in terms of structure and function, and suggest high vulnerability of the grassland biome in elevated mountains from the Mediterranean region.

Acknowledgements

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Cultural and biological diversity of grasslands in the Swiss Alps

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Abstract

In the cultural landscape of the Alps potential determinants of grassland biodiversity are topographical situation, cultural (Romanic, Germanic, and Walser) traditions, and land use. In a parcel-based design we are studying the biodiversity of 219 parcels of grassland in 12 villages in the Swiss Alps. We found the occurrence of particular parcel types to depend on land use history and altitude, and more different types of land use history occurred in the valleys of Romanic villages than in those of Germanic or Walser villages. Some formerly mown parcels are now grazed, and other mown and grazed parcels were abandoned, indicating that all changes in land use occurred in the direction of reduced labour. Plant species richness per 5 x 5 m records was higher in parcels at higher altitudes, in unfertilised parcels, and in currently grazed than in abandoned or currently mown parcels. Our research contributes to basic biodiversity research as it reveals the determinants and interrelationships of different levels of grassland biodiversity, and is of applied importance as it elucidates the effect of land use on biodiversity. The fear that the general trend of decreasing agricultural land use will drastically reduce man-made biodiversity in the Alps is supported by our results.

Keywords: cultural landscapes, diversity, land use, *Poa alpina*, Swiss Alps

Introduction

Since Rio 1992, the importance of biodiversity at all levels from the ecosystem to the gene has been acknowledged, and monitoring and research on biodiversity has become a priority in many countries. In the Alps several thousand years of land use have created a cultural landscape with grasslands as an important element whose biodiversity is shaped by the interaction between geological and topographical situation, cultural (Romanic, Germanic, and Walser) traditions, and modern impacts on land use. Today this biodiversity is largely threatened. However, we do not know how much of the existing biodiversity of the alpine landscape is due to cultural traditions, and we ignore even more the extent to which this biodiversity is threatened by changes in land use and by recent socio-economic changes in the alpine economy. We therefore comprehensively explore regional, altitudinal, and cultural differences in grassland biodiversity at all biological levels, and political and socio-economic impacts on this diversity in 219 parcels of land in 12 villages, 4 from each of the three different cultural traditions.

Materials and methods

The complementary parts of the project are all using the same hierarchical parcel-based design within and among alpine valleys (12 study villages, figure 1). For each parcel, we investigate cultural traditions, land use history, socio-economic impacts, geological and topographical situation, and plant biodiversity at all levels, including the levels of the plant community and species, biological interactions, and genetic (quantitative and molecular microsatellite) variation of the agriculturally important grass species *Poa alpina*.

In each valley we study parcels of land at three altitudinal levels: valley bottom, 'Maiensäss' level, and Alp level (above treeline). At each altitude study parcels represent up to 12 different combinations of two fertilisation levels (unfertilised or fertilised), of two traditional land uses (mown or grazed) and of three current land uses (mown, grazed, or abandoned). In each parcel diversity parameters are assessed in two 5 x 5 m quadrats. Here we present data on the occurrence of different land use types and on plant species richness.

Figure 1. Map of Switzerland with 12 study villages. Symbols indicate cultural traditions. Germanic ■, Romanic▲, Walser● .

Results and discussion

The likelihood of finding a parcel of particular land use type at a certain altitude depended on land use history (P < 0.001) and altitude (P < 0.001). Moreover, a significant interaction between these factors (P < 0.001) indicated that fertilised parcels was four times more likely to occur in valleys than at the highest altitudes. More different types of land use history occurred in the valleys of Romanic villages than in those of Germanic or Walser villages (P < 0.051), indicating that cultural traditions are still playing a role (Figure 2).

Some formerly mown parcels are now grazed, and other mown and grazed parcels were abandoned, indicating the important socio-economic trend that all changes in land use occurred in the direction of reduced labour. This is in line with the general trend of decreasing labour and increasing abandonment found throughout the Alpine arch (Bätzing, 2003).

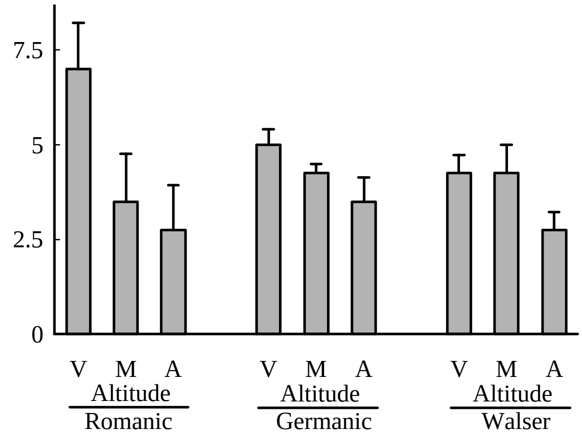

Figure 2. The mean number of different land use types of grasslands in the Alps at different altitudes (valley V, 'Maiensäss' M, Alp A) in villages of different cultural tradition. The maximum number of land use types would be 12, if all combinations of two fertilisation levels, two levels of traditional land use (mown or grazed) and three levels of current use (mown, grazed, or abandoned) would be present.

Mean plant species richness of two 5 x 5 m quadrats per parcel was lower (P < 0.0001) in valley parcels (average altitude 1260 m; 37.1 species per 5 × 5 m, Figure 3A), than in parcels at the so-called Maiensäss level (1616 m; 44.2 species) or in parcels above current tree line (1978 m; 44.1 species). The apparent contradiction between this trend and the usually reported decrease of species richness with higher altitude (Nagy *et al.*, 2003) is resolved by the higher frequency of fertilised parcels in valleys in our study.

As hypothesised we found grassland biodiversity greatly affected by the type of land use (Figure 3B). Plant species richness was 42.0 % higher in unfertilised parcels than in fertilised ones (P < 0.0001). Plant species richness was higher in currently grazed parcels (42.7 species) than in currently mown (39.4 species) or abandoned parcels (39.8 species). This suggests a positive effect of grazing on plant species richness. However, among unfertilised parcels, plant species richness was higher in traditionally mown parcels (47.7 species) than in traditionally grazed sites (44.4 species; P < 0.04), suggesting that in the long run mowing would result in the highest species richness. This corresponds well with the decreasing species diversity with increasing duration of grazing found in unfertilised traditionally mown parcels after conversion to grazing (Fischer and Wipf, 2003).

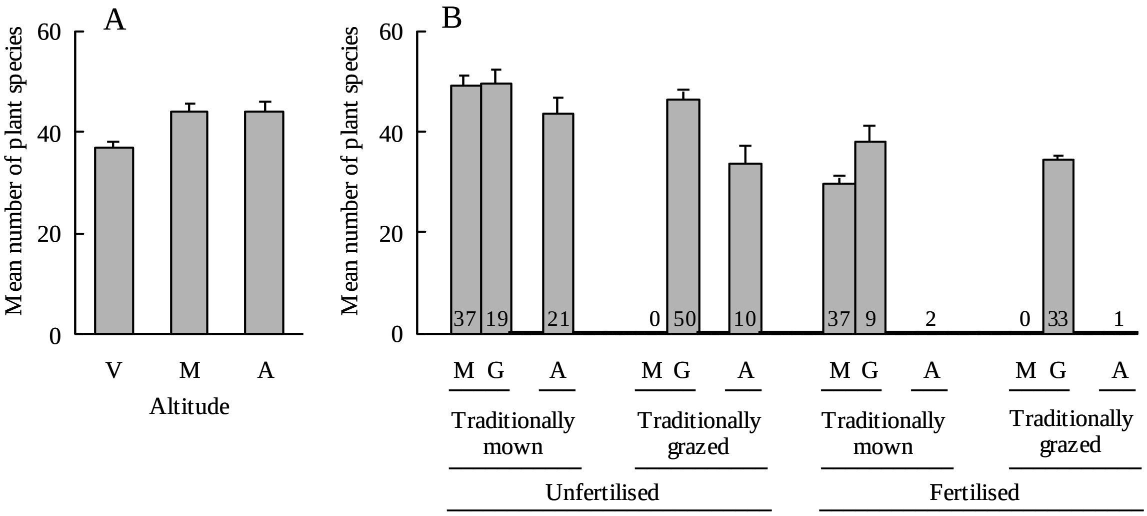

Figure 3. The relationship between the mean number of plant species per 5 x 5 m in grassland parcels in the Alps and A) the altitudinal belt where the parcel is situated (valley V, Maiensäss M, Alp A), and B) the combination of current land uses (mown M, grazed G, abandoned A), traditional land uses and fertilisation. The numbers in each column indicate the number of parcels to which the land use combination applied. Because no traditionally grazed parcel is now mown, and only three fertilised parcels were abandoned we did not draw columns for these land use combinations.

Conclusions

Our research contributes to basic biodiversity research as it reveals the relative importance of determinants of grassland biodiversity, and is of applied importance as it reveals the detrimental effect of abandonment and fertilisation on biodiversity and allows us to identify situations where grazing is most beneficial for grassland biodiversity and situations where mowing is most beneficial. The fear that the general trend of decreasing agricultural land use will drastically reduce man-made biodiversity in the Alpine belt is supported by our results. These results will contribute to evaluating the success of legal and economic measures to support biodiversity. Moreover, concrete proposals for legislation and conservation practice can be worked out on this basis and implemented in transdisciplinary collaboration with cantonal and federal authorities.

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Spatio-temporal changes in structural patterns in subalpine grasslands under different environmental conditions and management regimes

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Abstract

We conducted four surveys in subalpine grasslands in the Pyrenees to assess how changes in the patterns of plant species distribution at different spatio-temporal scales relate to changes in environmental factors and management regimes. Abiotic factors were found to be the main factors structuring subalpine grasslands, mainly along the mesic-xeric gradient. Grazing influenced vegetation distribution and plant diversity. Grazing by sheep reduced species richness and increased dominance by a few, low palatable plants, compared to cattle grazing. However, in a sheep-grazed area plant species diversity increased with grazing and decreased with abandonment. The dynamics of species richness throughout the growing season was also related to environmental factors, but the effect was scale-dependent. At small scales temporal patterns were site-dependent, while those at the intermediate scale were habitat-dependent.

Keywords: plant diversity, grazing, environmental gradients, land use changes, Pyrenees

Introduction

The interaction between plants and their environment is assumed to lead to the establishment of structural patterns that reflect community organization, but the relative role of the different environmental influences on spatio-temporal variations in the vegetation still has to be disentangled. There is widespread agreement on the significance of the abiotic factors in community assembly and species interactions (Dunson and Travis, 1991). Grazing is known to modify vegetation dramatically (Bullock *et al*., 2001), altering its spatial heterogeneity and influencing ecosystem processes and biodiversity (Collins *et al*., 2002). Multi-scale studies provide clear evidence that the effects of grazing on spatial heterogeneity can be scale-dependent (Adler *et al*., 2001).

We conducted four surveys on subalpine grasslands in the Pyrenees in order to determine: a) the role of abiotic factors in the distribution of plant communities and diversity; b) the influence of livestock management on vegetation; c) if temporal dynamics is related to the environment where grasslands develop and if it is dependent on the considered scale. In a previous study we found these systems to be very dynamic throughout the growing season in terms of species richness, although they are composed mainly of perennials (Sebastià *et al*., 1998).

Methodology

We conducted an extensive survey in 126 subalpine grasslands in the Eastern Pyrenees on limestone (S1, Table 1). We determined plant species frequency by the point-quadrat method, recorded topography variables and analysed soil samples (Sebastià, in press). In one location, we established twelve 100 m^2 plots on northern and southern facing slopes, with two replicates for each of the following treatments: abandoned, moderately grazed and frequently grazed (by sheep). We recorded the number of species in the 100 m^2 plots and in 1 m^2 plots established systematically inside each 100 m^2 plot (S2, Table 1). In a third survey carried out in the Central Pyrenees (S3, Table 1), we established 100 m^2 plots in 24 grasslands on acid and basic rocks, distributed according to the following management treatments: a) sheep /

cattle grazed; and b) heavy / moderate / light grazing. We determined the number of species by plot. We harvested 1 m^2 to determine biomass at the peak of the growing season. Finally, on two slopes located at Pla de Rus, Eastern Pyrenees, we established four 1024 x 1024 cm plots, two on mesic and two on xeric grasslands (S4, Table 1). Within each one we established a grid of 8 x 8 plots, 128 x 128 cm each. Systematically, we established another grid of 8 x 8 plots, 64 x 64 cm each, in one of the 128 x 128 cm plots. A third grid of 8 x 8 plots, 8 x 8 cm each was placed within this one. The total number of species present in each plot at the different scales was recorded every two weeks from mid May to mid September.

Table 1. Methodological details in four surveys conducted in subalpine Pyrenean grasslands.

No.	Location	Sampling method	Environmental factors	Vegetation response
S1	Eastern Pyrenees limestone 1800-2300 m	126 linear transects 10 m long, point-quadrat method	topography, soils	no. species per plot and species frequency
S2	Vall d'Alinyà 1900-2000 m Eastern Pyrenees limestone	12 × 100 m^2 plots with grid 1 m^2	grazing intensity, grazing species, high/low slope, north/south	no. species per plot and species frequency at two spatial scales
S3	Alta Ribagorça Central Pyrenees 2000-2250 m	24 × 100 m^2 plots with 4 subplots 0.5 × 0.5 m	grazing intensity, sheep/cattle, high/low slope, N/S, acid/basic bedrock	no. species per plot, total yield and species biomass
S4	Pla de Rus 2000 m Eastern Pyrenees limestone	4 × 1024 × 1024 cm plots with grid 128 ×128 cm, one with grid 64 × 64 cm, one with grid 8×8 cm	mesic/xeric conditions, temporal variation	temporal changes in no. species per plot at three spatial scales

Results and discussion

Samples from the extensive survey in the Eastern Pyrenees on limestone (S1) were distributed by multivariate analysis into two distinct groups, mesic grasslands, with deep, acidic, nutrient-rich soils, and xeric grasslands, with shallow, stony, nutrient-poor soils, indicating that fertility was the main factor structuring grassland vegetation (Sebastià, in press). In the survey at the Central Pyrenees site (S3) multivariate analysis separated communities dominated by *Festuca eskia*, particularly abundant on steep slopes, and, in the second term, distributed the samples along the mesic / xeric gradient. This indicates that, at the landscape scale, community distribution is highly associated to abiotic factors, probably in relation to resource availability. However, grazing also contributed to community distribution. From the four communities identified in S3, *Nardus stricta* (mesic) and *Festuca eskia* (mesic to xeric) communities were significantly associated with sheep grazing, while *Festuca nigrescens* (mesic) and *Festuca gautieri* (xeric) communities were mainly found in cattle-grazed areas.

Additionally, grazing affected species diversity. In S2, we found an increase in the number of species with increasing sheep grazing intensity. Species richness was lower in the abandoned areas. Grazing better explained the heterogeneity in the number of species at small scales (R^2_{adj} = 0.931) than at large scales (R^2_{adj} = 0.447). Diversity was also dependent on grazing species. Sheep-grazed areas had lower species richness than cattle-grazed areas in S3. In the same survey, the number of species was significantly lower on acid than on basic bedrock, but it increased with pH on limestone in S1, suggesting complex relationships between species diversity and nutrient availability. Mesic grasslands showed higher diversity than xeric grasslands at all considered scales (Table 2). At intermediate scales, the trajectories in number of species through time were different for xeric than for mesic grasslands, with small shifts between sites (Table 2). At the smaller scales, trajectories were site-dependent (Table 2).

Table 2. Repeated measurements ANOVA on number of species (up to 8 sampling times) by plot at three different scales in S4. Habitat: mesic / xeric; site (block): SITE1 / SITE2.

Factor	1024×1024 cm^2 scale T4-T8	64×64 cm^2 scale T1-T8	8×8 cm^2 scale T1-T8
Time	n.s.	$P < 0.001$	$P < 0.001$
Time × habitat	n.s.	$P = 0.002$	$P = 0.019$
Time × site	n.s.	n.s.	$P = 0.009$
Time × habitat × site	n.s.	n.s	$P < 0.001$

Conclusions

At the landscape scale, abiotic factors explain much of the variability in vegetation distribution. At small scales, grazing is highly related to spatio-temporal shifts in diversity. Although subalpine grasslands in the Pyrenees are mainly composed by perennial species that have a short growing season, the number of species is highly dynamic through time.

Acknowledgements

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Botanical composition of grassland in the Alps as an indicator for changes in management

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Abstract

In recent decades, there have been important changes in agriculture in the Swiss Alps involving shifts in the type and intensity of land use. Since grassland systems are the main source of forage production and a main contributor to biodiversity in the Alps, it is important to know the effects of these ongoing changes on the botanical composition of grassland. In order to study alterations in plant species composition, 114 relevés of six vegetation units (VU) made at Château d'Oex, Switzerland (between 920 and 2140 m asl) in 1981 were repeated in 2002. There were significant changes between the old and new relevés in all six VUs, with the time of recording explaining between 5.0 to 9.5 % of the total variation in botanical composition. For intensively managed meadows and nutrient poor pastures at lower altitudes, changes over time were mainly due to an intensification of management. In these VUs species indicating disturbed ground and species growing on nutrient rich soils increased. Such intensification of land use in nutrient poor pastures could in the future result in a decrease in biodiversity. In the other VUs shifts in the botanical composition could either not be explained by management or indicated different trends in land use practice.

Keywords: vegetation change, grassland, botanical composition, Swiss Alps

Introduction

Grassland systems are characteristic of landscapes in the Alps. They cover large areas and are an important source of agricultural production as well as providing an essential habitat for numerous organisms and various ecological processes. As a result of shifts in the economic and political situation, changes in the type and intensity of grassland management have occurred in recent years and more change can be expected.
The aim of this study was to test whether and how the changes in management of the last two decades have affected the botanical composition of grassland. It was hypothesised that such changes have lead to a polarisation between intensively and extensively managed grassland, with management of areas with favourable conditions being further intensified, whilst areas with unfavourable conditions being further extensified or abandoned.

Materials and methods

Changes in the botanical composition of grassland systems were studied in the municipality of Château d'Oex (Switzerland) by repeating 114 botanical relevés carried out in 1981 (Mercier, 1984) during 2002. The study sites were distributed along an altitudinal gradient from 920 to 2140 m asl and covered many different types and intensities of management. Based on their plant species composition, the old records were grouped into six vegetation units (VU) by cluster analysis. For each unit, change in species composition over time was analysed by Redundancy Analysis (RDA) and the Monte-Carlo permutation test (CANOCO, ter Braak and Šmilauer, 2002). The indicator value of species (Dufrêne and Legendre, 1997) was used to determine individual species that differed significantly in their occurrence or proportion between 1981 and 2002.

Results and discussion

The six vegetation units (VU) determined by cluster analysis represented different types and intensities of management at varying altitudes (Table 1A). VU1 represented meadows with moderately intensive management (*Arrhenaterion*, *Trisetion*) and a mean altitude of 1153 m asl Intensively managed pastures at a range of altitudes were grouped in VU2 (*Alchemillo-Cynosuretum*) and VU3 (*Crepido-Cynosuretum*). VU4 (dry conditions at a mean altitude of 1377 m asl) and VU5 (calcareous sites at a mean altitude of 1547 m asl) comprised nutrient poor pastures and VU6 corresponded to alpine pastures (*Crepido-Festucetum*) at a mean altitude of 1914 m asl.

In all VUs significant changes ($P < 0.01$; Table 1B) in the botanical composition over the last two decades were revealed by the RDA. These changes explained 5.0 to 9.5 % of the variation in the floristic data. Compositional changes in most VUs were associated with changes in management practice. However, changes in the species composition of alpine and nutrient poor pastures at higher altitude (VU5, VU6) could not be explained by management. Initial analyses revealed that these changes were related to alterations in the occurrence or proportion of species that are known to show strong annual and seasonal fluctuations.

Table 1. Mean site characteristics of the six vegetation units (VU) in Château d'Oex (A), the proportion of variability explained by changes in botanical composition over two decades (B) and changes in species richness and nutrient indicator value N (C).

			VU1		**VU2**		**VU3**		**VU4**		**VU5**		**VU6**		**SD**[1]
A	Number of sites		40		14		15		21		13		11		
	Altitude [m asl]		1153		1362		1588		1377		1547		1914		131
	Inclination [%]		28		27		47		52		53		50		17
B	Expl. var. [%] [2]		5.0		7.1		8.9		6.6		8.1		9.5		
	Significance level		**		**		**		**		**		**		
C	Species per plot	1980	25.4	**	32.0	ns	42.7	ns	52.2	ns	56.7	ns	34.9	ns	8.21
		2002	30.0		34.6		40.9		49.6		58.2		39.2		7.79
	N-value[3]	1980	3.54	**	3.20	+	3.02	+	2.66	**	2.53	ns	2.80	ns	0.15
		2002	3.62		3.31		3.15		2.98		2.59		2.80		0.19

[1] SD = mean standard deviation; [2] species variability explained by the factor 'Year'; significance level: + $P < 0.10$, * $P < 0.05$, ** $P < 0.01$, ns = not significant; [3] according to Landolt (1977).

Intensively managed meadows (VU1): The main function of this grassland type is the production of high yields of high quality forage, and it is not surprising that species richness was relatively low, with an average of 30 plant species per plot in 2002 (Table 1C). The nutrient indicator value N (Landolt, 1977) was already high in 1981 and had increased further by 2002, indicating a higher N availability. Species such as *Leontodon hispidus*, *Knautia arvense, Campanula rhomboidalis* and *Dactylis glomerata* (Table 2) that do not tolerate intensive cutting regimes decreased significantly. These changes suggest an increase in management intensity (cutting frequency and fertiliser input). Over-intensification of management can lead to sward degeneration and the observed increase of weeds associated with gaps (e.g., *Polygonum aviculare*, *Plantago major*, *Rumex obtusifolius, Capsella bursa-pastoris, Bromus hordeaceus*) may indicate this tendency. However, overall the proportion of these species remained at a low level (< 10 %).

Intensively managed pastures (VU2, VU3): In these VUs floristic changes indicative of altered management were not consistent. The N value increased slightly ($P = 0.07$; Table 1C) along with the frequency of nitrophilous forbs of gaps (VU3: *Cerastium fontanum* and

Polygonum aviculare), but species indicating reduced management intensity (VU3: *Thymus serpyllum*, *Stellaria graminea*, *Lotus corniculatus* and *Lathyrus pratensis*) also increased.

Nutrient poor pastures of dry conditions (VU4): This VU is important for the maintenance of biodiversity, with 50 plant species recorded per site. The strongest increase in N indicator value was observed in this VU ($P < 0.01$) and the frequency of nitrophilous species (*Galeopsis tetrahit*, *Cerastium fontanum*, *Lolium perenne*, *Polygonum aviculare*, *Cruciata laevipes*, *Geranium sylvaticum*, *Alchemilla vulgaris*) also increased. In contrast, species of vegetation types requiring low management intensity (*Phyteuma orbiculare*, *Linum catharticum*, *Carlina acaulis*) decreased. As high N indicator values are related to low species diversity (compare N values and species numbers of all VUs; Table 1C) this development may mark the beginning of a long-term decline of biodiversity in this VU.

Table 2. Species of the three vegetation units (VU) that changed significantly in their occurrence or proportion between 1981 and 2002 in Château d'Oex.

	VU1		VU2		VU4	
	IndVal[1]	Species	IndVal[1]	Species	IndVal[1]	Species
Increase	0.73 ***	*Cerastium fontanum*	0.62 **	*Cerastium fontanum*	0.62 ***	*Geranium sylvaticum*
	0.50 ***	*Polygonum aviculare*	0.56 **	*Vicia sepium*	0.61 ***	*Cerastium fontanum*
	0.46 **	*Veronica serpyllifolia*	0.45 *	*Lotus corniculatus*	0.59 **	*Alchemilla vulgaris*
	0.44 ***	*Bromus hordeaceus*	0.36 *	*Polygonum aviculare*	0.58 ***	*Vicia sepium*
	0.40 **	*Rumex obtusifolius*	0.31 *	*Crepis biennis*	0.56 ***	*Galeopsis tetrahit*
	0.37 ***	*Alopecurus pratensis*	0.29 *	*Thymus serpyllum*	0.45 *	*Tragopogon pratensis*
	0.28 **	*Veronica arvense*	0.29 *	*Stellaria graminea*	0.33 *	*Phleum pratense*
	0.24 *	*Plantago major*	0.46 *	*Lathyrus pratensis*	0.32 *	*Cruciata laevipes*
	0.23 *	*Galium album*			0.27 *	*Lolium perenne*
	0.23 *	*Agropyron repens*			0.24 *	*Polygonum aviculare*
	0.21 *	*Capsella bursa-pastoris*				
Decrease	0.57 ***	*Dactylis glomerata*	0.64 **	*Carum carvi*	0.71 ***	*Leontodon hispidus*
	0.54 **	*Anthriscus sylvestris*	0.61 **	*Agrostis capillaris*	0.57 **	*Festuca rubra*
	0.30 *	*Campanula rhomboidalis*	0.48 *	*Leontodon hispidus*	0.55 **	*Phyteuma orbiculare*
	0.21 *	*Leontodon hispidus*			0.47 *	*Carlina acaulis*
	0.13 *	*Knautia arvense*			0.32 *	*Linum catharticum*

[1] Indicator value of species (IndVal) showing the species' indicating power for changes in their occurrence or proportion; $n_{VU1} = 40$, $n_{VU2} = 14$, $n_{VU4} = 21$; significance level: * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$.

Conclusions

In intensively managed meadows (VU1) and nutrient poor pastures (VU4) at lower altitudes, changes in the botanical composition since 1981 were mainly indicative of an intensification in management. In the long-term this could result in decreased biodiversity within the nutrient poor pastures (VU4). In the other VUs shifts in the botanical composition could not be explained by management or suggested contrasting changes in land use practice.

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Long-term effects of cattle grazing upon the phosphorus status of alpine pastures

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Abstract

Long-term use of alpine pastures (alps) by cattle creates a strong heterogeneity in plant species composition and soil nutrient content. To understand how these patterns arise, we observed the activity of a herd of Scottish highland cattle on an alp in southern Switzerland and constructed a GIS model of the phosphorus balance resulting from the removal of P by grazing and the return of P in dung. According to our model, 2 % of the area had a positive P balance of > 5 kg ha^{-1} y^{-1}, 25 % had a negative P balance of > 0.5 kg ha^{-1} y^{-1}, and the remainder of the area was hardly used so that the P balance was close to zero. The comparison of data from two years (1996 and 1998) shows that restricting cattle movement with a fence can reduce (but not prevent) the lateral transfer of nutrients. Data on soil P concentrations suggest that spatial patterns of nutrient transfer on an alp are relatively stable; the long-term consequence is that large areas become depleted of P, while small areas accumulate high concentrations of P, some of which may be lost from the ecosystem through leaching and run-off.

Keywords: alpine pastures, cattle grazing, GIS model, nutrient transfer, phosphorus, sustainability

Introduction

Many alpine pastures in Switzerland have been used for summer grazing for hundreds and even thousands of years. We hypothesise that similar spatial patterns of habitat use by cattle over long periods have led to the redistribution of large quantities of nutrients within the grazing area and that this process has had major consequences for soil conditions and the species composition of vegetation. In this study we investigate the spatial redistribution of phosphorus by livestock, and how restricting cattle movement with a fence affects the lateral transfer of nutrients.

Materials and methods

The study was conducted in 73 ha of sub-alpine pasture at Alpe Nisciora on the south eastern flank of Mount Gradiccioli in southern Switzerland. Due to a long history of grazing by domestic livestock, the entire area above 1400 m is now free from forest vegetation and dominated mostly by grasses, in particular *Nardus stricta*. For several years during the 1970's and 1980's there was little or no use of the alp as a summer pasture but since 1994 it has been grazed by a herd of 60-70 Scottish highland cattle.

During 1996 and 1998 we made observations of the spatial distribution and activity of cattle. We recorded on a map the positions of all individuals to a precision of ± 10 m. In 1996, a fence divided Alpe Nisciora into two sections. The animals were grazed in the smaller eastern paddock (18 ha) from 30 May to 19 July and were then moved into the western paddock (55 ha), where they remained until the end of the season. In 1998, the cattle had free access to the entire area. At the end of each grazing season we mapped the spatial distribution of dung by walking over the entire site along parallel transects about 20 m apart. The data thus obtained do not provide a reliable measure of the quantity of dung but do reflect its spatial distribution.

A spatial model of the P balance in the study area was constructed using the GIS program Arc-Info. All model calculations were for 40 beef cattle units (40 cows plus their calves, i.e., around 80 animals) grazing for 100 days on an area of 73.5 ha (Table 1). This stocking density is probably close to the average number of cattle grazing on the alp during the 19^{th} century. The P off-take model was based on the assumption that animals ingest P in proportion to the time spent feeding, taking into account the structure and P concentration of the vegetation. In a study on the adjacent Alp Gem, Berry *et al*. (2002) found that the daily off-take of phosphorus through herbage by a Scottish highland cow and its calf (i.e., one beef cattle unit) was 26.2 g. Using this information we scaled the cattle distribution map so that it represented the spatial distribution of P off-take for 40 beef cattle units feeding on Alp Nisciora during the grazing season (i.e., 104.8 kg P $season^{-1}$). The spatial distribution of P returned to the soil was assumed to be the same as that of the dung pats, since very little P is returned in urine. According to Berry *et al*. (2002), an average Scottish highland cow plus calf excretes 22.3 g P per day. For 40 beef cattle units the seasonal return of P in dung is therefore 89.2 kg. The P-balance was obtained by subtracting the P-return model from the P-off-take model.

Results and discussion

The spatial distributions of grazing animals and of dung pats in the seasons 1996 and 1998 were relatively similar to each other. In both years, grazing and defecation were largely concentrated on the lower parts of the alp, and most of the area was used only lightly (ca. 40 % of the total area) or not at all (ca. 50 %). The distribution of grazing was negatively correlated with slope (r = -0.40 in 1996, -0.35 in 1998). Areas receiving high grazing pressure, i.e., the upper 20 % from the range of values, accounted for less than 1 % of the total area in both years (1712 m^2 in 1996, 389 m^2 in 1998).

Overall, less P was returned in dung than taken off with herbage, so that there was a net loss of P from the site of 15.6 kg per grazing season (Table 1), equivalent to 0.22 kg ha^{-1} y^{-1}. This loss represents the P retention in the bodies of the animals, especially the calves, which are removed from the alp at the end of the season. The model suggests that when the site is divided into two paddocks, as in 1996, the loss of P from each paddock is proportional to the time spent by cattle in each of them (assuming no seasonal differences in nutrition). Thus, one third of the total P loss in 1996 was from the eastern paddock (5 hg ha^{-1}) and two thirds were from the western paddock (11 hg ha^{-1}). When the animals have free access to both paddocks, the P loss is distributed differently. In 1998, the eastern paddock accounted for 43 % of P off-take but 77 % of P return, reflecting the strong preference of animals to use this paddock for resting, ruminating and defecation. As a result, the eastern paddock gained 24.4 kg P (1.36 kg ha^{-1} y^{-1}), whereas the western paddock had a net P loss of 39.8 kg (equivalent to -0.72 kg ha^{-1} y^{-1}). The spatial pattern of the P balance was broadly similar in 1996 and in 1998. In both years, 54 % of the site had a P balance close to zero (-0.5 to +0.5 kg ha^{-1}); approximately one quarter of the site had a net loss of P of > 0.5 kg ha^{-1} y^{-1} while a quarter had a net gain of > 0.5 kg ha^{-1} y^{-1}.

In both years the area gaining > 5 kg P ha^{-1} was half of the area losing P at this rate, indicating a tendency for P to become concentrated in small areas. This tendency was particularly strong in 1998 when a few small areas had a net P balance of > 50 kg ha^{-1} y^{-1}. Areas with significant gains or losses of P were all in the lower part of the alp, whereas the entire upper part had a P balance close to zero.

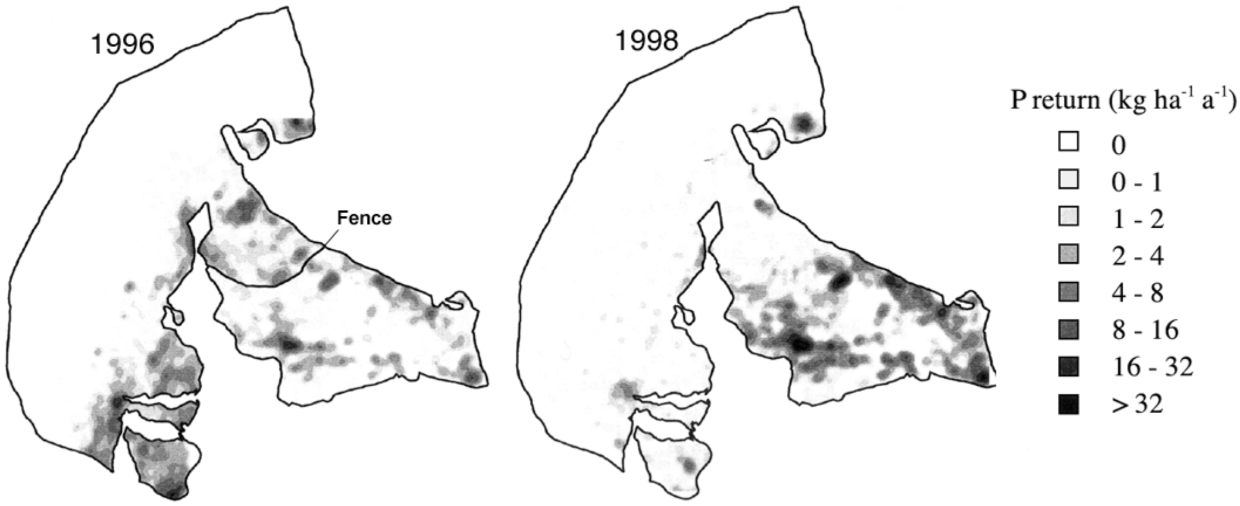

Figure 1. Model estimates of P return in dung on Alpe Nisciora.

Table 1. Model estimates of the uptake and return of phosphorus by cattle in two paddocks on Alp Nisciora. In 1996, cattle were kept for one third of the season in the eastern paddock and then moved to the western paddock. In 1998, paddocks were not separated and cattle had free access to both throughout the grazing season.

	Paddocks separated (1996)			Free ranging (1998)		
Paddock	West	East	Both	West	East	Both
Area (ha)	55.5	18.0	73.5	55.5	18.0	73.5
P consumed (kg)	70	35	105	60	45	105
P returned (kg)	58	29	89	20	69	89
P balance (kg)	-11	-5	-16	-40	24	-16

The data presented here suggest that patterns of habitat use by cattle can lead to substantial transfers of nutrients within a site. The spatial patterns of defecation that we observed in 1996 and 1998 are probably relatively stable, since the cattle tend to select the same few flat areas for resting and ruminating. This could explain the significant positive relationships ($P < 0.01$) we found between the P balance and the quantity of P in the top 30 cm of soil (determined in 1998 at 82 points over the site). All points with a high positive (> 10 kg P ha^{-1} y^{-1}) local P balance had a high P capital in the soil (3000-7000 kg ha^{-1}), whereas points with a negative P balance of more than 2 kg P ha^{-1} y^{-1} had a low P capital (1000-3000 kg ha^{-1}). If the spatial patterns of habitat use are fairly stable, the long-term effect of the fluxes of P described here (and also of other nutrients) would be for certain areas to become impoverished, leading to the development of vegetation of low nutritional quality. Probably, much of the *Nardus stricta* grassland has developed from former grazing areas as a result of this depletion process. There may also be substantial losses of nutrients due to leaching and run-off from these nutrient hot-spots. This would promote the loss of nutrients, leading to a progressive impoverishment of the grazing system.

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Sheep grazing in the high alpine under global change

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Abstract

To assess the combined consequences of atmospheric changes and altered land use in the alpine belt, a manipulative field experiment in steep grassland was established in the Swiss Central Alps. Complete swards were translocated to a lower elevation to simulate climatic warming, treated with nitrogen (N) 'deposition' at a rate of 25 kg N ha^{-1} y^{-1}, and simulated sheep trampling (by hoofed shoes). First results indicate that alpine plant species are sensitive to both warming and low rates of N addition. Graminoids were found to be particularly responsive to increases in N deposition. Plant responses to simulated warming (+ 1 K) were negative, partly due to the extremely dry weather conditions in 2003. Trampling caused very little change in growth, indicating that these alpine plants can cope with moderate mechanical disturbance. All significant treatment effects were species or functional type specific, and as such are likely to affect biodiversity in the long run.

Keywords: sheep trampling, nitrogen deposition, climatic warming

Introduction

As a result of traditional land use in the high alpine, highly diverse, stable and attractive plant communities have evolved. However changes in land use, increased atmospheric nitrogen deposition, and climatic warming all exert a major anthropogenic impact on alpine ecosystems. Changes in vegetation composition and plant cover are critical in steep slopes, since plant roots are the only forces that fasten soil in steep terrain.

Materials and methods

The study involves two experimental sites situated near the Furka pass on a west-exposed steep slope (46°34'N, 08°25'E) at an elevation of 2630 m and 2430 m asl. Forty complete swards (28 cm in diameter (0.068 m^2), 10 cm deep) were transplanted from 2630 to 2430 m asl, to expose them to conditions about +1 K warmer. At 2630 m asl, forty swards were transplanted locally in order to separate translocation effect from cut-only effect. Temperature data loggers (Tidbit, Onset Corporation, USA, 1 h measurement interval) were buried at a soil depth of 10 cm at both sites. To simulate an increase in wet N deposition, N (dissolved NH_4NO_3) at the rate of 25 kg N ha^{-1} y^{-1} was added to the transplanted swards. Sheep trampling was performed by hoofed-shoes (3 hooves per shoe, 60 steps m^{-2} (2002), and 120 steps m^{-2} (2003)). The weight of 60 kg per 3 hooves corresponds to the mean weight of female sheep (55-80 kg). N addition and trampling were applied to the swards in a randomised block design (10 replicates per treatment). Volumetric soil water content was measured with two theta probes (Delta-T devices, type ML2x, Cambridge, UK, 1 h measurement interval), inserted to a soil depth of 5 cm at 2430 m asl, with two probe readings averaged. At the site, a self-emptying rain gauge with a single counter (RainWise Inc. Maine, USA, rainfall resolution of 0.3 mm) was used to measure precipitation. For vegetation analysis, leaf length in the 5 most abundant plant species: *Carex curvula* (dominating sedge), *Helicotrichon versicolor* (grass), *Poa alpina* (grass), *Leontodon helveticus* (dominating forb), *Geum montanum* (forb), was measured non-destructively in June, July, and August 2003. Within each plot, 5 leaves from different individual plants were censused for length. Changes in total plant cover were determined by a point-intercept method, with 116 points per grid (28 cm diameter). Point-intercept measurements were made in June, July, and August 2003.

Results and discussion

At the lower (warmer) site, soil temperature was 0.5 to 1 K higher (depending on weather) than at 2630 m asl. The largest difference between the two sites were related to the daily minimum temperature (Table 1). The magnitude of this difference corresponds to the degree of warming in the Swiss Alps during last 100 years. The 2003 season was extremely warm and dry, especially for the plants transplanted to the lower site. Soil water contents were close to 5 vol % for 7 days in July, and for 11 days in August, indicating that there was no plant available water left in the uppermost soil layer (Table 1). In 2003, summer precipitation was only 40 % of the precipitation in the previous year (Table 1).

Table 1. Precipitation, soil temperature (-10 cm), and soil moisture (-5 cm) at the experimental site.

Year	Month	Precipitation (mm)	Soil temperature (K) at 2630 m asl			Soil temperature (K) at 2430 m asl			Soil moisture (vol %) at 2430 m asl		
			min	mean	max	min	mean	max	min	mean	max
2002	Jul	98	7.2	11.7	15.8	7.7	10.6	14.4			
	Aug	163	2.4	8.4	15.4	3.7	8.7	13.3			
	Sept	73	0.7	6.0	11.8	2.1	6.6	10.7			
	Jul-Sept	334									
2003	Jun[2, 3]	29	1.9	9.4	16.7	7.6	11.7	16.2			
	Jul	59							5	16	37
	Aug	42							5	13	28
	Sept	34							10	19	30
	Jul-Sept	135									

[2] Snow melt was 20 days earlier at 2430 than at 2630 m asl (11 and 31 May, 2003, respectively).
[3] In June 2003 loggers were exchanged by a new set of loggers (running until June, 2004).

Significant changes in leaf growth in 4 of the 5 selected plant species were observed already one year after the start of the experiment (Table 2). Under warming, reduced leaf growth was found in the sedge *Carex curvula*, in the grass *Helicotrichon versicolor*, and in the forb *Leontodon helveticus*.

Table 2. Effects of warming, N-addition and trampling on the leaf length of 5 plant species and on the total plant cover (measured in June, July, and August 2003). Data on leaf length were analysed by repeated-measures ANOVA (with 3 levels for time). For plant cover data, the pre-treatment vegetation cover data (2002) were included as co-variate (ANCOVA). Direction of arrow indicates positive or negative effect of the impact factor. Number of arrows corresponds to the significant probability level in the statistical analysis (↑: $P < 0.05$, ↑↑: $P < 0.01$, ↑↑↑: $P < 0.001$). Significant interactions between the impact factors are mentioned in the text.

Species	Effects of Warming	N-addition	Trampling
Carex curvula	↓↓	↑↑↑	n. s.
Helicotrichon versicolor	↓	↑	n. s.
Poa alpina	n. s.	n. s.	n. s.
Leontodon helveticus	↓	n. s.	n. s.
Geum montanum	n. s.	n. s.	n. s.
Total plant cover (%)	↓↓↓	↑	(↓)[1]

[1] Trampling had a marginal effect on the total plant cover ($P = 0.098$), cover changes were influenced by previous year data.

In contrast to the effects of warming, adding 25 kg N ha^{-1} y^{-1} stimulated leaf expansion in *Carex* and in *Helicotrichon.* In *Poa alpina*, N-induced growth stimulation was only found at the warmer site (+ve interaction W × N, $P < 0.05$). Forb species did not respond to the additional N input. Trampling had no direct effect on any of the plant species. Under trampling + warming, leaves of *Helictotrichon* were significantly shorter (-ve interaction W × T, $P < 0.05$). Treatment-induced changes in total plant cover were in line with observed changes in leaf expansion of the most abundant plant species *Carex curvula* (Table 2, Figure 1). Annual variation in weather conditions has a strong influence on above ground biomass production in alpine grassland (Schäppi and Körner, 1996). In warm seasons, above ground biomass productions was stimulated by 19 to 27 % compared to cool seasons. Here, under extremely warm and dry weather conditions, a considerable reduction in leaf expansion of 3 species and in total plant cover was observed. N addition (25 kg N ha^{-1} y^{-1}) stimulated leaf growth of the sedge and two grass species, providing evidence that graminoid plant species are more responsive to increased N supply than other plant life forms (e.g., forbs, Heer and Körner, 2002). In previous studies where late successional alpine plant communities were exposed to increased nutrient availability, higher amounts and complete fertiliser were normally used (e.g., 50 kg N ha^{-1} y^{-1} by Schäppi and Körner (1996)). However in the current study a considerably lower level of ‘N-deposition’ had a huge impact on the same plant community. Plants in the alpine zone have been faced with substantial grazing pressure of both wild and domestic animals during the last centuries (Bätzing, 2003). Consequently, trampling hardly affected the selected plant species, demonstrating that alpine plants are well adapted to moderate mechanical loads.

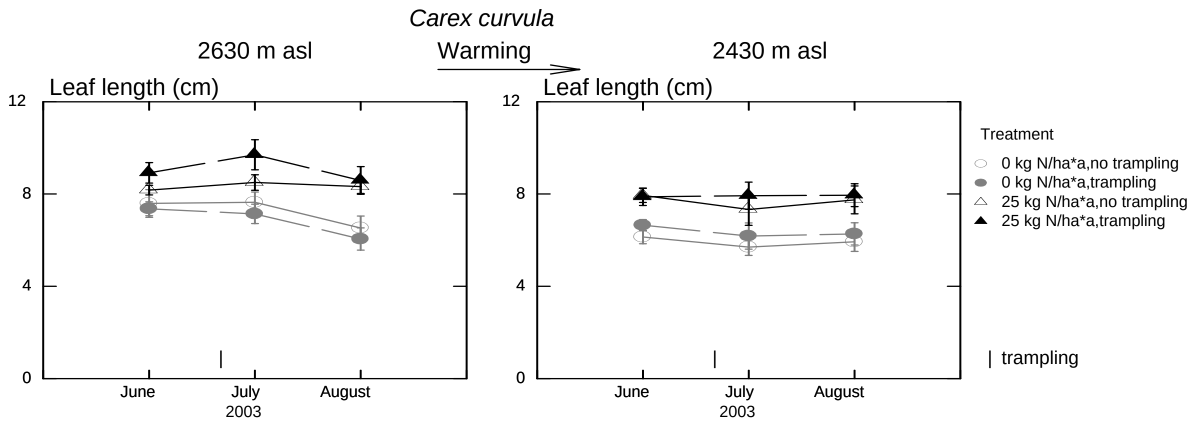

Figure 1. Effects of warming, N addition and trampling on the leaf growth of the most abundant plant species *Carex curvula* in 2003 (means ± SE, n = 10 plots per treatment, 5 leaves per plot). Significant differences between treatments are given in table 2.

Conclusions

Warming and N supply were the main determinants of plant growth in this manipulative experiment, indicating that alpine plant vegetation is responsive to such global changes. Effects were species specific, hence will alter biodiversity (abundance and / or presence of certain species). Impacts of such changes on soil stability will be explored.

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Effects of livestock grazing on plant diversity in alpine grasslands

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Abstract

The effects of grazing on plant diversity were studied in three grasslands on mountainous regions of Central Greece (Olympus, Othrys, Pindos). These alpine grasslands were under various grazing conditions for a long span of time. Ground cover, species richness and evenness were measured. Shannon-Wiener and similarity indexes were calculated. Results indicated that moderate stocking rate, and grazing by different animal species, favored the grassland species diversity.

Keywords: diversity index, similarity index, stocking rate, common grazing.

Introduction

In recent years, biological diversity has played an important role not only in the assessment of natural ecosystems but also in the definition of the main guidelines for sustainable management and for monitoring natural resources (Sabatini *et al*., 2001). The studies of herbivore behavior and of their grazing distribution are important tools to define sustainable management practices. (Bailey *et al*., 1998). Rangelands cover approximately 40 % of Greece and constitute the main type of land use in the country. Only some of them located in the alpine zone of the high mountains are determined by climate and thus considered as climax communities (Ganiatsas, 1964). The aim of this study was to investigate the effects of grazing on plant diversity in alpine grasslands.

Materials and methods

This research was conducted at three alpine grasslands located on the following mountains: Olympus, Othrys and Pindos in central Greece. The grasslands were at an altitude range between 1600-2100 m on Olympus, 1200-1700 m on Othrys, and 1600-2000 m on Pindos. These alpine grasslands were under heavy grazing conditions for a long span of time. The Olympus site was grazed by cattle at a stocking rate of 1.5 cattle ha^{-1} while the other two grasslands (Othrys and Pindos) were grazed in common by cattle, sheep, and goat at stocking rates 1.7 cattle ha^{-1}, and 2.5 cattle ha^{-1} respectively. All sites were grazed for approximately 5 months per year. The stocking rates were calculated according to the relationship: 1 cattle equals 5 small ruminants (Holechek *et al*., 1989). In each site three experimental areas 50 x 50 m were selected randomly. In all sites ground cover and species composition were recorded in late July 2003 using the line point method (Cook and Stubbendieck, 1986) from three 25 m transect-lines. Species number and abundance were measured from ten 0.5 × 0.5 m sampling quadrats in each site. The data were *analys*ed by the 'species diversity and richness' software (PISCES conservation Ltd., 1997). The following indexes were calculated:

1. Shannon-Wiener (H) calculated according to equation $H' = -\sum_{i=1}^{N} Pi \cdot \ln Pi$,

   where Pi is the proportion of individuals of the i_{th} species and N is the total number of species,
2. Species richness (N), which is the total number of plant species,

3. Equitability (J) is the ratio of observed diversity which could possibly occur and calculated according the formula J = H′/Hmax,
   where H is the Shannon-Wiener index and Hmax = lnN (case where all species are equally abundant),
4. The similarity of floristic composition was calculated by the percentage similarity (Pielou, 1984): Ps = 2a ·100/(2a + b + c),
   where P is the percentage similarity, a = number of species in both areas, b = number of species present in the first area only, and c = number of species present in the second area only.

One way ANOVA was used in order to compare diversity indexes of the three sites. Further differences were evaluated with Bonferroni's posthoc test, at 5 % level of significance, according to Sokal and Rohlf (1996). Statistical analysis were performed using SPSS rel. 7.5 for Windows (© SPSS Inc., 1989-96).

Results and discussion

Shannon-Wiener indexes (H) and species richness (N) values were significantly higher ($P < 0.05$) in the Othrys site grassland than the ones in the other sites (Table 1). On the contrary, equitability was significantly lower ($P < 0.05$) in Pindos grassland.

Table 1. Richness and diversity indices in three alpine grasslands.

	Othrys	Pindos	Olympus
Richness	24^{a}	21^{b}	19^{b}
Shannon-Wiener Index	2.746^{a}	2.307^{b}	2.385^{b}
Equitability (H′/Hmax)	0.864^{b}	0.758^{a}	0.820^{b}

Letters indicate differences at 0.05 significant level using Bonferroni's posthoc test
SE for Richness, Shannon-Wiener index and Equitability were 1.065, 0.062 and 0.023 respectively.

The grass plants group was represented with a higher number of species in the Othrys site compared to the other two sites (Figure 1). Grazing intensity appears to reduce the abundance of tall perennial grasses (Briske and Noy Meir, 1998). No significant differences were observed in the perennial forbs group among the three sites, while shrubs participated in both the Othrys and Pindos grasslands. Annual forbs were absent except in Pindos site where one species was found.

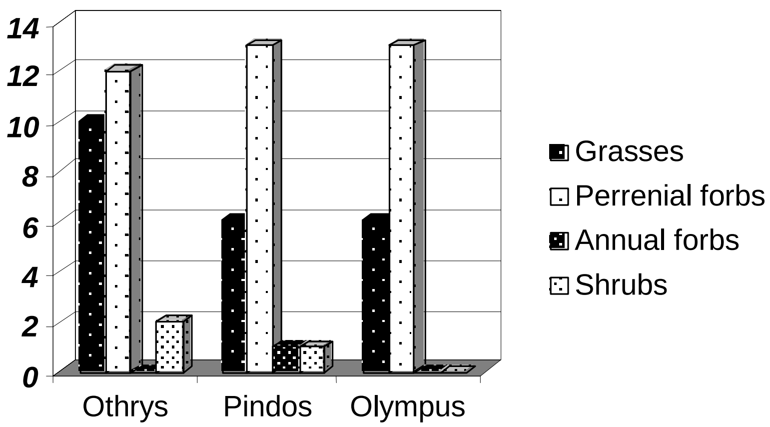

Figure 1. Plant groups in Othrys, Pindos and Olympus alpine grasslands.

Ground cover was increased in Othrys grassland (Figure 2). This can be mainly attributed to the higher participation of grass plants group. These results indicated that in Pindos grassland with high stocking rates (2.5 cattle ha^{-1}) and with three different animal species grazing, the plant species diversity as far as both components (richness and equitability) are concerned, was significantly lower than the one in Othrys where there were the same grazing animal species but moderate stocking rates (1.7 cattle ha^{-1}). Noy Meir (1998) supported that species diversity is predicted to increase at a maximum when moderate grazing intensity is performed and decrease when grazing intensity is high.

In the grasslands with similar stocking rates (Othrys and Olympus), grazing in common (Othrys) increased the richness in comparison with the Olympus site where grazing was performed by only one grazing species (cattle). Similarity indexes from the three alpine grasslands indicated that Othrys and Pindos had the highest Ps values (53.3 %) in comparison with Olympus and Othrys (41.9 %) and Olympus and Pindos (25 %). These results showed that grazing by different species of animals in common, favors alpine grasslands diversity regardless of the stocking rate variance.

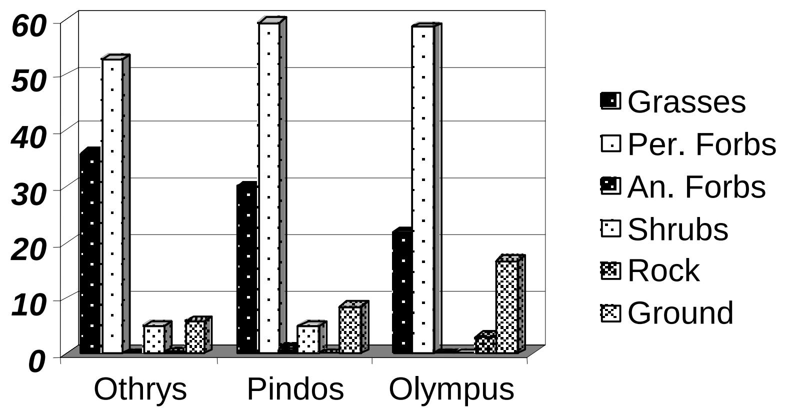

Figure 2. Plant cover (%) in three alpine grasslands.

Conclusions

Grazing in common by three animal species in intermediate stocking rates favored both components (richness and evenness) of the alpine grasslands floristic diversity.
Intermediate stocking rate grazing by one animal species (cattle) affected only the species richness component of the grassland diversity.

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Phytosociological characterization and pasture values of the grasslands on the north-west slopes of mount Cavallazza (NE-Italy)

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Abstract

The investigated area has a size of 100 ha and an altitude ranging from 1930 to 2320 m asl The site is located within the Natural Park 'Paneveggio – Pale di San Martino'. During the growing seasons of 2001 and 2002, 101 phytosociological relevés were recorded using Braun Blanquet modified approach. All the relevés coordinates were recorded by means of a GPS. For the numerical classification of the vegetation relevés, minimal variance as similarity function and correlation coefficient as classification algorithm were applied. Eight main vegetation types were recognised. Five associations were distinguished: *Juncetum trifidi*, *Pulsatillo albae-Festucetum varie*, *Carici curvulae-Nardetum*, *Vaccinio-Rhododendretum ferruginei*, *Nardetum alpigenum*. We derived a map of the vegetation. The pasture values were obtained for each cluster.

Keywords: grassland, pasture value, phytosociology

Introduction

Grasslands have a great importance in the European landscape because of their role in agriculture and their ecological, social and economic relevance. The patchy structure of the mountain, due to the interchange and the intersection of open and closed areas is quickly modifying. These changes have been strongly determined by human actions. Actually the intensification of cattle breeding have some economical advantages but create some environmental disadvantages such as water eutrophication and the increment of the landscape monotony. On the other hand, the extreme extensification and the abandonment of the agronomic practices have several negative consequences such as, a sharp decrease in productivity, production of forages rich in fibre and poor in crude protein, invasion of weed, changes in the structure of the phytocoenosis with preponderance of high grasses, reduction of the species number and invasion of shrubs. All these changes can be predicted and managed through the knowledge of the vegetation and of its spatial distribution. This case study aims to contribute to the solution of such problems through a spatial model of the vegetation patterns from a phytosociological and a phytopastoral point of view.

Materials and methods

The investigated area has a size of 100 ha, an altitude ranging from 1930 to 2320 m asl, and is located in the 'Paneveggio – Pale di San Martino' Natural Park (Trento, NE Italy). The annual mean temperature is 2.57 °C and the annual mean precipitation is 1284 mm. According to Rivas *et al*., (1999) the bioclimate of this area was defined oceanic temperate, with an orotemperate thermotype and a hyperhumid ombrotype. The pedogenetic substrate is silicatic. During the growing seasons of 2001 and 2002, 101 phytosociological relevés, were performed by mean of Braun Blanquet modified approach estimating full precision percentage cover-abundance values. The extension of the sample areas was fixed in 100 m^2 (Pirola, 1960). For the nomenclature Pignatti (1982) was used as reference. All the relevés were located using a GPS. For the numerical classification of the vegetation relevés, presence/absence transformation was applied and then minimal variance as similarity function and correlation coefficient as classification algorithm was adopted. The corrected positions of the relevés (DGPS) were inserted in a GIS and they were overlapped to four layers: a terrain digital model, a map of the slope, a map of the aspect and an ortho-photograph. Through the interpretation of the overlapped layers a map of the vegetation was created. Finally mean pasture values were weighted by means of the method proposed by Klapp *et al*., (1953). Since this method was designed regarding medium altitude meadows, in this case the values have to be considered as qualitative indexes.

Results and discussion

Eight statistically homogenous groups of relevés were obtained by means of the cluster analysis; these were reported in a map (Figure 1).

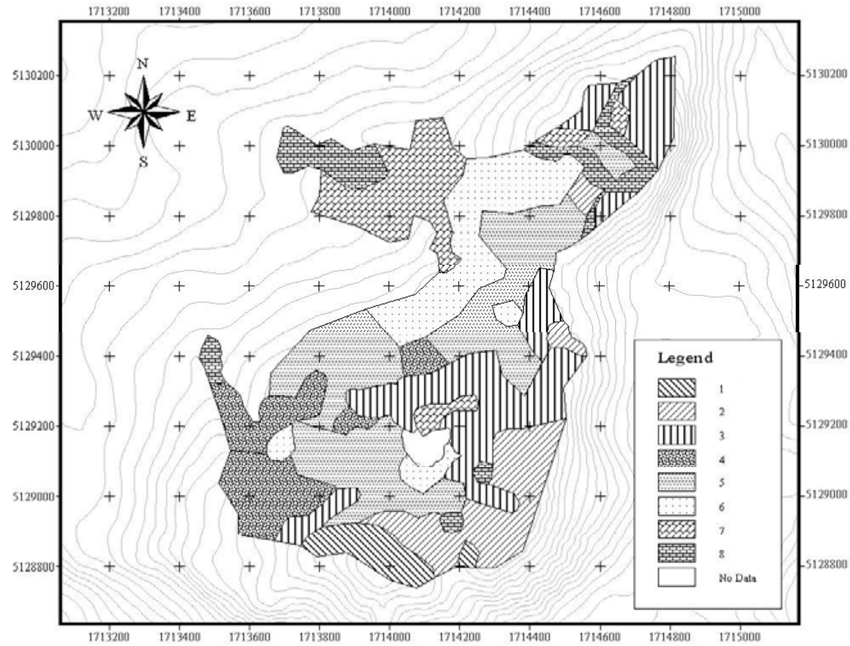

Figure 1. Vegetation map of NW slopes of mount Cavallazza derived from GIS elaboration. (Clusters: 1 *Juncetum trifidi*, 2 *Pulsatillo albae-Festucetum varie*, 3 *Carici curvulae-Nardetum*, 4, 5 *and* 6 *Vaccinio-Rhododendretum ferruginei*, 7 *Nardetum alpigenum*, 8 not classified).

1st cluster: *Juncetum trifidi* em. Krajina 1933. It is located on the top of mount Cavallazza, on slopes exposed to atmospheric agents. This is the less extended of the clusters (Table 1). This association is strongly characterized by *Juncus trifidus* and *Oreochloa disticha* (see also Mucina *et al*., 1993). 2nd cluster: *Pulsatillo albae-Festucetum variae* Theurillat 1989. All the relevés classified in this cluster are located on the exposed slopes under the top of mount Cavallazza. It is difficult to find characteristic species for this association, so the Grabherr's statement (in Mucina *et al*., 1993) asserting that the only characteristic of this association is the relevant presence of *Festuca varia*, was considered valid. 3rd cluster: *Carici curvulae Nardetum* Oberd. 1959. It is a vegetation type closed to the climactic association at this altitude on this soil (*Caricetum curvulae*) (Grabherr in Mucina *et al*., 1993). Wallosek (1999) reports that it is present on the snow beds and it's replaced by *Pulsatillo albae-Festucetum variae* on steeper slopes. The same trend were noticed in this study area. *Vaccinium myrtillus* is quite frequent (accompanying species) and *Carex sempervirens* (characteristic species) has high cover-abundance percentage values (see also Mucina *et al*., 1993) and characterise this group. 4th cluster, 5th cluster and 6th cluster: *Vaccinio-Rhododendretum ferruginei* Br.-Bl.

1927. These clusters were referred to the same association. It is considered the final step of the vegetation series in the alpine and sub alpine belt (Oberdorfer, 1992). *Rhododendron ferrugineum* is dominant in all the clusters while *Pinus cembra* (differential species) is absent in the sixth one. This association is extended on almost half of the entire area (48.3 %). 7th cluster: *Nardetum alpigenum* Br.-Bl 1949 em. Oberd. 1950. It is extended on quite flat ground (Table 1). *Nardus stricta* is dominant being present with high cover-abundance percentage values in almost all the relevés (see also Oberdorfer, 1993). 8th cluster. The relevés classified in this cluster are heterogeneous: three of them are located on a ski track (mean slope 21.6 %) while the others that are positioned in relatively flat areas (mean slope 6.0 %). In the first case some species used for restoring ski tracks (i.e., *Festuca rubra*) are dominant. In the second case there aren't dominant species.

Table 1. Extensions, mean altitudes, mean slope and mean pasture value of each cluster (Clusters: see legend in figure 1).

Cluster	number of relevés	extension (%)	Mean altitude (m asl)	standard deviation	mean slope (%)	standard deviation	mean pasture value	standard deviation
1	7	3.8	2268	23.0	29.4	3.5	2.9	1.2
2	14	10.3	2227	41.4	25.9	6.6	1.7	0.6
3	22	19.8	2169	35.9	18.9	10.2	2.0	0.9
4	7	10.3	2119	29.6	22.1	4.0	2.5	0.4
5	26	24.9	2136	42.4	21.9	6.0	2.5	0.5
6	7	13.1	2112	36.9	28.3	6.1	2.6	0.6
7	9	10.4	2047	84.8	11.4	8.1	2.0	0.3
8	9	7.4	2079	112.7	see text	see text	3.2	1.4

All the pasture values calculated for each cluster can be considered typical of poor pastures (Table 1). This can be due to the abandonment of the grazing practises that favoured the natural dynamics allowing the replacement of high nutritive species with high altitude ones.

Conclusions

The low pasture value of the site makes it difficult to reintroduce cattle grazing while the area is suitable for the sheep and wild ungulates. Therefore the knowledge of the spatial distribution of the vegetation can be considered as a useful tool to solve wildlife management problems as the high-density population of chamois present in the area all the year round. This would be possible by integrating the vegetation data with the information about the animal population (both the distribution and sanitary status).

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Effects of arboreal and shrubby components on some features of pastures in a dolomitic area

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Abstract

The reduction or the abandonment of pastoral practices in mountain areas have some negative consequences as the penetration of intrusive species (herbaceous, shrubby and arboreal), the reduction of the number of species, i.e., the specific biodiversity, an increase of the unaltered necromass on the ground surface and therefore the worsening of the pastoral features. With the aim to contribute to define these changes in the dolomitic area, the pastures of Malga Castello, located in the municipality of Livinallongo del Col di Lana (from 1,747 to 2,204 m), were studied. In these areas, the decrease in pasture quality caused by the entrance of young trees and the expansion of shrubs was evaluated. Twenty-five botanical relevés, in wooded and in treeless pastures, were performed, with the aim to measure variation in forage value and specific biodiversity. The comparison between the sample plots shows a progressive decrease in the forage value (FV) from the treeless and shrubless pastures (FV = 2.17) to the highly wooded ones (FV = 0.19), followed by a decrease in the number of species in the abandoned and wooded areas.

Keywords: dolomitic pastures, forage value, biodiversity, resources management

Introduction

Until 30 years ago dolomitic grasslands, usually located below the forest vegetation limit, maintained an artificial equilibrium with environment, due to long established traditional agro-pastoral activity. When this activity stopped, considerable changes to the pastoral vegetation occurred (Cernusca, 1978; Sabatini *et al*., 2000). An arboreal and shrubby component invaded driving the vegetation towards that which would be climactically typical of that area. However, nowadays the maintenance of specific biodiversity (also in terms of ecosystems) represents one of the most important purposes of international environmental politics; it is also important in the development of the tourist and recreational functions of the mountain region. This study was undertaken to obtain more information about the consequences of abandonment of pastures on the ecological equilibrium, and the variation in forage value and in specific biodiversity in different vegetated areas.

Materials and methods

The research was conducted in Livinallongo del Col di Lana (Belluno, NE Italy), North Dolomites. The pastures of Malga Castello (from 1,747 to 2,204 m) were studied. Geological substratum is mainly volcanic (arenarie vulcaniche, brecce caotiche poligeniche, siltiti) associated also to dolomitic and calcareous rocks (arenarie, calcareniti). Soils are *Leptosols* and *Cambisols* , with pH from 4.44 to 7.70. The climate is continental, with average annual rainfall of 1,100 mm with the maximum during spring and autumn, associated with abundant snowfall in winter. The annual average temperature is 6.07 °C. Malga Castello is grazed with free ranging beef cattle. In this area, during the growing season of 2002, twenty-five botanical relevés were performed in wooded pastures (with different levels of arboreal cover) and in treeless ones. The relevés were performed on sample plots of 100 m^2 (Pirola, 1960) following the Braun-Blanquet approach (Westhoff and Van der Maarel, 1978) with the abundance values expressed in percent. The species were named according to ‘Flora d’Italia’ (Pignatti, 2002). The botanical relevés were subjected to cluster analysis, using Mulva 5 software (Wildi and Orloci, 1996). Forage value was calculated in accordance with Klapp (1971) and Staehlin (1970).

Results

Based on the statistical analysis, the 25 relevés were divided into 4 different clusters (Table 1). The first cluster, composed of 4 relevés, had an average species number of 49.7 and an average forage value of 1.60. Arboreal species, such as *Picea abies*, *Larix decidua*, *Pinus cembra* occurred widely, determining the level of tree cover, together with some shrubby species, such as *Erica carnea* and *Vaccinium* spp. These associations, characterized by normal recolonization processes, were present in very humid sites, and this was confirmed by the presence of some *Molinietalia* species, as *Selaginella selaginoides* and *Prunella vulgaris*.

Table 1. Principal characteristics of the four clusters identified. F = frequency; Ac = average cover (%).

Cluster	1		2		3		4	
N° of relevés	4		9		7		5	
Average altitude (m)	1896		2017		1982		2042	
Average inclination (%)	17		25		22		21	
Average exposition	116°		156°		128°		89°	
Average number of species	49.7		45.3		47		31.4	
Average forage value	1.60		1.73		1.7		0.68	
	F	Ac	F	Ac	F	Ac	F	Ac
Festuca rubra L.	V	2.8	V	4.3	V	5.6	II	2.6
Arnica montana L.	II	4.0	V	5.9	V	4.8	IV	2.6
Lotus corniculatus L.	V	3.2	IV	0.7	V	1.1	II	1.5
Nardus stricta L.	II	4.0	V	23	IV	8.5	III	4.3
Trifolium badium Schreb	IV	1.2	III	1.1	V	1.7	I	0.3
Phleum alpinum L.	II	0.6	III	1.1	V	2.6	III	1.1
Juniperus communis L.	III	0.5	II	1	0	0	V	16.3
Rhododendron ferrugineum L.	0	0	0	0	I	0.6	V	14.1
Agrostis tenuis Sibth.	IV	1.8	III	1.8	IV	3.4	II	1.5
Vaccinium uliginosum L.	II	0.2	III	2.3	III	3.2	IV	19
Larix decidua Miller	IV	4.8	I	0.8	II	3	II	4
Erica carnea L.	IV	3.9	0	0	I	1.9	I	26.5
Picea abies (L.) Karsten	IV	5.6	I	4.2	I	3.2	I	6.3
Geum montanum L.	0	0	III	3.9	II	4.4	III	1.1

The second cluster included 9 relevés, with an average number of species of 45.3 and average forage value of 1.73. *Nardus stricta* was represented in all the relevés, with a maximum index of coverage of 34.21. In the low-lying surfaces with intermediate substratum some *Nardetum* (*Mildenardetum*) was found along with some good quality fodder plants, such as *Lotus corniculatus*, *Trifolium badium* and *Agrostis tenuis*.

At high altitude, however, species occured that are closer to *Aveno Nardetum* association, e.g., *Antennaria dioica*, *Arnica montana* and *Hypochaeris uniflora*. The third cluster was represented by 7 relevés; it included 47 species on average and was characterized by a forage value of 1.7. This vegetation was found in the widest clearings of the wood; many species of the *Nardetum* association were present, for example *Nardus stricta*, *Geum montanum*, *Luzula campestris*, *Arnica montana*, together with typical understorey species, such as *Knautia longifolia*, *Avenella flexuosa*, *Silene vulgaris*. The clearings which were grazed contained an increase in eutrophic species, such as *Carum carvi*, *Myosotis silvatica* and *Rumex alpestris*. The final cluster, cluster 4, included 5 relevés; the average number of species was 31.4 and the average forage value amounted to 0.68. This cluster represented those areas rarely frequented by cattle, at high altitude, facing north. So the prolonged cover of snow ensured protection, allowing the prolific growth of shrubby vegetation, characterized by *Erica carnea*, *Vaccinum uliginosum*, *Rhododendron ferrugineum* and *Juniperus communis*, often followed by arboreal conifers. Forage value and the number of species were negatively correlated to arboreal and shrubby cover (Figure 1). However, a low arboreal coverage (< 20 %) did not significantly reduce the forage value nor did the number of species decrease discernably, due to the presence of both herbaceous and shrubby plants generally.

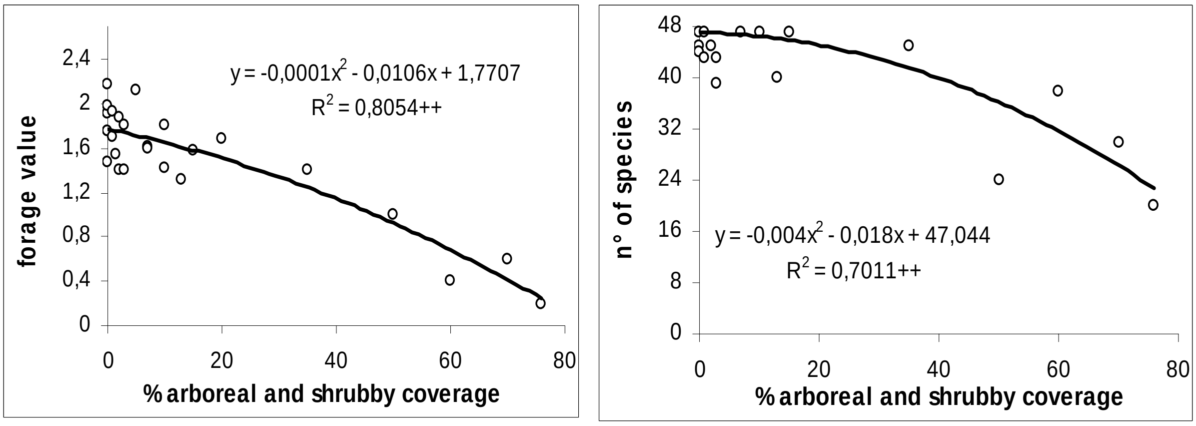

Figure 1. Variation of forage value and number of species at different shrubby and arboreal coverage levels.

Conclusions

After the abandonment or the reduction of grazing activity and traditional agricultural practices on the secondary pastures of Livinallongo del Col di Lana, ecological succession soon commences, causing the spread of many arboreal and shrubby species. *Rhododendron ferrugineum*, *Vaccinium uliginosum*, *Vaccinium vitis-idea* and *Calluna vulgaris* are often found in those areas with low soil pH, while where pH is intermediary, *Erica carnea* prevails. Also *Juniperus communis* is usually found. The most common arboreal species are *Picea abies*, *Larix decidua* and *Pinus cembra*. The abandonment of pastoral practices results in some negative effects on the grassland, such as a strong reduction in forage value and a decrease in the floristic richness, that can be limited only when woody and shrubby plants are properly controlled. This can be efficiently attained in the mid-long term by imposing suitable stocking rates, making use of traditional breeds of cattle and following rational grazing practices but, above all, reducing continuous grazing and supporting the use of high stocking levels in restricted areas.

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Remote sensing in NW Italian Alps for pastoral inventory and improvement of grassland management

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Abstract

Thematic maps are helpful tools in the ecologic and agronomic management of native pastures for the possibility of representing land from several different point of view. Drawing territorial maps may take advantage from the use of satellite images, especially for wide geographic regions. An application of Landsat 5TM image analysis for the identification of pastoral vegetation types of NW Italian Alps is proposed in this paper. Six physiognomic types of pastures were distinguished among 19 classes of land cover, that resulted from supervised classification using agro-ecologic and geo-morphologic surveys as ground control. A good correspondence between classification results and ground control data was highlighted by statistics. The analysis of vegetation maps derived from the satellite images might improve the knowledge of the grazing-land and be of advantage in pastoral planning, in the study of land cover evolution, in the analysis of land mosaic, and in the determination of forage availability and its variation.

Keywords: pastoralism, satellite images, supervised classification, vegetation maps

Introduction

Alpine pastures are becoming increasingly important for their ecologic role, for landscape quality and for the capacity of supplying 'typical' quality products. Therefore a good knowledge of pastoral vegetation is the basis for the valorisation and the conservation of such natural systems. The aim of the present study was to test the applicability of remote sensing in a wide alpine region as a support to the discrimination of land cover types suitable for grazing and to the classification of pastoral physiognomic types. The research, based on the experiences of French range researchers (Bernard-Brunet *et al*., 1999), was carried out to answer the demand by land managers for tools for inventorying pastoral resources and monitoring their changes over large areas, and also to assist control of *terroir* productivity.

Materials and methods

The study was carried out in the humid zone (mean rainfall > 1200 mm y^{-1}) of NW Italian Alps, in the mountain, sub-alpine and alpine belts, over an area of about 1 million ha. The pastoral vegetation of three sample areas (Ossola, Sesia, and Lanzo valleys) was characterized by 768 phyto-pastoral surveys (Daget and Poissonet, 1971). An accurate description of the pastoral vegetation of the sample areas (Martinasso, 2003), together with 1:25,000 maps, supplied the ground knowledge to draw satellite-based maps for the whole territory. As a first step, pastoral vegetation types, resulting from the classification of phyto-pastoral surveys, were grouped into physiognomic types (Table 1), on the basis of common descriptors like herbage mass and cover, and forage nutritional value (expressed by milk forage units, MFU).
Physiognomic types were identified using twin Landsat 5 TM images taken at two different moments of the growing season, namely i) an earlier image (July) to classify the grazing-land of mountain and sub-alpine belts, whose maximum productivity occurs in that period; ii) a later one (September), to mark out high altitude pastures, glaciers, perennial snow cover,

shrubs, and higher productive pastures characterized, near the end of the growing season, by vegetation regrowth.

Table 1. Correspondence between pastoral vegetation types and physiognomic types.

Physiognomic type code	description	herbage cover %	herbage mass t s.s. ha^{-1}	forage value MFU ha^{-1}	pastoral vegetation type
P5	high productive pastures	100	2.5-3.5	1200-1450	*Agrostis tenuis* and *Dactylis glomerata*; *D. glomerata* and *Trisetum flavescens*; *Festuca* gr. *rubra*, *Chaerophyllum hirsutum* and *D. glomerata*; *Molinia arundinacea*; *Polygonum bistorta* and *A. tenuis*; *Taraxacum* gr. *officinale* and *D. glomerata*
P4	middle-high productive pastures	90-100	1.5-2.5	500-750	*A. tenuis* and *D. glomerata*; *Nardus stricta* and *F.* gr. *rubra*; *F.* gr. *rubra* and *A. tenuis*; *Carex sempervirens* and *F.* gr. *rubra*; *Poa chaixi*; *Brachypodium caespitosum* and *F.* gr. *ovina* or *F.* gr. *rubra*; *Helictotrichon parlatorei*; *F. paniculata*
P3	middle-low productive pastures	90-100	0.5-1.5	350-700	*Trifolium alpinum*, *N. stricta* and *C. sempervirens*; *Ligusticum mutellina* and *N. stricta*; *N. stricta* and *F.* gr. *rubra*; *Avenella flexuosa* and *C. sempervirens*; *Helictotrichon parlatorei*; *F.* gr. *varia*; *Sesleria varia*; *Onobrychis montana*; *F.* gr. *ovina*
P2	short alpine grasses	80-100	0.5-1.5	350-700	*T. alpinum*, *N. stricta* and *C. sempervirens*; *T. alpinum* and *Poa alpina*; *Plantago serpentina*, *Poa alpina*, *Leontodon hispidus* and *F.* gr. *rubra*; *L. helveticus* and *Poa alpina*; *L. helveticus* and *N. stricta*
P1	open pastures	70-90	0.5-1.0	150-300	*F. quadriflora* and *L. helveticus*; *C. curvula*; *F.* gr. *varia*; *Polygonum viviparum*, *Salix retusa* and *F.* gr. *violacea*; *A. rupestris*; *Elyna myosuroides*
E/R	grass/rock mosaic	50-70	0.3-1.0	150-250	*C. curvula*; *E. myosuroides*
E1	debris	10-20	< 0.2	-	-
E2	debris with grass	20-50	< 0.5	20-100	-
B	shrubs	> 60	< 0.5	< 180	*Rhododendron ferrugineum*; *Juniperus nana*
O	*Alnus viridis*	-	-	-	-
Ls	hardwood forest on S slopes	-	-	-	-
Lo	hardwood forest on N slopes	-	-	-	-
C	coniferous forest	-	-	-	-
R1	white or in light rocks	-	-	-	-
R2	dark or in shadow rocks	-	-	-	-
R3	ferrous rocks	-	-	-	-
A	water / lakes	-	-	-	-
N-G	perennial snow - glacier	-	-	-	-

Satellite images were interpreted in three steps: 1) pre-processing: making mosaics of traces, orthorectification, calibration, atmospheric and topographic correction; 2) classification, assuming that the researcher is able to identify groups of pixels on the image that represent features of interest on the ground. Since the ground knowledge of the grazing-land was provided by phyto-pastoral surveys, a supervised classification was adopted, on the basis of maximum likelihood algorithm. Eighty 'training sets' were selected to build classification model, which was also improved by ecologic, topographic (elevation, aspect and slope derived from DTM) and land management additional information. Subsequently, provisional classification maps were drawn; 3) evaluation of the classification by statistical analyses (confusion matrix and probability ellipses), showing map to ground goodness of fit. Step (1) was performed by using PCI Geomatics 7.0 and RSI ENVI 3.4 software, while step (2) and (3) were performed by using Erdas Image 8.3.1.

Results and discussion

High productive pastures (P5) were easily recognized using the earlier image, but sometimes they were confused with hardwood forest, especially when located on steep slopes. Middle-high productive pastures (P4) were accurately discriminated in 8 out of 10 cases. Residual 20 % confusion concerned middle-low productive pastures (P3) and short alpine grasses (P2). A lower percentage of P3 pastures was correctly classified (69 %), but nevertheless such a value is still considered as acceptable for natural herbaceous cover. P2 pastures were precisely classified only by using the September image, as they show their maximum herbage mass production in that period. Open pastures (P1) were about 30 % confused with P3, P2, E1 and E2 (debris) and E / R (grass-rock mosaic). Rocks and debris were generally accurately classified (> 82 % in the confusion matrix). When confusion occurred, it was between similar physiognomic classes, like E / R and P1. Perennial snow cover (N), glaciers (G) and lakes (A) were always recognised with a low probability of misclassification (< 6 %). Even if identification of the forestland was not a goal of the study, an acceptable level was achieved for woodlands too (> 80 %), as an indicator of the good quality of the classification in general.

Conclusions

The first physiognomic map of vegetation ever drawn for the Italian Alps from satellite images provided an acceptable interpretation of grazing-land cover. An in-field validation of the classification, which requires a large number of ground surveys (Bernard-Brunet *et al.*, 1999), has been carried out since 2003 to improve the reliability of the map, but has still to be completed. Nevertheless, taking the probability of a misclassification into account, a use of the map for pastoral inventory, as a support to grazing management (planning of herd movements on a large scale, setting of medium-long term exploitation schedule), for monitoring the evolution of land cover, and for landscape planning, is still trustworthy.

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Veterinary antibiotics in animal slurries – a new environmental issue in grassland research

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Abstract

About 50 % of the antibiotics administered in Switzerland are used in animal production. Due to the increase in resistant bacteria, interest in the environmental fate of such pharmaceuticals has strongly increased in recent years. A simple mass balance shows that the upper limit of their average input into Swiss agricultural soils is about 30 g ha^{-1} y^{-1} reaching 80 g ha^{-1} y^{-1} for grassland regions with high stocking densities. Using measured sulfonamide concentrations in manure, we calculate an input into soils in grassland regions reaching up to several hundred g ha^{-1} y^{-1}. Existing regional differences in the loading are difficult to assess because of a lack of data. Nevertheless, it seems plausible that intensively used grassland contain possible 'hot spots'. With experiments we demonstrated that high concentrations of sulfonamides – an important class of veterinary antibiotics – may occur in surface runoff after manure application. In plot-scale experiments we observed concentrations of sulfamethazine up to 0.68 mg L^{-1} in surface runoff. During flow events, we measured concentrations of sulfamethazine up to 4 μg L^{-1} in a brook. However, it is difficult to interpret these numbers properly because the concentration-effect relationship is not known so far.

Keywords: antibiotics, sulfonamides, surface runoff, manure, mass fluxes

Introduction

Eutrophication problems due to P losses from intensively used grassland have been observed and studied for many years. The major processes controlling the fate of P in such soils, and the hydrologic factors governing the actual losses to surface waters are fairly well understood. In order to mitigate P-losses, concepts have been developed that should allow watershed managers to focus on the critical areas.

Compared to the P problem the topic of the environmental fate of veterinary antibiotics (VA) is of much more recent origin. Due to the occurrence of more and more bacteria that are resistant to antibiotics it has been realized that the undesired side-effects of extensive use of these pharmaceuticals may pose a serious threat to human and veterinary health in the future. The role of antibiotics excreted by animals and spread on agricultural land is still obscure in the context of resistance induction. Accordingly, research programs to investigate this issue have been launched in several countries. In Switzerland, the National Research Priority Program 49 'Antibiotic Resistance' (NRP 49) was started in July 2001. About 50 % of the antibiotics administered in Switzerland are used in animal production. Since there is a close (spatial) relationship between animal production and grassland agriculture, it seems plausible that veterinary antibiotics may well become an important environmental topic in grassland research in the near future. In this paper we present some preliminary results of our work on the fate and behavior of VA that we are conducting in the framework of the NRP 49 mentioned above, i.e., transport experiments at the plot and field scale investigating the mobilization of sulfonamides – an important group of VA – into runoff water.

Materials and methods

The plot and field experiments have been conducted in a small agricultural catchment ‘Ror’ in the Greifensee area. It lies at an altitude of about 500 m, receives on average 1300 mm y^{-1} of rain and is characterized by Gleyic to Eutric Cambisols.

In autumn 2002, 8 grassland plots of 2 m^2 each were irrigated with 30 mm of deionized water within 90 min after receiving an application of pig manure containing 11 mg L^{-1} sulfamethazine (SMA) on the vegetated surface. The runoff induced by the irrigation was collected in a gutter installed at 5 cm depth at the lower end of the plots. In March and May 2003, manure containing SMA was applied to two grassland plots of 0.4 ha each. Thereafter, we monitored the SMA concentration in the brook draining this area.

The runoff samples were *analys*ed by LC-MS. The samples of brook water were measured by LC-MS/MS. All analyses were carried out using isotope-labelled internal standards.

Results and discussion

Based on usage data and land-use statistics it is possible to estimate the upper limit of the average VA fluxes reaching agricultural soils. In 2001, about 35 t y^{-1} of antibiotics (Spring, pers. communication) were administered in Swiss animal production. Only a small portion of this amount is metabolised (Halling-Sørensen *et al.*, 2001) and between 35 and 100 % of the substances are excreted unaltered. As a worst-case scenario we assume a 90 % excretion rate and neglect degradation during subsequent storage. Actually, sulfonamides and tetracyclines, as two of the most important classes of VA, are rather stable in manure tanks, whereas other substances like penicillins or macrolides have only short half-lives. With these worst-case assumptions the annual usage translates into an average input into agricultural soils of about 30 g $ha^{-1}y^{-1}$. Assuming that the VA flux to soils is proportional to stocking densities, this average will increase in regions dominated by intensively used grassland. With an average animal density of 1.2 livestock units ha^{-1} for Swiss agriculture, we expect the average VA flux to increases to about 80 g $ha^{-1}y^{-1}$in areas of maximum animal densities.

This simple mass flux calculation for average conditions can be compared with results obtained from measuring the concentrations of some antibiotics in liquid manure. In grab samples of pig manure collected from different farms, we have found between 0.1 and 11 mg L^{-1} of the single substance SMA (Haller *et al.*, 2002; Burkhardt *et al.*, in prep.). The high value came from a farm where we know that large amounts of SMA were used. Assuming four manure applications on grassland of 15 m^3 ha^{-1} each, these concentrations would result in loads ranging from 6 to 660 g ha^{-1} y^{-1}. This demonstrates that the actual fluxes will vary considerably, not only depending on the amount of manure that is applied but also on the antibiotics administered on a given farm. The large range also indicates that spatial fluxes will be much more heterogeneous than fluxes of nutrients or pesticides. Nevertheless, because veterinary antibiotics enter the environment mainly via the spreading of manure we expect that ‘hot spots’ of soil exposure to these substances will be found in grassland areas.

The input of antibiotics into the soil is not the only factor relevant for the assessment of the environmental risk of VA. Losses from soils to surface waters are also of concern. Because the mass fluxes of up to several hundred g $ha^{-1}y^{-1}$ are of the same magnitude as herbicide application rates, we may conclude that there is a substantial risk for losses of antibiotics into surface waters. However, there are only a few empirical studies that have focused on the transport of VA (Boxall *et al.*, 2002). To our knowledge there is no such study published explicitly focussing on grassland soils.

Therefore, we have carried out two experiments to investigate the fate and transport of sulfanamides after spreading manure onto grassland. In the plot experiments, we observed concentrations up to 0.68 mg L^{-1} for SMA in the surface runoff (Burkhardt *et al*., in prep.). The total SMA loss amounted to less than 2 % of the applied mass when irrigation was applied 3 d after manure was spread. For comparison, losses of Br^{-}, which is a non-sorbing tracer, were about sevenfold larger.
The monitoring study after spreading manure on two plots revealed high concentrations of SMA of up to 4 μg L^{-1} in the brook draining the area. This demonstrates that sulfonamides may not only be mobilized from soil and manure into runoff but that they may reach open waters in high concentrations. After the first runoff event, maximum concentrations during subsequent events decreased substantially to well below 1 μg L^{-1}.

Conclusions

The simple mass balance calculation demonstrates that the input of VA into soils may be substantial. This holds especially for grassland areas. However, the spatial variability is probably very large. For the class of sulfonamides, our results show that high concentrations can be found in brooks draining agricultural areas during high flow periods shortly after manure applications. However, our understanding of the fate and behaviour of antibiotics is still rudimentary: reliable data on the mass fluxes reaching agricultural soils are scarce and uncertain. The processes governing the fate of VA once on the soil are only starting to be studied in sufficient detail to allow a proper understanding. Furthermore, the quantitative relationship between mass fluxes onto soils or waters and the possible induction or spread of resistance genes is large unknown. Ongoing interdisciplinary research programmes like the NRP 49 ‘Antibiotic Resistance’ will hopefully close important knowledge gaps in the near future.

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Diffuse pollution of bacteria from grassland farms: risk identification and mitigation

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Abstract

The objective was to design best management practices (BMPs) to reduce the potential risk of faecal indicator organism (FIO) contamination from livestock farms to rivers. 48 farms were surveyed in four river catchments across Scotland. Waste storage facilities, farming practices, field conditions, grazing management and risks of FIO contamination to watercourses were assessed on each farm and BMPs were designed, costed, implemented and monitored.The average estimated cost per farm to implement all field and steading based BMPs to reduce FIO pollution risks was approximately € 71,000 which is not affordable without public funding and support. The highest costs were associated with upgrading slurry storage facilities. Over 90 % of the farms required other actions such as fencing and provision of water drinking facilities to prevent livestock accessing watercourses. Similarly over 80 % of farms required roofing of steading areas to reduce the volume of contaminated water or other BMPs to divert clear water from waste storage facilities.

Keywords: agriculture, diffuse pollution, livestock, manure, rivers

Introduction

In the grassland farming dominant area of south-west Scotland, all the bathing waters are potentially impacted by faecal indicator organism (FIO) bacteria from farmland (SEPA, 2003). Aitken *et al*. (2001) reported on a risk assessment of 117 farms in Scotland and found that risks of discharges of effluents and FIOs into watercourses occurred on over 50 % of farms. These mainly arose from the leakage from steadings including middens, poorly designed or mis-managed waste storage facilities, and run-off from self-feed silage aprons, farmyards, cattle courts and cow tracks. Field diffuse discharges via run-off and field drainage, particularly from areas of poorly managed slurry application and intensive grazing were other potential pathways of FIO to watercourses. Diffuse FIO water pollution from agriculture is therefore the cumulative affect of many small steading and field based sources over a large area and by its very nature, is hard to quantify and fully control.

The EU Water Framework Directive will establish a system of river basin management and will identify measures to deal with diffuse pollution. However there is currently insufficient quantitative information on agricultural FIO diffuse pollution control measures in terms of their costs, practicalities and pollution reduction. The overall project objective was therefore to design, implement and assess farm scale measures to reduce the risk of diffuse FIO contamination from farms to rivers.

Materials and methods

The study was carried out in four river catchments potentially impacted by FIO bacteria from farmland draining into bathing waters in the south, west and north-east coast of Scotland. Detailed steading and water margin audits along with Manure and Fertiliser Plans were carried on all 48 farms out to assess manure and dirty water volumes, storage conditions, steading discharges and clean water contamination. Best management practices (BMPs) were then designed to reduce pollution pathways (Table 1). All watercourses were assessed to determine buffer zone and fencing needs to protect the water from livestock. An examination and soil survey of every field was also carried out to assess each farm's suitability for spreading organic manures.

Table 1. Best management practices to reduce risk FIO contamination from farms to rivers (from Aitken, 2003).

Repair of existing roof guttering where this contributes to waste water production
Clean and dirty water separation (provision of new drains etc.) to ensure only 'clean' water discharges to watercourses
Roofing 'contaminated yards' or storage structures (including middens)
Provision of new access routes for cattle, ensuring containment and reduction run -off
Re-laying of concrete areas and provision of bunding to prevent contamination of clean yards, etc.
Fencing in fields, along water margins
Provision of water troughs, where existing livestock drinking is from watercourses only
Provision of channels, sumps and drains to allow collection and transfer of dirty water/slurry to existing storage
Roofing of uncovered silo (only if structure is suitable)
Increased slurry storage capacity
Increased silage effluent collection/storage provision

Results and discussion

Apart from one of the four catchments, the area of farmland with a low risk land for manure spreading is only 1 to 6 % and more than half the total farmland area in two catchments is unsuitable for land application of manures. Applying manure to the right field at the right time would minimise pollution risk and maximise the fertiliser value of the manure.

The type and cost of BMPs to reduce the risk of pollution is summarised in table 2. The average estimated cost per farm to implement all BMPs to reduce pollution risks is approximately € 71,000. Costs were higher in the dairy areas. The highest costs (mean € 34,000) were associated with upgrading slurry storage facilities, although this was only required on 26 % of all farms. Over 90 % of the farms required remedial actions such as fencing and provision of water drinking facilities to prevent livestock accessing watercourses. Average cost of fencing per farm was € 13,000 while provision of water troughs would cost around € 9,000. Similarly over 90 % of farms required action to reduce the volume of contaminated water (e.g., by roofing of key steading areas) with average costs of € 26,000. A high proportion of farms (81 %) required actions to divert clear water from waste storage facilities. Recovering and using rainwater and plate cooling water will reduce water costs as well as reduce manure storage and application costs.

Table 2. Average estimated cost (€) per farm for BMPs to reduce the risk of pollution (% of farms requiring these actions in brackets).

Remedial action required	Catchment			
	Cessnock	Ettrick	Nairn	Sandyhills
Slurry storage	30,000 (7%)	48,000 (39%)	0	23,600 (50%)
Reception / collecting tanks	4,000 (93%)	10,000 (62%)	8,500 (30%)	0
FYM storage and handling	14,200 (13%)	14,000 (39%)	0	0
Contaminated water reduction and drainage	11,000 (100%)	40,000 (85%)	19,000 (90%)	33,400 (90%)
Clean water diversion	6,400 (100%)	9,600 (92%)	3,400 (90%)	4,400 (40%)
Cattle access routes (farm)	12,300 (20%)	7,300 (54%)	0	0
Cattle access routes (field)	6,500 (80%)	20,300 (85%)	3,500 (70%)	20,900 (30%)
Cattle access to watercourses	15,600 (100%)	11,800 (85%)	10,200 (100%)	13,900 (90%)
Field water troughs	9,000 (93%)	12,600 (85%)	4,800 (100%)	5,500 (90%)
Field supplementary feeding arrangements	0	2,600 (8%)	1,320 (10%)	0
Other	12,300 (7%)	3,500 (8%)	6,650 (50%)	0
Average total cost per farm in catchment	58,000	115,000	43,250	67,200

Conclusions

The average cost per farm to implement all BMPs to reduce FIO pollution risks is approximately € 71,000. This is not affordable to farmers without public funding and support. However most river catchments in Scotland will contain several hundred livestock farms and the resulting total cost per catchment could be many € millions which is very likely too high a cost to guarantee the essential financial support required.

There are low cost options given in Four Point Plan (SEERAD *et al*., 2002) which all farmers should be encouraged to follow. Many potential risks to river and bathing water quality may be reduced through improved manure/dirty water and grazing management, forward planning of land spreading activities and improved operational procedures.

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Persistence, mobility and pollution risks of sheep dip (diazinon and cypermethrin) when applied to grassland

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Abstract

Sheep dips, if used properly, can be very effective against parasites that colonise sheep skins and fleeces but are highly toxic if mis-managed. If good practice is not followed during the disposal of spent sheep dip to grassland, there can be devastating consequences for the water environment. Four experimental sites on grassland were established and diluted spent sheep dip (diazinon and cypermethrin) was applied to investigate the persistence, mobility and pollution risks to soil and water. Low concentrations (0.4-21.6 μg kg^{-1} fresh soil) of cypermethrin were detected in the surface soil layer (0-5 cm) at three of the four sites between 30 and 62 days after the sheep dip application. 1.2-2.4 μg cypermethrin kg^{-1} soil was detected at a greater depth (20-25 cm) in two soils. Diazinon was also present at low concentrations (2.0-15.9 μg kg^{-1} fresh soil) in the 0-5 cm layer at both sites but was not present at 20-25 cm. Grassland suitability for disposal of sheep dip should therefore be assessed on soil sorption properties and degradation capability along with proximity to watercourses and groundwater, slope, soil surface condition, soil type and depth.

Keywords: pollution, pesticides, sheep-dip, diazinon and cypermethrin

Introduction

Sheep dipping is an important part in the maintenance of good animal welfare. The pesticides used are effective against parasites, but can also be hazardous to the environment if not used carefully. In Scotland, spent sheep dip is normally applied to grassland in accordance with SOAEFD (1997). For grassland sites receiving sheep dip, little is known of the ecotoxicological effects on soil and there may be risks to groundwater and wildlife. The active ingredients of residual biocides in the sheep dip waste such as the synthetic pyrethroids and organophophates target invertebrates but both are widely regarded as being relatively easily degraded in soil.

In general, organic matter and clay content are the soil properties involved in pesticide sorption. Sheep dip pesticides are expected to be strongly adsorbed in the topsoil layer (if it contains organic matter) and to have very low leachability. The objective of this study was to assess the persistence, mobility and pollution risks of sheep dip (diazinon and cypermethrin) when applied to four contrasting grassland sites.

Materials and methods

Diluted sheep dip (diazinon or cypermethrin) was applied to four grassland sites in the south-west, east, west and north-east of Scotland and compared to an untreated control. 2 kg ha^{-1} of the organophosphate (OP) diazinon (16 % w / w) and 1 kg ha^{-1} of the synthetic pyrethroid (SP) cypermethrin (10 % w / w) was applied. Application rates and water dilution were representative of UK farm practice (20 m^3 ha^{-1}) and in accordance with existing UK legislation (SOAEFD, 1997). The treatments were applied using a watering can (fine rose) at a rate of 2 litres m^{-2} in March 2002 to unreplicated 4 m by 4 m plots.
The soil was sampled between 30 and 62 days later, depending on the site, using a 'cheese corer' sampler which collected 10 sub-samples from each control and treatment plot at two

depths (0 to 5 cm and 20 to 25 cm). The soil was analysed for for diazinon and cypermethrin and three breakdown products of the pesticides. A range of soil properties were assessed including soil microbial biomass, mineralisable nitrogen and respiration rate along with infiltration rate and bulk density.

Results and discussion

The active ingredient of the synthetic pyrethroid (SP) dip (cypermethrin) was detected in the 0-5 cm layer in three of the four sites (Table 1). 1.2-2.4 μg cypermethrin kg^{-1} soil was detected at a greater depth (20-25 cm) in two soils. The deeper penetration of SP in the latter two soils (Bush Estate and Craibstone) could have been a consequence of higher infiltration rates measured at those sites. The organophosphate (OP) ingredient, diazinon, was detected at the 0-5 cm depth in two out of four sites but not detected at 20-25 cm. Breakdown products of the dips were detected at the 0-5 cm depth at Bush (both OP and SP dips) and Craibstone (SP only) but not detected at 20-25 cm. The levels of sheep dip detected at all sites were very low compared to the application rate of the active ingredient (OP at 2 kg ha^{-1} and SP at 1 kg ha^{-1}). This confirmed that both sheep dips were degrading rapidly in the soil.

Table 1. Sheep dip and breakdown product content (μg kg^{-1} fresh soil) of soil at the 0-5 cm depth for control (C), organophosphate (OP) and synthetic pyrethroid (SP) treatments.

Site and treatment	Diazinon	Cypermethrin	3-(2,2-dichlorovinyl)-2,2-dimethyl-(1-cyclopropane)-carboxylate)	2-isopropyl-6-methyl-4-pyrimidinol
Auchincruive C	nd	nd	nd	nd
Auchincruive OP	2.0	nd	nd	nd
Auchincruive SP	nd	nd	nd	nd
Kirkton C	nd	nd	nd	nd
Kirkton SP	nd	0.8	nd	nd
Bush C	nd	nd	nd	nd
Bush OP	15.9	nd	nd	2.4
Bush SP	nd	4.8	1.2	nd
Craibstone C	nd	nd	nd	nd
Craibstone SP	nd	21.6	2.4	nd

nd: below lower limit of detection, where limits are: 0.4 ppb for diazinon and cypermethrin, and 1 ppb for the two metabolites.

There were no consistent patterns in the effects of sheep dip on soil properties including the microbially sensitive properties of soil microbial biomass carbon and soil respiration rate (Table 2). Soil biomass carbon provides a measure of the amount of C present in the living part of soil organic matter, excluding plant roots and soil animals larger than an amoeba. Soil respiration gives an indication of the activity of the soil microbial population by measuring CO_2 evolution.

Table 2. Soil microbial biomass carbon (μg C g^{-1} oven dry soil) and soil respiration rate (μg CO_2-C g^{-1} oven dry soil h^{-1}) at 0-5 cm.

Site	Biomass C			Respiration rate		
	Control	OP	SP	Control	OP	SP
Auchincruive	596	693	768	0.60	0.62	0.73
Kirkton	722	-	656	1.08	-	0.89
Bush Estate	751	725	682	1.22	1.28	1.20
Craibstone	637	-	641	0.90	-	0.91

Conclusions

The low detected concentration of residual pesticide indicated that degradation of both sheep dip pesticides in the soil was rapid and satisfactory at all four sites. Approximately 0.5 % of the organophosphate and 1.4 % of the cypermethrin originally applied was found in the soil between 30 and 62 days after the sheep dip application. The deeper penetration of cypermethrin at two sites (20 to 25 cm) merits further investigation and could have been a consequence of generally higher infiltration rates at those sites. There were no consistent effects of type of sheep dip chemical on soil properties. Further work is recommended on the ecotoxicological effects on soil of long-term sheep dip applications. Grassland suitability for disposal of sheep dip should therefore be assessed on soil sorption properties (organic matter and clay content) and high degradation capability (based on microbial biomass activity: a function of organic matter, texture, drainage status, pH and nutrient status). Other factors to be considered include land use, proximity to watercourses and groundwater, slope, soil surface condition, infiltration rates, soil type and depth.

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Effect of silage additives on soil contamination by silage effluent produced in the process of unwilted sward conservation

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Abstract

In the experiment, which was carried out in 2002, the impact of various silage additives (without, KemiSile 2000, Lactacel L) on the conservation process of unwilted sward with 175.3 g per kg dry matter was investigated. The ensiling process was conducted in barrels of 120 l volume each equipped with a perforated bottom so as to allow a free outflow of silage effluent. Experimental barrels were placed on three different types of soil: Cambisols (loam), Histosols (organic) and Luvisols (sand) as well as indoors where silage effluent was collected. After a period of 6 weeks the chemical composition of silages was determined. In addition, after removing experimental barrels, samples of soils were collected to the depth of 20 cm and water soluble elements: K, Na, Ca, Mg using the AAS method and N-NO_3 using colorimetric method, pH in 1 M KCl and soil conductivity were assessed. It was found that the application of silage additives decreased quantities of outflowing silage effluent. The type of soil on which barrels with silage were placed was also found to be significant. The greatest changes in chemical composition caused by seeping silage effluent were recorded in Luvisols and Histosols soils, whereas in the case of Cambisols soil, this effect was the smallest.

Keywords: conservation, silage additives, silage effluent, soil contamination

Introduction

Despite the fact that wilting is the widely recommended method of meadow sward conservation, in practice many farmers still employ the old system of ensiling unwilted forages. Unfortunately, this process is accompanied by the seepage of silage effluent that can contaminate the soil environment (Merry *et al*., 2000). From this point of view, it seemed interesting to investigate the effect of both the application of silage additives and the type of soil on soil contamination, with silage effluent produced in the process of unwilted sward conservation.

Materials and methods

This experiment was carried out in 2002 in the Brody (52º26' N, 16º18' E) Agricultural Experiment Station near Poznań. The impact of various silage additives on the conservation process of an unwilted sward containing 175.3 g kg^{-1} dry matter was investigated. The silage additive treatments were (1) without, (2) KemiSile 2000 – formic acid 55 %, ammonium tetra formate 24 %, propionic acid 5 %, benzoic acid 1 %, esters of benzoic acid 1 %, water 14 % – added at rate 5 ml kg^{-1} fresh herbage, and (3) Lactacel L – *Lactobacillus plantarum* 10^6 viable cells g^{-1}, enzymes complex: endo-1.4-beta glucanase, xylanase, glucoamylase – added at rate 1 g kg^{-1} fresh herbage). The ensiling process was conducted in barrels of 120 l volume each equipped with a perforated bottom to allow a free outflow of silage effluent. Experimental barrels were placed on three different types of soil according WRB (Anonymous, 1998): Cambisols (loam), Histosols (organic) and Luvisols (sand) as well as indoors where silage effluent was collected. After a period of 6 weeks the chemical composition of silages was determined. In addition, after removing experimental barrels, soil samples were collected to the depth of 20 cm and water soluble elements: K, Na, Ca, Mg using the AAS method and N-NO_3 using colorimetric method, pH in 1 M KCl and soil conductivity were assessed.

Results and discussion

The sward intended for ensiling was characterised by an advantageous, from nutritional point of view, chemical composition (CP – 208.8 g kg^{-1} DM, CF – 240.7 g kg^{-1} DM, WSC – 21.8 g kg^{-1} DM). Following a conservation process using various kinds of additives, silages characterised by different chemical compositions were obtained (Table 1). In comparison with untreated silage, in treatments with KemiSile 2000 and Lactacel L the obtained silages were found to contain higher concentrations of dry matter by, respectively, 11.7 and 9.6 %. Moreover, silages with experimental additives contained higher levels of CP and WSC. The silage treated with Lactacel L was characterised by the highest pH value – 4.48, as well as concentrations of lactic and acetic acids. Formic acid (16.5 g kg^{-1} DM) was determined only in the silage treated with KemiSile 2000.

Table 1. Effect of silage additives on chemical composition and properties of unwilted sward silage.

Item	Silage additives		
	untreated	KemiSile 2000	Lactacel L
Dry matter (g kg^{-1})	188.0	210.0	206.0
Crude protein (g kg^{-1} DM)	203.3	212.9	207.2
Crude fibre (g kg^{-1} DM)	222.4	225.6	223.0
WSC (g kg^{-1} DM)	9.3	21.6	13.1
pH	4.1	4.0	4.5
Lactic acid (g kg^{-1} DM)	55.6	36.2	58.0
Acetic acid (g kg^{-1} DM)	23.4	27.3	35.9
Propionic acid (g kg^{-1} DM)	2.7	2.4	2.4
Formic acid (g kg^{-1} DM)	-	16.5	-

Depending on the applied silage additives, various quantities of silage effluent seeped out of the ensiled unwilted sward during the process of ensiling: 1425 ml of effluent was obtained from the silage without any additives, only 180 ml - in the treatment with KemiSile 2000 and barely trace quantities when the bacterial-enzymatic preparation Lactacel L was applied. This confirms a significant influence of silage additives on the course of the ensiling process of unwilted sward. This phenomenon was also observed by Jones and Jones (1995), Keady and Steen (1994) and Winters *et al*. (1996).

The seeping silage effluent causes contamination of soil environment (Merry *et al*., 2000). Depending on the soil type, the influence of silage effluent on soil properties and chemical composition varies. According to our own investigations (Table 2), in the treatment without silage additives, markedly higher concentrations of nitrates (88.35 mg N-NO_3 kg^{-1}) were found in the Luvisols soil than in Histosols (54.95 mg N-NO_3 kg^{-1}) and Cambisols (14.25 mg N-NO_3 kg^{-1}) soils. Similar correlations were found with regard to magnesium, sodium and potassium concentrations in soils. The highest conductivity was observed in the Luvisols soil (2795.0 µS cm^{-1}), then Histosols (1142.5 µS cm^{-1}) and the lowest – in Cambisols soil (230.0 µS cm^{-1}). This indicates that individual soil types were characterised by different capabilities for buffering the seeping silage effluent.

The influence of the application of silage additives was also evident within each soil type. Lower quantities of seeping silage effluent found their expression in decreased concentration of the majority of mineral components, including nitrates as well as a drop in its conductivity.

This appears to justify the use of silage additives in the process of ensiling of unwilted sward as it decreases soil contamination with silage effluent. In this respect, Lactacel L was most advantageous on the Luvisols soil, while in the case of the remaining soils – KemiSile 2000 was more beneficial.

Table 2. Effect of silage additives on chemical composition and properties of soil under silage in the process of unwilted sward conservation.

Type of soil	Silage additives	Content ($mg\ kg^{-1}$) K	Na	Ca	Mg	$N\text{-}NO_3$	pH in KCl	Conductivity ($\mu S\ cm^{-1}$)
Cambisols	untreated	25.56	6.80	1.52	1.37	14.25	5.47	230.0
	KemiSile 2000	113.05	52.30	2.29	2.27	21.80	5.56	257.5
	Lactacel L	28.78	10.10	3.71	1.51	18.80	5.46	372.5
	control*	20.93	4.13	1.17	1.27	15.85	5.57	207.5
Histosols	untreated	13.09	11.48	186.75	8.26	54.95	7.35	1142.5
	KemiSile 2000	24.76	12.18	44.16	3.91	23.30	7.51	702.5
	Lactacel L	16.12	12.15	106.21	5.30	36.25	7.46	852.5
	control*	16.03	6.63	52.24	4.51	14.32	7.30	577.5
Luvisols	untreated	148.80	43.83	18.26	16.50	88.35	5.18	2795.0
	KemiSile 2000	151.38	52.98	5.49	4.08	50.28	4.81	3022.5
	Lactacel L	17.35	2.70	2.19	1.35	14.30	4.47	232.5
	control*	13.86	2.33	2.16	0.86	11.33	4.53	202.5

*area without cover of silage barrels

Conclusions

The highest soil contamination, measured by its conductivity and concentration of mineral components, especially nitrates, as a result of effluent seepage in the process of conservation of unwilted meadow sward was observed in the case of the Luvisols soil, while the lowest contamination was observed in Cambisols soil. The application of silage additives KemiSile 2000 and Lactacel L limited quantities of silage effluent and, consequently, reduced soil contamination.

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Nitrous oxide fluxes from grassland soils with different fertiliser regimes

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Abstract

Nitrous oxide (N_2O) flux rates were measured over 11 months on a sandy grassland soil cropped with grass/clover in northern Germany using the closed chamber method. Emissions were quantified from an unfertilised control and after application of mineral N fertiliser and/or cattle slurry. After each N application, gas samples were taken daily for a period of two weeks, then at intervals of two to three days, and once per week during the winter. Enhanced N_2O emissions occurred two to three weeks after N fertiliser application in spring 2001. Cattle grazing induced high N_2O emission peaks during summer. In winter, emissions took place in all treatments during freeze-thaw events. Mean total N_2O-N loss was 3.0 kg ha^{-1} y^{-1}. Differences among treatments were not significant, which was caused by a high variance in emissions during and after cattle grazing. With increasing N input, the N_2O flux rates tended to increase. ^{15}N labelling indicated that more N_2O was emitted from mineral N than from slurry treated plots. Much of the N_2O was derived from the soil N pool.

Keywords: nitrous oxide emissions, permanent grassland, N-fertiliser, N losses, ^{15}N, slurry

Introduction

N_2O emissions from soils are of concern since they represent a loss of N from agriculture and they contribute to global warming and to the reduction of stratospheric ozone. Microbiological nitrification and denitrification in soils are the main sources of N_2O. Long-term studies on grassland of at least one year or more are relatively scarce but necessary for reliable estimates of annual N_2O release from soils. Most investigations have focused on the growing season but several studies have shown that the winter period is of major importance for the assessment of total N_2O losses in temperate climates (Kammann *et al.*, 1998). The present work is part of an integrated research project at the University of Kiel (Taube and Wachendorf, 2000) aiming at a general improvement of N efficiency and reduction of N losses in dairy farming systems. N_2O fluxes were quantified over one year under four regionally relevant fertiliser combinations. The objective of this study was to obtain general information on rates of N_2O emissions from permanent grassland over a full year and to evaluate the effect of cattle grazing and form and amount of N supply on the flux of N_2O from the soil.

Materials and methods

A field experiment was conducted on the experimental farm ‘Karkendamm’ near Kiel, Germany, from April 2001 to March 2002. Treatments commenced in spring 1997 and were managed as a mixed system (two cuttings and two successive grazings) of permanent grassland sown with grass/clover. During grazing, excretal returns were randomly distributed on the plots. After each 2-day grazing period, the dung patches were immediately removed by hand. The experiment consisted of 5 treatments and 3 replicates with the micro-plot size of 2.25 m^2 each (Table 1). ^{15}N labelled slurry (0.72 at % ^{15}N) was produced by feeding two steers with ^{15}N labelled hay and maize silage. After each N application, gas samples were taken daily over two weeks, then at intervals of two to three days, and once per week during the winter, using the closed chamber method (diameter 60 cm). The N_2O concentration of the gas samples and the isotopic composition of N_2O were measured with a continuous flow mass spectrometer (Finnigan Delta Plus with Precon). The ratio of ^{15}N to ^{14}N in N_2O allowed differentiation of N_2O from soil, slurry and fertiliser.

Table 1. N input (kg ha^{-1}) in the experimental treatments.

Treatment	Mineral N[1] (kg ha^{-1})	Slurry N (kg ha^{-1})	N_2 fixation[2)] (kg N ha^{-1})	Total N (kg ha^{-1})
Control (C)	0	0	89	89
^{15}N slurry (S)	0	74	41	115
^{15}N 100N (M)	70 + 30	0	34	134
Slurry + ^{15}N 100N (MS)	70 + 30	74	59	233
^{15}N slurry + 100N (SM)	70 + 30	74	88	262

[1] given as CAN and $^{15}NH_4{}^{15}NO_3$ (2.0 at % ^{15}N), [2)] estimated by difference method (Haystead, 1981), n = 3.

Results and discussion

Directly after the first mineral N application on April 6 (70 kg ha^{-1}), a significant increase in N_2O release from the N fertilised treatments (M, SM) was observed (Figure 1). Within three weeks N_2O fluxes decreased to the rate of the unfertilised plot. Cattle slurry application (20 m^3 ha^{-1}) did not increase N_2O losses in the slurry treatment (S). The second N fertiliser application in late spring (30 kg N ha^{-1}) had no impact on N_2O emissions because soil moisture content was lower (16 vol. %) than in early spring (35 vol. %). After each 2-day grazing period, high N_2O emission peaks occurred from treatments C, S and SM. NH_4^+ and NO_3^- contents (not shown) in the soil of those treatments also increased. The mineral N content in treatment M did not increase. Plants cannot utilise the large amounts of N from animal excreta and therefore a large part is available for microbiological processes and consequently N-losses. In winter, periodic emissions took place in all treatments during freeze-thaw events. Flux rates varied between 17 and 147 µg N_2O-N m^{-2} h^{-1}. During thawing the microbial activity is enhanced because of increased carbon availability from micro-organisms killed by freezing under wet soil conditions (Christensen and Christensen, 1991). N_2O emissions during winter (December 13, 2001 – March 4, 2002) contributed to 26 % of the total emission.

For calculation of total annual N_2O-N emissions, flux rates over 75 measuring days were interpolated linearly and cumulative losses calculated. Total N_2O emissions ranged from 1.7 kg N ha^{-1} y^{-1} (M) to 4.9 kg N ha^{-1} y^{-1} (SM) and were not significantly different (Figure 2A) between treatments. The measured rates are comparable to results of Velthof and Oenema (1995), who calculated annual N_2O-N releases from a sandy soil (313 kg mineral N ha^{-1} y^{-1}) of 2.7 and 7.1 kg ha^{-1} for mown and grazed grassland, respectively. The lack in differentiation among our treatments is partly caused by the heterogeneous distribution of excreta during grazing periods and by the N_2 fixation of white clover in the sward leading to a reduced contrast between treatments in N inputs.

Forty-four gas flux measuring dates were averaged to provide mean N_2O emission rates in the cutting period (April 2, – July 31, 2001). Mean N_2O emissions increased significantly with increasing N inputs (Figure 2B). Mean N_2O-N flux rates were 15, 19, 25 and 37 µg m^{-2} h^{-1} for the C, S, M and SM treatments, respectively. When mean N_2O losses of the fertilised treatments were compared with emissions from the unfertilised control (Dunnett-test), N_2O flux rates from SM differed significantly from C (P < 0.05). Significantly more N_2O-N was emitted from M (39 %) compared with S (9 %) treatments (T-test, P = 0.0002). An explanation for this phenomena may be that all the mineral N fertiliser was rapidly available for microbiological processes but only about 50 % of slurry-N in form of NH_4^+-N.

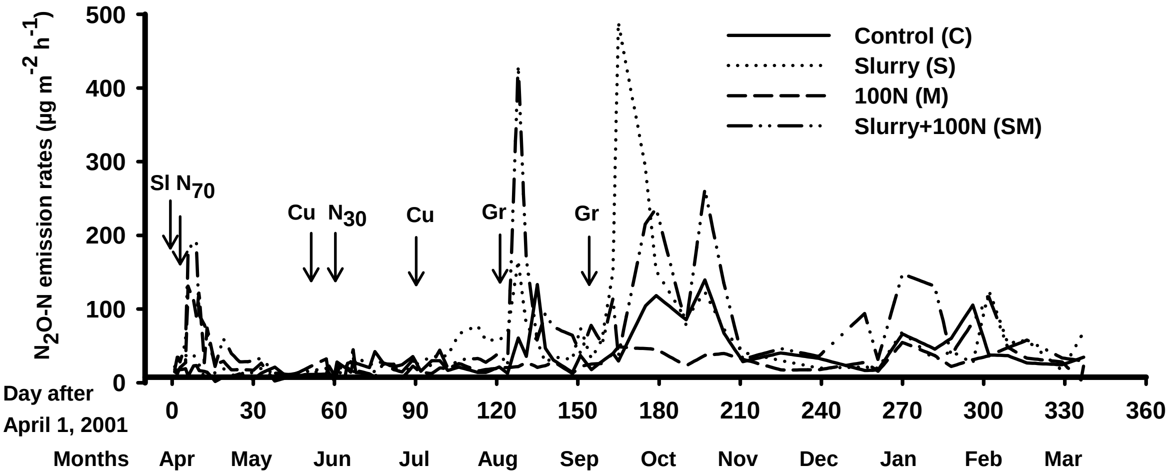

Figure 1. N_2O-N emission rates (µg m^{-2} h^{-1}) from April 2, 2001 to March 4, 2002 (Sl = 20 m^3 ha^{-1} slurry applied, N = 70 + 30 kg N ha^{-1} applied, Cu = Cutting, Gr = Grazing).

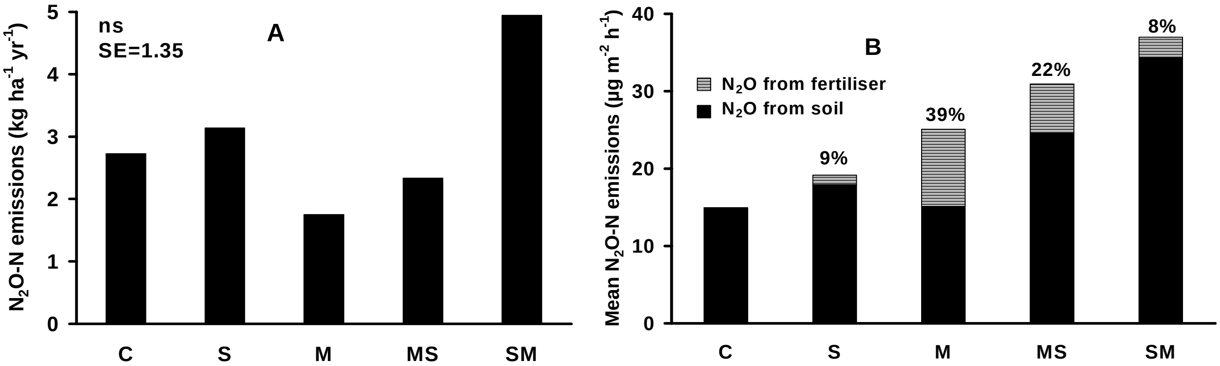

Figure 2. Total N_2O-N emissions (kg ha^{-1} y^{-1}) from April 2, 2001 to March 4, 2002 (A) and mean N_2O-N emission rates (µg m^{-2} h^{-1}) for the cutting period (April 2, – July 31, 2001) and fertiliser-borne N_2O (%) (B).

Conclusions

N_2O-N emissions were enhanced in excretal patches during grazing and also by N fertilisation. Emissions in winter made a considerable contribution to the total annual N_2O losses. No correlation of yearly emitted N_2O and N input was found because of the large emissions during and after grazing. ^{15}N labelling of N fertilisers indicated that the soil N pool was a large source of N_2O.

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Nitrous oxide and ammonia emissions from dairy pasture in Finland

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Abstract

Gaseous N losses from pastures can be large. In this study the total amount of NH_3-N and N_2O-N emitted was calculated by using the percentage of the surface covered by dung and urine and measured emissions from simulated excretal patches and a control patch. N_2O was emitted continuously from soil and the peak values in summer were measured immediately after simulated urination and later in the summer after rainfall. N_2O emissions were at their lowest in the autumn but increased again after the topsoil was frozen. When air temperature was very low for several weeks, reaching -35 ^oC, N_2O emissions remained constantly at higher level than in the autumn. The proportion of NH_3-N emitted from the urine and dung patches was 17.2 and 1.3 % of the applied N, respectively. As expected, the emission period was short and 79 % of the total emission occurred within 44 hours after the simulated urine deposition. The peak value for the urine patch NH_3-N emission was measured 4 hours after the simulated urination. Over half of the dairy production in Finland is located on soils similar to that in this experiment. Therefore the results are useful when estimating N emissions from the main dairy production area in Finland.

Keywords: nitrogen, grazing, N_2O, NH_3, volatilisation, emission

Introduction

Nitrogen (N) load is high in dung and urine spots in pasture soils and this causes different forms of N losses. In the literature, approximately 14-23 % of the easily degradable N excreted onto pastures is estimated to be lost in gaseous form of which 8 % as ammonia (NH_3), 1.5 % as nitrous oxide (N_2O), 5-13 % N_2 and the rest as NO (Webb, 2001).

Nitrous oxide is a powerful greenhouse gas that is produced microbiologically in soil-water environments (by nitrification and denitrification). Agricultural soils are the greatest potential sources of N_2O and approximately 50 % of the N_2O emissions in Finland originate from agriculture. In the boreal region, wintertime N_2O emissions have been reported to account for 10 to 90 % of the annual emissions. High N_2O emissions during winter have been generally related to the freezing-thawing cycles (e.g., Teepe *et al.*, 2001). Ammonia emissions from excreta of grazing animals may also cause considerable N losses from pastures. Simultaneous measurements of N_2O and NH_3 emissions from the same experimental area are rare and there are no previous results on N_2O or NH_3 emissions from pastures in the boreal region. We measured the annual N_2O emissions, including wintertime, and NH_3 emissions in summer from pasture on a mineral soil.

Materials and methods

The total amount of the NH_3-N and N_2O-N emitted was calculated by using the percentage of the surface covered by dung and urine (measured earlier, 4 and 17 %, respectively) and the measured emissions from simulated excretal patches and a control patch. The N_2O emissions from 6 replicate plots were measured manually between 8 am and 4 pm with a static chamber method (Crill *et al.*, 1988) once a week through the summer until October and was then continued by measuring the N_2O concentration gradients in the snow layer (Maljanen *et al.*, 2003) during the winter. The samples were analysed with a gas chromatograph (with an EC detector). The NH_3 emissions were measured by the equilibrium concentration technique (JTI method, Svensson and Ferm, 1993) during 90 min periods, four times per day for the first two days with one period at night. For the next two days, measurements took place three times per day (no measurements at night) and once a day in the afternoon over the remainder of the study period. Experiments were done with 4 replicates per treatment in two measuring periods in June and August, which lasted for 5 and 8 days, respectively.

Results and discussion

The dynamics of the N_2O and NH_3 emissions differed as expected. N_2O was emitted continuously and the peak values in the summer were measured immediately after simulated urination and later in the summer when the soil was moist after rainfall. The total amount of N_2O emitted between June and September was 1.34 kg N ha^{-1} (Table 1). N_2O emissions were at their lowest in the autumn but increased again after the topsoil was frozen (Figure 1).

Table 1. N_2O-N and NH_3-N emissions from pasture calculated as kg ha^{-1} and as a proportion (%) emitted of the total N added between June and September in 2002.

N_2O-N emission			NH_3-N emission			$(N_2O + NH_3)$-N		
	kg ha^{-1}	% of total N added		kg ha^{-1}	% of total N added		kg ha^{-1}	% of total N added
Dung	0.7	1.3	Dung	0.7	1.3	N_2O-N	1.3	1.9
Urine	0.3	0.3	Urine	14.2	17.4	NH_3-N	14.9	18.7
no excreta	0.3	0.3						
Total	1.3	1.9		14.9	18.7		16.2	20.6

The wintertime N_2O flux rates were even greater than those during the non-frozen season (Figure 1) and was, on average, 50 % of the annual flux. Surprisingly, when the air temperature was very low for several weeks, reaching -35 ^{o}C, N_2O emissions remained constantly at a high level. However, throughout the snow cover period the soil temperature remained constantly above -2 °C. Therefore, these high wintertime N_2O emissions were not strictly connected to the freezing-thawing cycles. The results show that the overall mechanisms/conditions for high N_2O emissions from soils at low temperature are still poorly understood.

The simulated urination was equal to 48.5 and defecation 113.6 g N m^{-2}. The proportion of NH_3-N emitted from the urine patch and the dung pat was 17.2 and 1.3 % of the total N added, respectively. As expected, the emission period was relatively short and 79 % of the total emission occurred within 44 hours after the simulated urine deposition. High NH_3 emission values occurred soon after excreta deposition. The peak value for the urine patch NH_3-N emission (0.67 g m^{-2} h^{-1}) was measured four hours after the simulated urination. The largest NH_3 values were measured in the afternoon and smallest in the night.

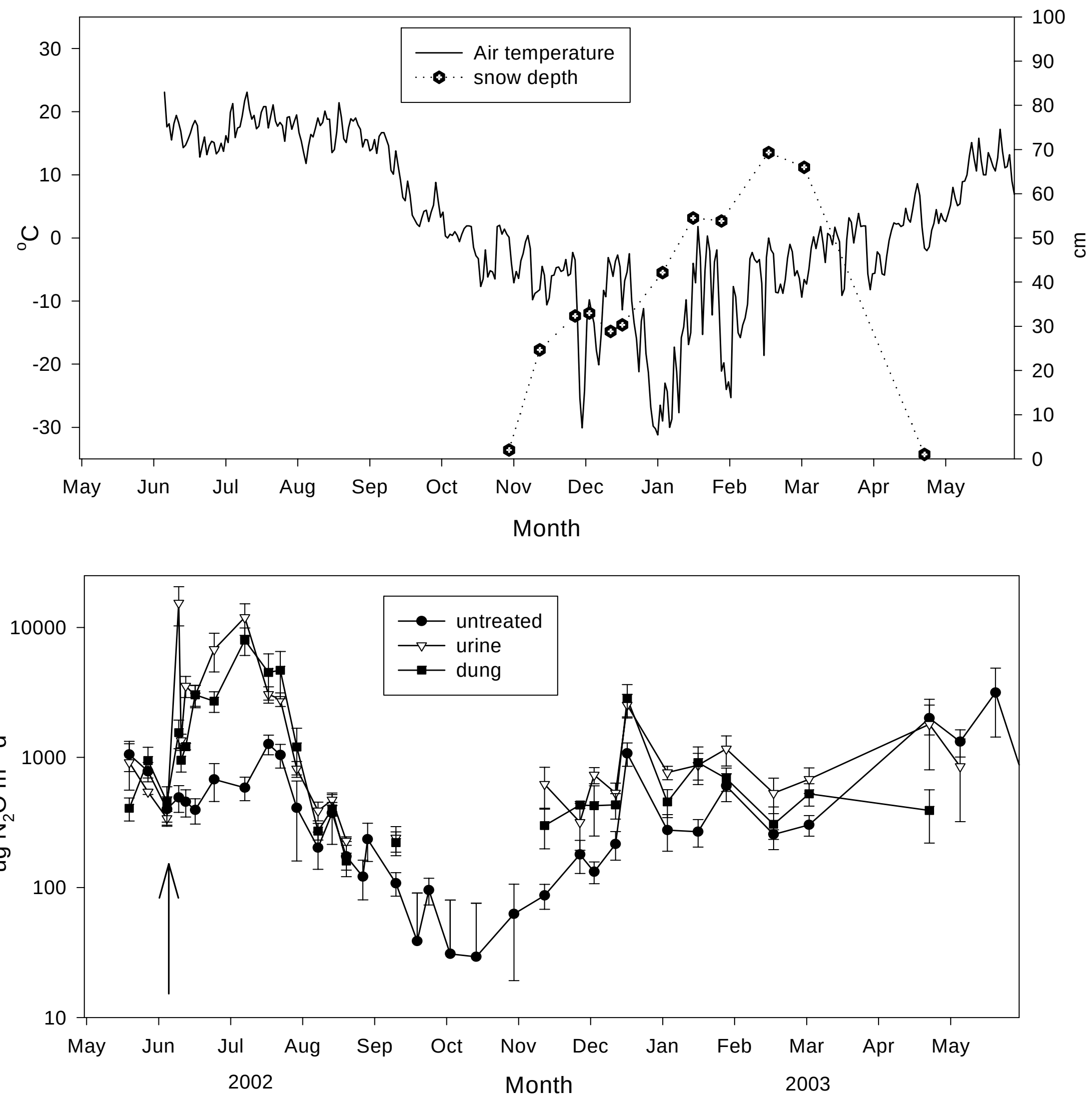

Figure 1. The upper graph shows air temperature (°C) and snow cover depth (cm) in May 2002 – May 2003. The lower graph shows N_2O emissions from dung pats, urine patches and untreated soil in May 2002 – May 2003. The arrow indicates simulated urination and defecation. Error bars represent standard error of the mean.

Over half of the dairy production in Finland is located on soils similar to that in this experiment and the results therefore have relevance when estimating N emissions from the main dairy production area in Finland.

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Effect of DMPP on NH_3, N_2O and NO emissions from grassland

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Abstract

The nitrification inhibitor 3,4-dimethylpyrazol phosphate (DMPP) was applied to a mixed clover/ryegrass sward in the Basque country together with ammonium sulphate nitrate or cattle slurry. DMPP reduced NO emissions by 44 % after ammonium sulphate application, and N_2O emissions by 29 % and NO emission by 26 % after slurry treatment but did not significantly increase NH_3 volatilisation.

Keywords: ammonium sulphate nitrate, nitrification inhibitor, nitrogen losses, slurry

Introduction

The inefficient use of nitrogen fertilisers can lead to large N losses, producing undesirable ecological problems. Gaseous nitrogen loss can be through ammonia volatilisation (NH_3), nitric oxide (NO) or nitrous oxide (N_2O) emissions.
Ammonia volatilisation is a major N loss process for surface applied slurries. Some 70 to 90 % of the N in cattle urine is urea and this is rapidly hydrolysed by urease in the soil. Total hydrolysis can occur within 24 hours.
NO and N_2O emissions are significant N loss mechanisms from agricultural soils, coming from both denitrification and nitrification processes. In the edaphoclimatic conditions of the Basque country, they have been proved to be a significant pathway of N losses in cut grassland (Merino *et al*., 2001).
The use of nitrification inhibitors (NI) has been proposed as a means of reducing N losses by denitrification and leaching. Although application of NI can reduce nitrate losses and N_2O emissions, the risk of increasing ammonia volatilisation exists. The NI 3,4-dimethylpyrazol phosphate (DMPP) has been tested in several trials in order to reduce N losses by nitrate leaching and N_2O emissions after its application, but few studies exist on NH_3 and NO emissions.
The aim of this study was to evaluate the effectiveness of the NI 3,4-dimethylpyrazol phosphate (DMPP) on NH_3, N_2O and NO emissions following application of ammonium sulphate nitrate or cattle slurry to a mixed clover/ryegrass sward in the Basque country.

Materials and methods

This work was conducted on cut grassland in the Basque country (northern Spain) during the spring of 2003. The experiment was established on a poorly drained clay loam soil on a typical permanent pasture in April 2001. Sowing density was 40 kg seeds ha^{-1} (*Lolium perenne* L. var. Herbus, 60 %; *Lolium hybridum* L. var. Texi, 32 %; *Trifolium repens* L. var. Huia, 8 %).
A randomized complete block factorial design with four replicates was established, each experimental plot covering an area of 12 m^2 (4 x 3 m). Two kinds of fertilisers were applied on 19th May 2003 at a rate of 97 kg N ha^{-1}: ammonium sulphate nitrate (26 %) (M treatment) or cattle slurry (S treatment). Characteristics of the slurry were: total N = 2.04 (w/w); NH_4^+-N = 0.23 % (w/w) and C:N ratio = 11.22. DMPP was applied or not with both types of fertiliser. In the mineral fertiliser DMPP was applied as the marketed product *ENTEC® 26*, containing

0.8 % of the NH_4^+-N (M + DMPP treatment). Ammonium sulphate nitrate (26 %) and *ENTEC® 26* were surface applied in granular form by hand. The slurry was obtained from a concrete storage pit on a dairy farm. DMPP was used at a rate of 0.8 % of the N applied (approx. 1 kg ha^{-1}) diluted in a small volume of water. This solution was sprayed together with the slurry in the S + DMPP treatment. A treatment with no fertiliser was included as a control (C), where N_{min} was 5 kg NH_4^+-N ha^{-1} and 4.75 kg NO_3^--N ha^{-1} prior to the beginning of the experiment.

Nitrous oxide emissions were measured using a closed air circulation technique in conjunction with a photoacoustic infrared gas *analys*er for 40 minutes (Merino *et al*., 2001).

Nitric oxide emissions were measured just before N_2O measurements using an open chamber technique as described by Harrison *et al*. (1995) by chemilumiscence *analys*er (AC31M Environment S.A).

Ammonia emissions were measured using an open chamber technique. Concentrations of NH_3 were measured at the air inlet and outlet of the chamber using a photoacoustic infrared gas *analys*er (Brüel and Kjaer 1302 Multi-Gas Monitor).

Results and discussion

N_2O and NO emissions, water content (expressed as water filled pore space, WFPS) and soil temperature are presented in figure 1.

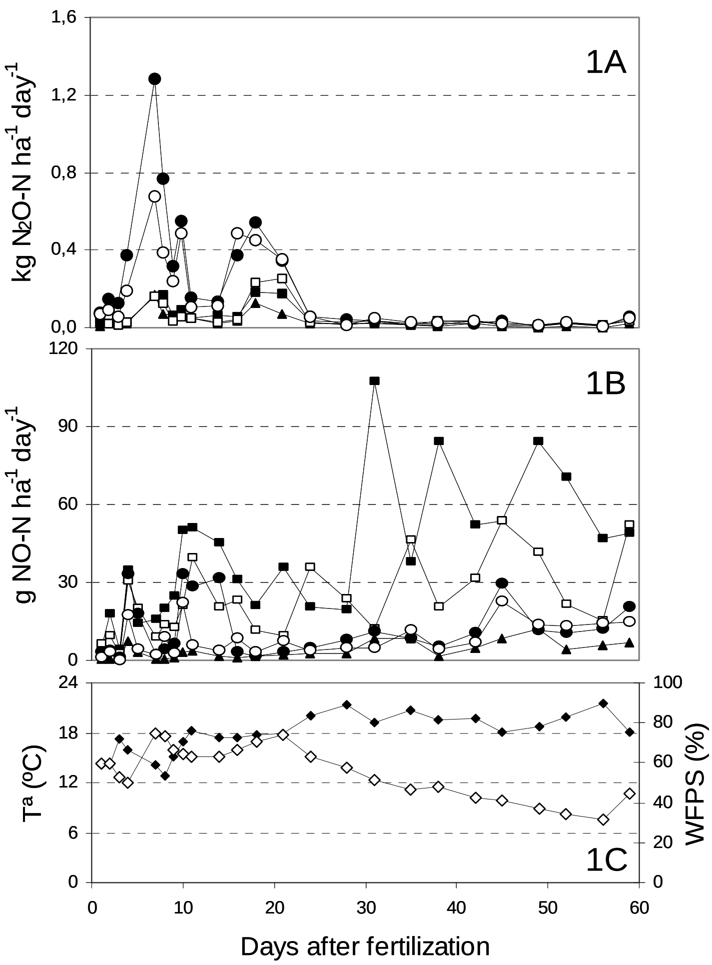

Figure 1. N_2O (1A) and NO (1B) emission rates, and WFPS and soil temperature (1C). C (▲) = control, M (■) = ammonium sulphate nitrate, M + DMPP (□) = ENTEC®, S (●) = slurry, S + DMPP (○) = slurry with DMPP, soil temperature (◆), WFPS (◇).

The main N_2O emissions took place during the first 24 days after fertiliser application (Figure 1A), when the WFPS was over 60 %. The highest rates of N_2O emissions were observed in the slurry treatments on day seven after fertiliser application, with rates of 1.28 kg N_2O-N ha^{-1} day^{-1} in S and 0.68 kg N_2O-N ha^{-1} d^{-1} in S + DMPP (Figure 1A).
When cumulative losses over time were calculated, DMPP was shown to reduce the N_2O emissions from the slurry by 29 % after 24 days (Table 1). Cumulative losses in treatments with inorganic fertiliser were not significantly different from the control treatment.
The main NO emissions (Figure 1B) took place after day 24, when WFPS decreased below 60 % (Figure 1C). NO emissions were always higher in treatments with inorganic fertiliser than in treatments with slurry. Cumulative NO losses up to 59 days showed that DMPP reduced in the emissions from inorganic fertiliser by 44 % and from slurry by 26 % (Table 1).

Table 1. Cumulative N_2O-N, NO-N and NH_3-N emissions. Different letters within a column indicate significantly different figures (P < 0,05, n = 4). C = control, M = ammonium sulphate nitrate, M + DMPP = ENTEC®, S = slurry, S + DMPP = slurry with DMPP.

Treatment	kg N_2O-N ha^{-1} (24 days)	kg NO-N ha^{-1} (59 days)	kg NH_3-N ha^{-1} (3days)
Control	2.68 c	0.26 d	0.29 b
M	4.44 c	2.76 a	0.29 b
M + DMPP	4.05 c	1.54 b	0.14 b
S	15.49 a	0.70 b	7.53 a
S + DMPP	10.98 b	0.52 c	10.69 a

Cumulative NH_3 losses are presented in table 1. NH_3 emissions occurred during the first 72 hours after fertiliser application. In the treatments with inorganic fertiliser there were no differences from the low emissions of the control. As expected, NH_3 emissions occurred mainly in the slurry treatments. NH_3 losses were 40 % higher in treatment S + DMPP than in treatment S, although not significant, probably due to the effect of DMPP, which maintains soil N in ammonium form for a longer time, and thus more susceptible for volatilisation.

Conclusions

We conclude that DMPP is an effective NI in reducing N_2O and NO emissions in fertilised cut grassland, although it does not significantly increase NH_3 volatilisation losses.

Acknowledgements

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Influence of different methods of sward irrigation on pasture yield and nitrate content in percolating water

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Abstract

The aim of this work was to evaluate the influence of two systems of soil irrigation on yield and nitrate content in percolating water. The study was carried out during 1995 in 20 lysimeters with 0.20 m^2 area and 1.1 m depth, sown with a pasture mixture. In treatments A and B irrigation was obtained by capillary ascension with a stable water-level fixed at 0.6 m in treatment A and 1.0 m in treatment B. No water was received by precipitation in these treatments. Treatments C and D had precipitation but no access to ground water. In treatment C spray irrigation was applied when the water deficit exceeded 40 % of the field water capacity. All treatments received a similar NPK fertilisation and were cut five times. Chemical analyses of percolating waters were made. It was observed that in a dry and warm year capillary ascension, particularly with stable water-level at -0.6 m, had a significant influence on the dry matter yield. The highest leaching of nitrate was observed with infiltration irrigation. In the case of capillary ascension, nitrate leaching was lower and never exceeded 3.0 mg dm^{-3}.

Keywords: irrigation, pasture, DM yield, nitrates, lysimeters

Introduction

The problem of environment protection, and particularly the pollution of waters from grasslands, has special importance when they are utilised by grazing. Usually, pastures receive higher nitrogen applications than meadows. On pastures, the animals leave excrements and residual herbage and tread the surface layer of soil, especially close to the watering-places. The shortage of water in the root layer is often the restrictive factor for efficient utilisation of manures by plants. In order to assure reliability of pasture sward yield and good utilisation of nitrogen fertilisers in poor water-soil conditions, it is necessary to rectify the shortages of moisture in soil by irrigation. This in turn has a close relationship with nitrate leaching to ground waters (Nazaruk and Piekut, 1992; Sapek, 1996).
Migration of nitrogen from the root layer to ground water is one of the most important factors in the ecological equilibrium of meadow ecosystems and simultaneously influences the quality of underground waters (Piekut and Pawłat, 1996), which has in recent years been the basic problem in protection of the agricultural environment.
The aim of the presented work is to show the relationships between soil irrigation (capillary ascension or infiltration) during the vegetation period, dry matter yield and nitrate content in percolating water.

Materials and methods

The study was conducted during the vegetation season 1995 in the lysimeter station of the Institute for Land Reclamation and Grassland Farming at Falenty, in typical conditions for most pastures outside of valley areas. Twenty lysimeters with 0.20 m^2 surface and 1.1 m depth, filled with mineral soil type black earth degraded, were used. Lysimeters were sown with a grass mixture, appropriate for pastures on mineral soils and harvested five times per year. The sward in all lysimeters was fertilised uniformly: 200 kg ha^{-1} N in five equal doses of

40 kg ha^{-1} applied in spring and after every harvest, 66 kg P ha^{-1} once in spring and 65 kg K ha^{-1} in three equal doses applied in spring and after the second and fourth cuts. Two methods of irrigation, each with two treatments, were compared, each one with five replications:

I) capillary ascension with stable level of water held at a defined depth during the vegetation period and without rainfall: treatment A = water level at 0.6 m, treatment B = water level at 1.0 m;

II) infiltration irrigation (surface) without access to ground waters (plants can use only water from post-winter retention): treatment C = irrigation + precipitation, treatment D = only precipitation.

The level of ground water on treatments A and B was held by daily inspection and supplementing or pouring off water to the required depth. Soil moisture was measured with field probes of type FP/mts (EASY TEST ltd.). Irrigation in treatment C was applied when the average soil moisture in layer 0-30 cm exceeded the water deficit of about 40 % of field water capacity. The seasonal application was 160 mm.

The DM yield was measured at each cut. Water samples were taken from every lysimeter in spring before the start of growth and after the harvest of cut IV and V and were *analys*ed for their content of nitrate nitrogen.

Results and discussion

The research shows that the moisture level in the soil and the method of irrigation had a significant influence on the DM yield (Table 1 and 2). In conditions of higher soil moisture due to a higher level of ground water (A), the DM yield was higher than in treatments without access to ground water (C and D). The dependence mentioned above was manifested from the second cut to the fifth cut. From the half-way of the second cut the plants in all treatments drew water from post-winter retention.

The highest yields were obtained with a 0.6 m deep water level. Yields were reduced in treatment C without access to ground waters + irrigation and drastically reduced on plots without access to ground water and without irrigation (D).

Table 1. DM yield (g per lysimeter) for the different irrigation treatments.

Irrigation treatment	Cut					Annual yield
	I	II	III	IV	V	
A	16.0	72.8	39.7	33.5	16.9	178.9
B	18.4	69.3	31.2	30.4	15.7	165.0
C	18.3	66.7	26.4	25.4	15.8	152.6
D	17.2	66.2	18.7	17.4	17.2	136.7
$LSD_{(0.05)}$	2.54	3.65	4.02	2.17	2.42	7.52
$LSD_{(0.01)}$	3.56	5.11	5.64	3.05	3.40	10.55

Table 2. Differences in annual DM yield between irrigation treatments and their significance according to Student-Newman-Keulsa (SNK) test.

Irrigation treatment	annual DM yield g per lysimeter	Differences		
		2	3	4
A	178.9	13.8*		
B	165.0	12.4*	26.3*	
C	152.6	15.8*	28.3*	42.0*
D	136.7			
$LSD_{SNK(0.01)}$		11.80	13.66	14.83

*– significant

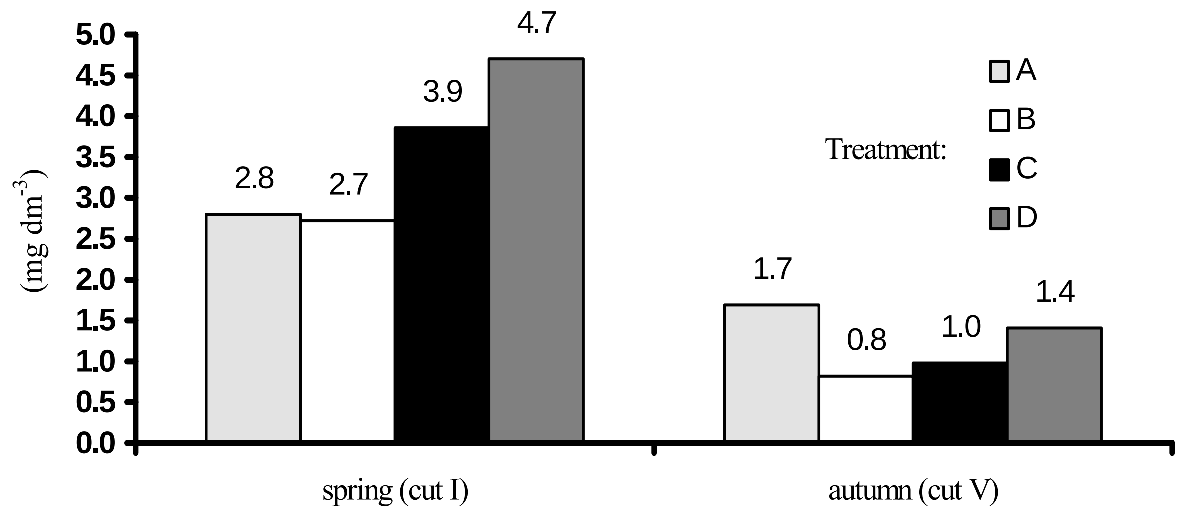

Figure 1. Nitrates content in percolating waters (mg dm^{-3})

The limiting factor for growth and development in this trial was the deficit of water in soil, which increased during the vegetation period in consequence of large shortages of rainfall. In the case of longer periods of dry weather, drying out of older leaves was observed.

Measurements of nitrate content in percolating waters during the vegetation period showed that the highest average leaching of nitrate (4.9-6.1 mg dm^{-3}) occurred in plots with infiltration irrigation and rainfall (treatments C and D), where applied manure can easy escape to ground water when water is added (Figure 1). In the case of capillary ascension (treatments A and B), nitrate leaching was smaller (3.5-4.5 mg dm^{-3}) and never exceeded 3.0 mg dm^{-3} in a single measurement.

The results of the research, with regard to the low nitrogen content in waters flowing away when using capillary irrigation, are consistent with the results of Piekut and Pawłat (1996) and Martyniak (2001).

Conclusions

1. In a dry and warm year, capillary ascension, particularly with a stable water-level of 0.6 m, increased significantly the DM yield. The highest leaching of nitrate was observed with infiltration irrigation.
2. The infiltration irrigation increased nitrogen leaching far inside of the soil profile in comparison with the capillary ascension, as shown by higher nitrogen content in waters flowing away from sites irrigated by infiltration.

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Nitrate leaching losses under a forage crop rotation

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Abstract

In the presented study a three-year crop rotation was established, including a grass/clover mixture (two cuts in spring and two succeeding grazings), silage maize and triticale for one year each. It was hypothesised that the short grassland period would prevent excessive nitrogen accumulation in the soil and that the succeeding crops would take up most of the remaining surplus N, resulting in reduced nitrate (NO_3) leaching losses. Three levels of mineral fertiliser (0, 75, 150 kg N ha^{-1}, average over the three crops) and two levels of slurry (0, 25 m^3 ha^{-1}) were applied. Nitrate leaching losses were measured in all crops by suction cups over three years and N balances on a field scale were calculated. The results showed that in the crop rotation N-losses from grazed grassland were lower than the losses from the maize and triticale crop. In all crops nitrate losses increased with increasing N surpluses. N-leaching losses under maize were highest while the surpluses were negative, indicating that the maize took up large amounts of the remaining N from the ley, but N mineralised later was highly prone to NO_3-leaching.

Keywords: crop rotation, nitrate leaching, groundwater, grassland

Introduction

In northern Germany intensive dairy farming is mainly located in the Geest region, which has freely draining sandy soils for which the nitrogen recovery is known to be low. This causes serious environmental problems due to increased losses of NO_3 to the groundwater (Wachendorf and Taube, 2002). On permanent grassland, high N returns from grazing animals result in leaching losses far-exceeding the EU limit for nitrate in drinking water (Büchter, 2003). Silage maize is known to have high N use efficiency (Volkers *et al*., 2002) and with fertiliser rates based on the demands of the plant, leaching losses are relatively low (Büchter, 2003). The intention of this project was to determine whether the inclusion of grassland as a short term ley in a rotation before a maize crop and following a cereal crop may reduce NO_3 leaching losses through an efficient uptake of possible surpluses from the ley period by the maize crop. Possible negative effects of maize grown in monoculture, such as soil erosion or humus degradation, might be reduced as a side effect. To evaluate the potential of this strategy, a forage crop rotation as a field experiment was established in 1999 at the same site as a previous permanent grassland (Trott *et al*., 2002) and maize trial (Volkers *et al*., 2002). The crop rotation included a grass/clover mixture (two cuts in spring and two succeeding grazings), silage maize and triticale for one year each (Wachendorf *et al*., 2004). The aim of this study was to show whether the nitrate leaching losses were reduced within this experimental design and whether N balances on a field scale provided information about the nitrate concentration in the leachate.

Materials and methods

The field trial was conducted at the experimental farm 'Karkendamm' of the Institute of Crop Science and Plant Breeding of the University of Kiel in northern Germany. The whole project deals with quantitative measurements of nitrogen flows in a 'soil-plant-animal' system (Taube and Wachendorf, 2000). The mean annual precipitation is 824 mm and the mean annual temperature 8.4 °C. The soil type is a Treposol (deep ploughed gleyic podzol) and the texture is sand with less than 5 % clay and a pH of 5.6. The clover/grass ley was managed as a mixed system with two cuts and two succeeding grazing periods. The last cut remained on the field and was incorporated in spring prior to maize sowing. Silage maize was used as a whole crop silage and triticale as whole crop silage and grain, respectively. The experiment consisted of three nitrogen intensity levels as shown in table 1.

Table 1. N supply by mineral fertiliser and slurry at various intensity levels in the crop rotation trial.

	High Intensity (kg N ha^{-1})			Reduced Intensity (kg N ha^{-1})			Low Intensity (kg N ha^{-1})		
Crop	Fert.[†]	Slurry[#]	Total	Fert.	Slurry	Total	Fert.	Slurry	Total
Clover/grass (CG)	150	75	225	100	75	175	0	75	75
Silage maize (SM)	100	75	175	25	75	100	0	75	75
Triticale (TR)	200	75	275	100	75	175	0	75	75
Mean	150	75	225	75	75	150	0	75	75

[†]: Mineral N fertiliser, [#]: 3.1 kg total N m^{-3} slurry

In order to achieve greater variation of N intensity in the trial, all intensity levels were used with and without slurry. All crops were grown for one year. In the experiment, every crop was grown in each of the three years. N balances on a field level only considered external N sources and were calculated as follows:

N input	N output
Mineral fertiliser N	N yield in harvestable biomass
+ slurry N	– residual biomass N (grazed swards)
+ N biologically fixed by clover	– excrement N (grazed swards)
+ deposition N	

N surplus = N input – N output

Nitrate leaching losses were measured by means of ceramic cup samplers located at 60 cm soil depth and collected weekly during the winter months. A central pumping station maintained the suction. In each plot, four suction cups were installed. With each treatment replicated four times, mean concentrations were obtained from 16 ceramic suction cups. The leaching data are weighted means over 3 leaching periods. Ceramic cups were installed each autumn and removed in spring at the end of the leaching period.

Results and discussion

There were strong positive correlations between N surpluses and nitrate concentration in the leachate for each crop and for the mean crop rotation (Figure 1). Nitrate concentrations in the leachate after maize and triticale exceeded the critical EU limit for drinking water (50 mg l^{-1}), whereas concentrations after grassland were below the critical value. N-leaching losses were highest after maize, while the corresponding surpluses were even negative. This emphasises the fact that maize took up N that was being released after ploughing the grass/ clover sward in spring. Therefore the high leaching losses after maize may have resulted from increased mineralisation after incorporation of the stubble and a low N uptake in autumn by the following triticale (on average 10-15 kg N ha^{-1}). High losses after triticale probably resulted from the cultivation during establishment of the grass sward in autumn, causing increased mineralisation.

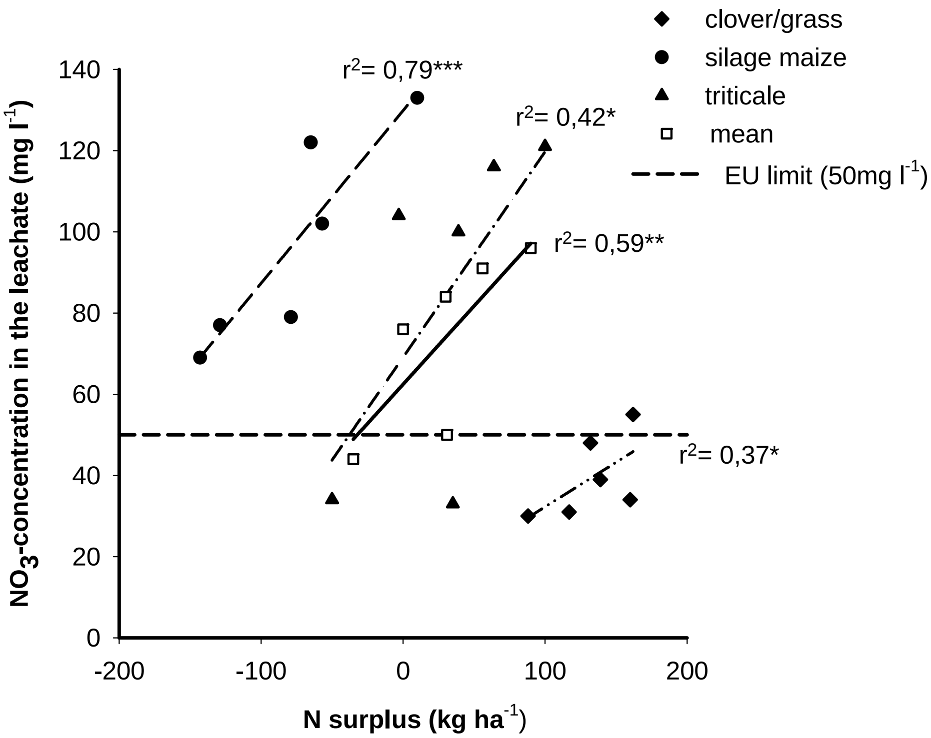

Figure 1. Correlations between N surplus (kg ha^{-1}) and NO_3 concentration (mg l^{-1}) in the leachate after a clover/grass ley, silage maize and triticale in a crop rotation.

Conclusions

The results show that a short-term grassland ley in a crop rotation prevents excessive NO_3 leaching and that the succeeding crops (mainly silage maize) take up parts of the remaining surplus N. NO_3 concentrations above the EU limit for drinking water could be found after maize and triticale. Evaluation of N surplus on a field scale allows the prediction of nitrate concentrations in leachate with satisfactory accuracy.

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Nitrate leaching from reseeded grassland: The effect of season, technique of renewal and former N fertilisation

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Abstract

Reseeding of grassland may increase the *mineralis*ation of organic material and lead to a greater amount of mineral nitrogen in soil, which can be leached during the winter-period.
In this experiment nitrate leaching was measured after reseeding of an 8-year old pasture on a sandy soil in northwest Germany. Several factors, which may influence the intensity of the *mineralis*ation, were investigated in two years after reseeding: the season of reseeding, spring or autumn; the technique, rotary cultivator or direct drilling; the amount of N-fertilisation, 0 or 320 kg N ha^{-1} y^{-1} in seven years before the reseeding. Nitrate-N leaching losses during winter were significantly higher following autumn reseeding (36-61 kg N ha^{-1}) compared to reseeding in spring (1-6 kg N ha^{-1}). This effect was only seen in the first, not in the second winter after the reseeding. The technique had no significant influence on the nitrate-N leaching losses. The highest N losses (on average over 60 kg N ha^{-1}) appeared after reseeding high-fertilised grassland in autumn. To reduce N-leaching losses after reseeding it is therefore necessary to postpone the reseeding from autumn to spring or to reduce the amount of N-fertiliser before a reseeding in autumn, respectively.

Keywords: grassland, nitrate, leaching, reseeding

Introduction

A break-up of grassland for renewal will often increase the *mineralis*ation of accumulated organic material and release nitrogen (N) that may leach during the following winter periods. Sandy soils especially, are prone to N leaching losses from high amounts of soil mineral nitrogen in autumn. The potential for *mineralis*ation and the intensity of the actual *mineralis*ation are influenced by several factors, among which are: age and former use of the grassland, previous N fertilisation, and season and technique of reseeding. Shepherd *et al*. (2001) observed a relationship between the mineral-N-content in soil and the age of the grassland. The amount of N fertilisation can be of greater influence on N *mineralis*ation and N losses after reseeding than the previous management, for example the use as cut or grazed grassland (Eriksen, 2001). More technical aspects like season and technique of reseeding have also been found to have an effect on N *mineralis*ation (Djurhuus and Olsen, 1997; Lloyd, 1992).
The aim of this experiment was to analyse the effects of the factors ‘previous N fertilisation’, ‘season of reseeding’, and ‘technique of reseeding’ on N leaching after renewal, and to make recommendations for a reseeding practice with less adverse effects on groundwater quality in a water catchment area.

Materials and methods

The experiment was carried out on a sandy soil in northwest Germany. Factors and levels are shown in table 1. After being used for several years as arable land, the field was converted to mown grassland in 1991.

The experiment lasted three years from 1999 to 2002. Each plot was 72 m^2 in size; three ceramic suction cups were installed at a depth of 75 cm in order to collect water for analysis of N concentrations in leached water.

Table 1. Design of the experiment.

Factor	Level		Notes
1. Season of reseeding	1.1	spring	reseeding in two years (1999 and 2000)
	1.2	autumn	
2. Previous N fertilisation	2.1	0 kg N ha^{-1} y^{-1}	over a period of 6-7 years
	2.2	320 kg N ha^{-1} y^{-1}	
3. Technique of reseeding	3.1	rotary cultivator	grassland sward killed with a total-herbicide
	3.2	direct drilling	

Number of replications is 2.

No N was applied after reseeding. The new grassland swards were mown four times a year and dry matter yield and N concentration determined.
During the period of leaching from mid-October to April (1999/00, 2000/01 and 2001/02), the leachate was sampled weekly and analysed for nitrate concentration.

Results and discussion

Nitrate-N leaching losses during the first winter were significantly higher following autumn reseeding (36-61 kg N ha^{-1}) compared to reseeding in spring (1-6 kg N ha^{-1}). This effect did not appear in the second winter after reseeding (Figure 1). Francis (1995), in experiments in New Zealand, found decreasing soil mineral-N contents (140 to 20 kg ha^{-1}) and N losses with leached water (100 to 15 kg N ha^{-1}) by shifting the reseeding from early autumn to spring.

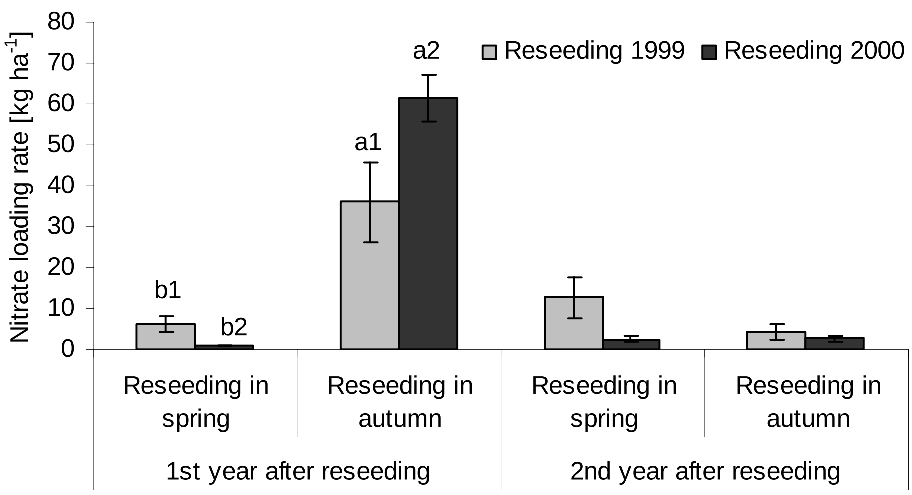

Figure 1. The effect of season of grassland renewal on N leaching losses for the following two winter leaching periods (mid-October to April); error bars represent standard errors; n = 8.

The previous N fertilisation had relatively little effect on N leaching after reseeding (Figure 2). This is true especially for reseeding in spring. However, there are more pronounced N losses from the highly fertilised plots that were reseeded in autumn. This can, at least partly, be explained by the fertiliser-N these plots had received during summer, before the reseeding in autumn.

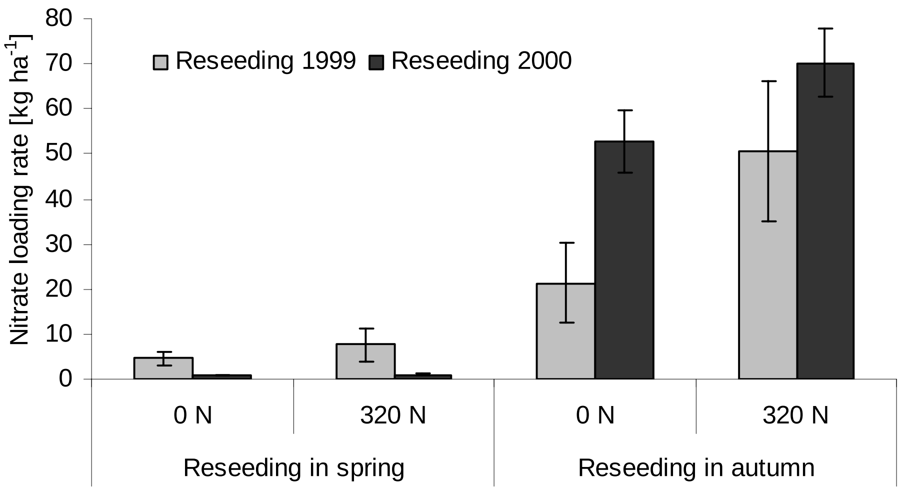

Figure 2. The effect of time of reseeding and the previous level of N fertilisation on N leaching losses during the first winter after reseeding (mid-October to April); error bars are standard errors; n = 4.

The technique of reseeding, either direct drilling or rotary cultivator had no significant influence on the nitrate-N leaching losses.

Conclusions

In order to minimize the risk of groundwater pollution in water catchment areas, grassland renewal in spring should be chosen over reseeding in autumn. For fields with similar conditions as described here, the influence of the previous level of N fertilisation and the technique of reseeding can be disregarded, when grassland is reseeded in spring.

If it is necessary to reseed grassland in autumn, fertilisation in the summer before should be avoided to prevent high N leaching losses.

It might not be appropriate to directly transfer the results from these experiments to sites on heavier soils with higher clay content. While the effects of date of reseeding might also hold true for other soils, the impact of the previous N fertilisation and follow-up effects in the coming years might be of greater importance on heavier soils and direct drilling could be more beneficial.

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Phosphorus in surface runoff from dairy pasture in Finland

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Abstract

The dynamics of surface water flow and the amount of Phosphorus (P) in surface runoff from pasture were studied at the North Savo Research Station (63°10'N, 27°18'E), Finland. The amount of P in surface runoff varied between 0.8-1.1 kg ha^{-1} y^{-1}. Peak PO_4-P concentrations, ranging from 3.2 to 4.2 mg l^{-1}, occurred at the beginning of thaw and then dropped rapidly to approximately 1 mg l^{-1}. The significance of the effects of surface runoff P from pastures on the water quality of lakes is discussed.

Keywords: eutrophication, grazing, phosphorus, pasture, surface runoff

Introduction

Phosphorus (P) is the main cause of eutrophication of Finnish lakes, which are vulnerable to eutrophication because they are fairly shallow (mean depth 6.9 m) and broken up by many divisions. A major part of agricultural land is located around lakes and other watercourses and so the P loading from the surrounding fields is likely to be large and mostly transported into the water by surface runoff. Accumulation of P in the soil surface layer is considerable under grass production and grazing. However, soil-soluble P concentration alone is not a reliable indicator of the risk of P runoff because, for example, soil structure and P binding capacity affect P runoff. A large proportion of the runoff P is particle-bound if the soil is sloping, bare or poorly drained and thus vulnerable to erosion. In well-drained, vegetation-covered soil, most of the P runoff is in a soluble form. If the total amounts of P input and output are known, a P balance can be calculated. This is not a reliable method of estimating the risk of P runoff, since soluble P is strongly buffered against changes in P output and input as most of the applied P is fixed in the soil (Uhlen, 1988). There are no published results of P runoff from pastures in Finland. In the study region, one third of the yearly precipitation (578 mm y^{-1}) is in the form of snow and the frost period lasts from five to six months, preventing most water movement in soil. We studied the effect of intensive dairy grazing on the total amount of P in the surface runoff, fractionation of P and concentrations of the different forms of P on well-drained sandy soil in Finland. We also sought to evaluate the significance of the surface runoff P from pastures on the water quality of the lakes.

Materials and methods

The dynamics of surface water flow and the amount of P in surface runoff from pasture were studied at the North Savo Research Station (63°10'N, 27°18'E), Finland. The study area was medium-textured Dystric Regosol soil, with a soil profile to 60 cm consisting mainly of 0.06-0.2 mm particles (43 %) and 0.02-0.06 mm particles (22 %) and low (7 %) clay content. The slope of the plots was approximately 1 %. Surface runoff water was collected from two 400 m^2 plots and throughflow was measured from ten 100 m^2 lysimeters on the same experimental field. Total runoff is the sum of surface runoff and throughflow. Dairy cows rotationally grazed the field during the summers of 2001-2003, with a fixed herbage allowance of 25 kg DM d^{-1} cow^{-1} and concentrates of 6 kg d^{-1} cow^{-1}. The pasture was fertilised with 22.8 kg P y^{-1}. Surface runoff and throughflow water were measured and total concentrations of P, PO_4-P and total dissolved P were determined. The amounts of P given in the concentrates and removed in the milk were calculated. Numbers of dung pats on the surface runoff plots were counted after each grazing period. The P concentration of the dung was analysed and the total amounts of P excreted onto the plots were calculated from the numbers of dung pats, as over 90 % of ingested P is excreted in the dung.

Results and discussion

Two-thirds of the P input into the pasture came in the form of fertiliser and one third was in concentrates and mineral mixtures fed to the cows (Table 1). Over 16 kg P ha^{-1} were cycling within the system during the grazing season as calculated from the average P concentration in the dung and numbers of dung pats on the surface runoff plots. This is 46 % of the total P input. The major P output is in milk production, which accounted for 54 % of the total P output. Surface runoff was a minor item, accounting for only 5 % of the total P output. P balance is dependent on fertiliser level and grazing intensity. In this case the mean P excess was 18 kg ha^{-1}, of which only 4.5 % was detectable as an increase in the soil-soluble P fraction and 13 % was lost in surface runoff (Table 1). This clearly supports the findings of Uhlen (1988) and indicates that P balance alone is not a good estimate of the amount of P runoff from an area.

Table 1. P inputs and outputs and soil P in the grazing system 2001-2003 (surface runoff and through-flow included from January 2001 to June 2003).

	2001	2002	2003
Input kg ha^{-1}			
Fertiliser	22.8	22.8	22.8
Concentrates	13.6	13.1	14.0
Total input	36.4	35.9	36.8
Output kg ha^{-1}			
Milk	10.5	9.6	9.6
Estimated excretion during milking	7.3	7.7	7.5
Surface runoff	0.75	1.00	1.08
Throughflow	0.01	0.02	0.02
Total output	18.5	18.3	18.3
Balance kg ha^{-1}	17.9	17.6	18.5
Increase in soil soluble P kg ha^{-1} (0-2 cm)	1.1	0.5	[1]
P remaining in the soil kg ha^{-1}	16.7	17.1	[1]

[1] analyses results not available

Approximately 90 % of the surface runoff was caused by thaw and the proportion of dissolved P was high at 90 % of the total P. Peak PO_4-P concentrations, ranging from 3.2 to 4.2 mg l^{-1}, occurred at the beginning of thaw and dropped rapidly to approximately 1 mg l^{-1} (Table 2). This supports Uhlen's (1988) conclusion that P is released from grass tissues during the winter freeze-thaw cycles. The mean proportion of particulate P was only 12 % of the total P, an expectedly low value, as the experimental plots were grass covered and the soil was well drained.

Table 2. The amounts of total and surface runoff, and the amounts and concentrations of total and phosphate phosphorus in the surface runoff from January 2001 to June 2003.

Year	total runoff (mm)	surface runoff (mm)	Tot-P (mg l^{-1})	Tot-P (kg ha^{-1})	PO_4-P (mg l^{-1})	PO_4-P (kg ha^{-1}?
2001	270	113	0.66	0.75	0.60	0.69
2002	173	62	1.61	1.00	1.48	0.92
2003	157	89	1.24	1.08	1.14	0.99

The significance of pasture-originated surface runoff for the lake ecosystem depends on a number of factors. The most important ones are the volume, water outflow rate, surface area of the lake and the amount of pasture in the lake catchment area. High solubility of P in runoff means that P is readily available for algal growth. As little as 10 μg l^{-1} increase can affect the lake eutrophication (Sharpley and Smith, 1989). Figure 1 shows the effect of the proportion of pasture in the lake catchment area on the eutrophication risk of lakes of different sizes. Critical load values (mg m^{-2} y^{-1}) are from Vollenweider (1975) and these values are combined with surface runoff P-data from this experiment to evaluate the importance of the pasture on the lake catchment area. The model is static and cannot be used alone to estimate the eutrophication risk to the lake, since there are other sources of P loading. However, it is a useful tool to assess the effects of pasture production and their potential impact on lake eutrophication.

Conclusions and practical implications

In regions with hard and long winters, most of the P loss occurs during the spring runoff. The proportion of surface runoff can be 40-100 % of the total. Even though P amounts in the runoff from pasture are nearly the same as from other agricultural land, a pasture differs in that most of the P is in a dissolved form. This can, under certain circumstances, cause eutrophication of the lakes. Buffer strips used for water protection efficiently remove particulate P, but are not efficient in removing soluble P. A possible treatment to reduce the pasture-originated P load would be to cut the herbage after it has adapted to winter conditions in late autumn.

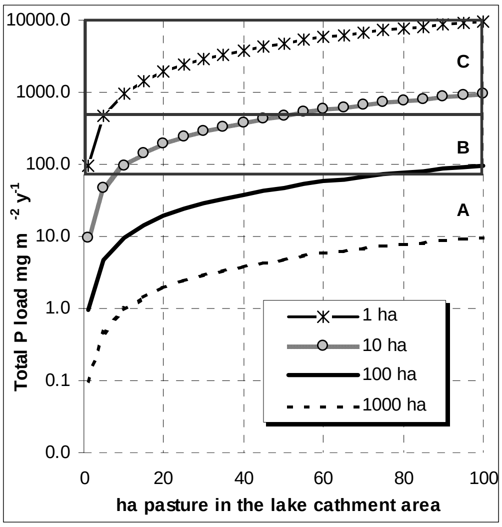

Figure 1. Pasture-originated P load to 1, 10, 100 and 1000 ha lakes. The eutrophication risk is low in Area A, Area B represents the potential eutrophication risk zone, depending on the lake properties, and Area C is the high eutrophication risk zone (limit values given by Vollenweider, 1975). The figures are drawn using 10 months with a constant lake water outflow rate.

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Potassium leaching from grassland

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Abstract

Potassium (K^+) leaching from grassland is of agronomic interest, but not yet of serious environmental concern. Generally, information concerning this topic is scarce. The effects of four fertiliser regimes on the dynamics of K^+ in mown grassland grown on a sandy soil were investigated. The swards differed in the source and level of N input and K^+ fertilisation: grass with no fertiliser N, with 320 kg N ha^{-1} in mineral form or as cattle slurry, and a grass-clover sward with no artificial N input. After six years the swards showed distinctive features in terms of nutrient balance and leaching, nutrient content of the soil, and botanical composition. These swards then formed the basis of a mini-lysimeter study on the fate of K^+ and N from urine patches on grazed grassland. Plant and soil were the major sinks for K^+ from fertiliser, manure, or urine. High levels of exchangeable K^+ in the soil and/or high and late fertiliser or urine applications stimulated leaching of K^+.

Keywords: grassland, potassium, leaching, nutrient balances, urine patches

Introduction

Balanced nutrient systems require consideration of other nutrients aside from N. Potassium is required by plants in amounts second to N. Apart from mineral sources, urine patches or regular high slurry applications are the main pathways for K^+ input on grazed grassland (Anonymous, 1991). In intensive dairy farming the input of concentrates and fertiliser lead to surpluses of K^+ which are returned to the grassland and may lead to increasing K^+ content in the soil. Organic farming, on the other hand, is characterised by limitations of the input of nutrient sources and quantities and therefore, long-term maintenance of soil fertility and yields is important. Leaching of K^+ from mown grassland with high removal of K^+ by herbage is usually relatively low (Mengel and Kirkby, 1987). Relatively little is known of the exact fate of K^+ in urine patches on grazed grassland.
The objective of the experiments was to gain information on the dynamics of K^+ in mown and grazed grassland particularly in relation to leaching losses.

Materials and methods

The effect of four fertiliser regimes on the leaching losses and soil content of K^+ of mown grassland on a sandy soil were investigated over a six-year period (1994-1999/00). The swards differed in the source and level of N input and K^+ fertilisation. The four treatments were: CAN 0 (grass sward with no N applied), CAN 320 (grass sward receiving 320 kg N ha^{-1} y^{-1} as calcium-ammonium-nitrate), SLR 320 (grass sward which received 320 kg N ha^{-1} as cattle slurry) and WCL (grass-clover swards received no artificial N and had an average white clover proportion of 40 %). Potassium input was 166 kg K^+ ha^{-1} applied as KCl for CAN 0 and WCL, 300 kg K^+ ha^{-1} for CAN 320 and 427 kg K^+ ha^{-1} with cattle slurry for SLR 320. The plot size was 72 m^2 and there were four replicates of each treatment. Swards were cut four times per year. Three ceramic suction cups were installed at a depth of 75 cm in each plot to collect leaching water. These swards formed the basis of a mini-lysimeter study (April 2000-July 2001) to simulate the fate of K^+ from urine patches on grazed grassland. The unfertilised grass swards (CAN 0) had developed a higher proportion of forbs compared to the CAN 320 treatment. Soil monoliths of 19 cm diameter and 22 cm length were placed on 20 cm sandy subsoil in an above-ground lysimeter construction. Apart from 16.6 g K^+ m^{-2} from fertiliser, cow urine with 60 g N and 74 g K^+ m^{-2} was applied either in summer or autumn or no urine was applied. Treatments were replicated six times. Herbage was cut by hand to simulate grazing. Water draining through the lysimeter profile was collected and sampled for analysis of K^+, Ca^{2+}, and Mg^{2+}.

Results and discussion

Six years of different nutrient management on mown grassland led to different surpluses of K^+ and subsequently to different soil contents of exchangeable K^+ and leaching losses (Table 1).

Table 1. The K^+ input, surplus, and leaching losses as *sums of six years* and the content of exchangeable K^+ (DL) for the topsoil as sampled in the sixth year; means of four replications with standard errors.

Fertiliser regime/sward	K^+ input[#] (kg ha^{-1})	K^+ surplus (kg ha^{-1})	K^+ leaching (kg ha^{-1})	K^+ soil (exch.) (mg kg^{-1})
CAN 0[§]	1014	279 ± 35.2 b*	45 ± 12.4 b	62 ± 8.8 b
WCL 0	1014	-334 ± 65.6 c	89 ± 22.2 ab	27 ± 3.2 c
CAN 320	1818	236 ± 66.5 b	32 ± 2.0 b	32 ± 3.8 c
SLR 320	2580	955 ± 46.8 a	149 ± 35.8 a	212 ± 5.8 a

* values in columns with different letters are significantly different at the $P < 0.05$ level
[#] including atmospheric deposition (3 kg K^+ ha^{-1} y^{-1})
[§] CAN 0, CAN 320, and SLR 320 are grass swards with no N fertilisation or input of 320 kg N in mineral form or as cattle slurry; WCL is grass-clover mixture with no fertiliser N.

The N fertilised grass sward (CAN 320) and the grass sward with no N input (CAN 0) were adequately provided with K^+. Cattle slurry as the only source of K^+, and applied at high rates, resulted in a high cumulated surplus of K^+ and in increasing K^+ content in the soil. This caused greater losses of K^+ with leaching water. Askegaard and Eriksen (2000) concluded that the degrees of saturation of the soil profile with K^+ and the fertiliser history as well as current K^+ budgets need to be considered to predict K^+ leaching losses.

Only the grass-clover sward did not follow the general trend of a positive correlation between increasing K^+ surpluses, higher exchangeable K^+ content in the soil and higher leaching losses. The higher leaching losses of K^+ from the productive grass-clover swards may be related to a preferential flow as induced by root structure, as well as to specific characteristics of cation transport in soil, where K^+, among other cations, is thought to act as a counterion to leached NO_3^- (Tinker and Nye, 2000). An enhanced H^+ secretion from the roots balancing the generally excess cation uptake of clover plants can displace K^+ from soil exchange sites and add to K^+ leaching (Mengel and Kirkby, 1987). Residues of clover are easily decomposed and may add to the provision of K^+.

Differences among the unfertilised (N) grass sward (CAN 0), the grass-clover sward (WCL) and the fertilised (N) grass sward (CAN 320) in plant, soil and leaching response to input of K^+ from urine on grazed grassland were small (Figure 1). There was, however, less leaching of K^+ from the CAN 320 swards coupled with a higher recovery in plant and soil. As with the mown grassland, leaching losses were higher from grass-clover swards. The overall amount of leachate, however, was only 60-75 % of the long-term average.

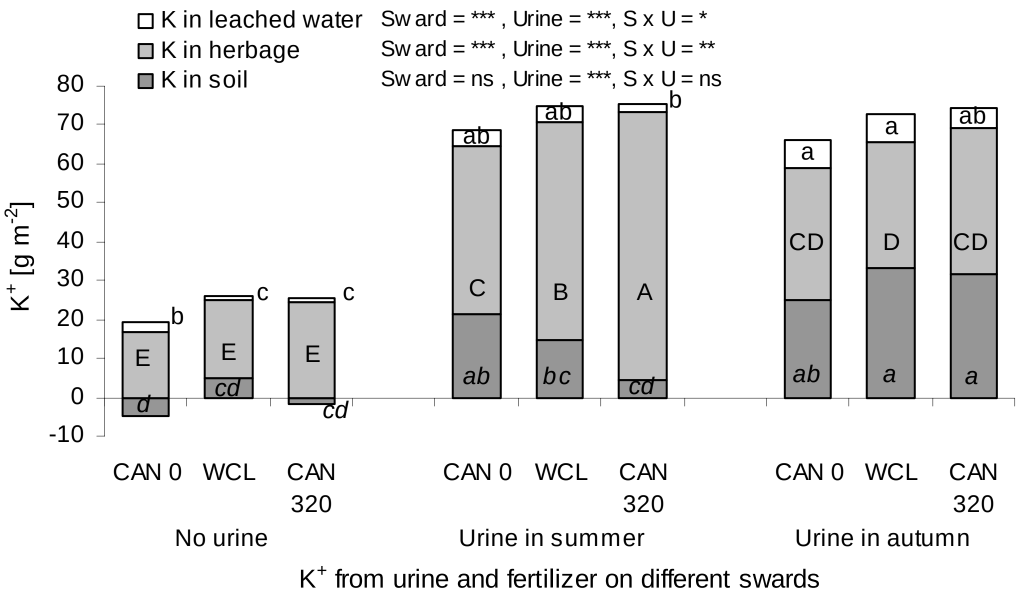

Figure 1. The retention of K^+ from fertiliser (16.6 g K^+ m^{-2}) and urine (74 g K^+ m^{-2} and 60 g N m^{-2}) in herbage, in the exchangeable K^+ fraction of the soil (as the difference between the amount at the start and end of the experiment), and in water leached from mini-lysimeters at a depth of 42 cm. Urine was applied to grass swards with no N input (CAN 0) or fertilised with 32 g N m^{-2} (CAN 320) and to a grass-clover sward (WCL) with no N fertilisation. Values with different letters among treatments are significantly different at the $P < 0.05$ level.

Plants and soil constitute the main sinks for K^+ and apparent recoveries amounted to 75 % of K^+ applied in the urine. The K^+ not accounted for may be retained in non-exchangeable fractions in the soil, in stubble and roots. While K^+ recovery in plant material was higher from a urine application in summer, higher retention in soil of K^+ from an application in autumn partly compensated for the reduced plant uptake. Leaching during the winter period was therefore higher from an autumn application compared to the urine input in summer. Translocation of K^+ and other cations is generally dependent on corresponding anion leaching, K^+ input, and level of exchangeable K^+ in the soil. K^+ is the major cation in urine, but usually not the major cation leached (Haynes and Williams, 1993). Leaching of Ca^{2+} and Mg^{2+} was accelerated under mini-lysimeters with urine input (data not shown). As uptake of Ca^{2+} and Mg^{2+} by plants is impeded by high K^+ concentrations in plant and soil at urine patches, this may have implications for animal nutrition and health status. Urine patches can cover up to 24 % (at 700 cow-days ha^{-1}) of the pasture and the area affected may be up to double that size (Whitehead, 1995). In grazing management, in addition to date of grazing and fertiliser input, stocking rate is the main factor which directly determines the amount of K^+ returned to the sward and the intensity of K^+ cycling against the background of a certain soil status.

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Optimising best practice for N management in livestock systems: meeting production and environmental targets

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Abstract

Opportunities still exist to improve the utilisation of nitrogen (N) within grassland systems and reduce its transfer to water and the atmosphere in forms which may pollute under both UK and Swiss conditions. On farm information is being used to define current conditions and effectiveness of N use by farmers. This, with the ever increasing understanding of the complex N cycle in dairy systems from experimental studies, is providing opportunities to improve N use and maintain production at acceptable levels. This paper discusses the situation under both UK conditions and the range of circumstances which exists in Swiss agriculture and identifies some solutions for current issues, but also notes potential problems such as that of 'pollution swapping' which may be generated in the future.

Keywords: nitrogen flows, dairy farms, optimisation, pollution, nitrogen cycling

1 Introduction

Much research has been conducted on aspects of nitrogen (N) management in grassland / forage based livestock systems with much synthesis of information and conceptualisation of new approaches to N management. Nevertheless, there are still major concerns relating to effective N use within livestock systems, the controls that should be imposed to meet specific demands to reduce various emissions of N species and the need to define opportunities to achieve optimised efficiencies. There are also still unknowns about some components of the fate of N, especially those concerned with rates of internal supply / release and turnover from, and accumulation in, organic materials. For much of this complex cycle within grassland farms, it will not be possible to make large changes, but as other previous reviews have noted (Jarvis and Aarts, 2000), options to improve efficiency in different sectors of the system have been identified to a certain extent (Table 1). Table 1 indicates that there is still opportunity to improve efficiency from what is currently achieved in practice to that technically attainable.

Table 1. Efficiencies (%) of N use in intensive dairy farms in the Netherlands on sandy soil: (a) technically attainable and (b) average achieved by skilled farmers (Jarvis and Aarts, 2000).

Component	Technically attainable	Average achieved
Soil: transfer from soil to harvestable crop	77	53
Crop: transfer from harvested crop to feed intake	86	71
Animal: conversion from feed to milk meat	25	18
Slurry / dung+ urine: transfer from excreta to soil	93	80
Whole farm: from inputs to outputs	36	16

Despite the continued flow of information and the contingent improved understanding (viz. Hatch *et al*., 2004), there are still pressures to change attitudes to the management of N within farming systems to improve N use and reduce transfer to the wider environment. Legislation is in place in relation to the NO_3^- directive within EU countries, although this is complied with, and reacted to, to different extents and in different ways (de Clercq *et al.*, 2001). Whilst this will, over time, have an impact on water quality with respect to NO_3^-, one of the consequences of this is that the pressures upon other parts of the N cycle will change and may require alternative actions. As other environmental issues relating to N (NH_3, N_2O, etc.) pollution become more immediate, comparable pressure points on the N cycle will become more apparent with a further set of demands as illustrated later.

Although the basic processes involved in the cycle and their impact remain the same, and although the means of estimating and predicting N requirements, losses and impacts has improved substantially, some new requirements and concerns have developed over recent years which can be summarised as follows: i) a need for an appreciation of the 'bigger picture' with full life cycle analyses which incorporate components of the cycle before and after entry and exit from the farm gate; ii) a requirement for practical indicators to assess N use, efficiency and pollution, especially those incorporating some element of economic assessment and which are based on sound mechanistic understanding of the basic process(es) involved (this can only be done with the availability of good baseline information of what currently occurs on farms); iii) an appreciation of the problem of pollution swapping, i.e., defining the circumstances in which the mitigation of one problem generates another; iv) an improved definition of the relationships between events and effects at different scales and how these can be incorporated into practical predictive tools and decision support systems to be operated for a range of requirements; v) the need to define the relationship between N management and impact on water quality with respect to the requirements of the Water Framework Directive (EU, 2000), i.e., not just with respect to NO_3^- but also to NH_4^- and NO_2^- as well as other, non-N issues; and vi) a need to refine knowledge and predictive capability for those parts of the cycle which are poorly quantified e.g., the rates of supply of N from organic materials. In this paper we examine some of the opportunities and possibilities to improve the utilisation of N and reducing its emission to the wider environment from systems based on dairying and compare effects under typical English and Swiss conditions.

2 Changes in dairy farm structure influencing N requirements and use

UK: Agriculture is practised on 75 % of the total UK land area (24 million ha; Scholefield, 2001) and contributes 1.4 % of Gross Domestic Product. Most livestock production is concentrated in the wetter, western half of England (which has the largest proportion of the total British dairy herd), with most cows in the SW peninsular and counties in the NW. This distribution reflects a combination of climate and geography allowing production of large amounts of dry matter for intensive high yielding cows. This distribution is also important with respect to the local, national and international impact of emissions to waters and the atmosphere. There have been significant changes in dairy farm structure over recent decades.

Table 2. Changes in dairy herd numbers and size between 1995 and 2000 in England and Wales (Defra, 2003).

Herd size	Numbers of holdings (,000)		Numbers of livestock (,000)	
	1995	2000	1995	2000
1 – 49	17.4	12.8	468	316
50 – 99	13.7	11.0	673	793
> 100	7.8	8.0	1159	1226
Average herd size	66.8	73.3	-	-
% of herd with > 100 cows	-	-	44.6	52.5

Over the short period of 1995-2000 (Table 2), dairy farm holding numbers decreased by *ca.* 20 % (this trend has continued in the following years). However, cow numbers have remained more or less constant, but those in herds of < 100 have decreased by 23 % and those in herds of > 100 cows have increased by 6 %. This illustrates an apparent trend for polarisation (i.e., bigger, intensive units on the one hand and a smaller number of specialist units on the other) which has implications for both production and the associated pollution potential. Milk yields per cow have continued to rise with consequences for the whole infra-structure of dairy farms (Table 3). These changes will have major impact on the dispersion of nutrients, greenhouse gases and other materials which affect the environment from both local and national / international perspectives: effects with N contribute significantly to this.

Table 3. Changes in farm characteristics between 1996/7 and 2001/2 (Defra, 2003) in a sample of dairy units in England.

	1996/7	2001/2
Sample size (numbers of farms)	423	364
Average farm size (ha)	78	71
Livestock numbers:		
dairy cows	83	76
total livestock units	133	122
Annual labour units	2.7	2.3
Inputs (£,000)		
Total	130.4	100.1
of which – feed	34.7	25.1
fertilisers	7.6	4.2
labour	18.0	13.6
Total outputs (£,000)	160.5	110.9
Net farm income (£,000)	30.1	10.8

Switzerland: Agriculture occupies *ca*. 26 % of the total Swiss land area of 4.1 million ha and another 13 % is used as mountain pastures during summer (BFS, 2002a, b). Agriculture and forestry contribute *ca.* 1.2 % of the GDP. Farms at an altitude of 350 to *ca*. 1400 m above sea level operate all year round. Cattle and dairy production occur over the whole country with

Table 4. Typical structure of Swiss dairy farms (derived from BFS, 2002a).

Region	Total	Valley zone	Hill zone	Mountain zone
Agricultural surface (ha)	17.0	19.2	15.8	15.9
Grassland (ha)	13.4	11.5	13.3	15.4
% sown grassland	16.2	32.6	19.9	2.8
Silage maize (ha)	0.58	1.18	0.44	0.04
LU ha^{-1} forage surface [1,2]	1.60	2.04	1.55	1.18
Cattle LU [1]	19.1	21.9	19.2	15.9
Dairy cows	14.7	17.9	14.7	1.3
Milk yield (kg cow^{-1}) [3]	6000	6300	5900	5500
Mineral fertiliser N (kg ha^{-1}) [3,4]	47	67	43	20
Concentrates (kg cow^{-1} day^{-1}) [3]	1.1	1.1	1.1	1.1

[1] LU = Swiss livestock unit: equivalent to N and P excretion of a dairy cow yielding 5000 kg
[2] Forage surface = grassland plus silage maize
[3] Data from representative survey (November 2002; described by Reidy *et al*., 2004)
[4] Average use on the total agricultural surface including arable crops

43 % in the valleys, *ca.* 30 % in the hills and < 25 % in the mountains. Swiss farms are relatively small and not specialised: 76 % of all farms (including horticulture and viticulture) have livestock (Table 4). After continuous previous growth, the average size of farms with cows was 17.0 ha in 2000. Of farms with cattle, 44 % also have pigs (49, 51 and 31 % for valleys, hills and mountains, respectively) and 44 % also have at least 10 % of the total agricultural surface for non-roughage crops especially in valley and hill zones. Over 50 % of

dairy farms have < 20 cows; only 3 % of the dairy farms have > 50 cows. Between 1996 and 2001, the number of cows decreased by 6 % and the number of dairy farmers by 15 %. Greater changes in farm structures, especially in size, are expected over the next 10 years.

3 Nitrogen balances on dairy farms

UK: There are only limited published data on nutrient use and utilisation for UK dairy farms. A simple survey of N use amongst some 110 dairy farms in the UK demonstrated some wide ranges in the use of N fertiliser with consequences for the on-farm N surpluses. Surplus is a key indicator not only because it is directly related to input (Jarvis, 1999), but also directly to measured or modelled N losses (Jarvis and Aarts, 2000). When the wide range in the use of N was expressed in relation to the unit of production (milk), i.e., litres produced per unit of N applied, to provide an indicator of effectiveness of utilisation for production, there was also a very wide range (a 13 fold difference from 6.5 to 84.6 l milk kg^{-1} N fertiliser applied) indicating some major differences in effectiveness of nutrient management (Jarvis, 1999).

Another recent, more detailed analysis of N use and losses on six typical dairy farms in SW England (Cuttle, 2002) has been made. The farms had 59-95 ha with stocking rates of 2.0-2.3 LU ha^{-1}, milk outputs of 5790-6420 l cow^{-1} (Table 5) and > 75 % of their area under grass. Activity data were collected so that N inputs, outputs and flows into, within and from the farms could be calculated (Cuttle, 2002): losses were estimated with models and emission factors. A surprising feature was the wide range in N use and efficiency that occurred in apparently similar farms resulting in substantial surpluses of N: total N inputs ranged from 290-416 kg N ha^{-1}, of which 12-19 % was recovered in milk and livestock sales, with N surpluses of 234-367 kg ha^{-1} (Table 5). When surplus was expressed per unit of production, there was a 1.5-fold difference between upper and lower rates, demonstrating substantial differences in the potential to pollute per unit of production on apparently similar farms.

Table 5. Characteristics and N statistics for 6 dairy farms in SW England (Cuttle, 2002).

	range	mean
Farm size (ha)	59 - 95	84
Number cows	88 - 155	124
Milk yield (l cow^{-1})	5790 - 6420	6071
Overall stocking rate (livestock units ha^{-1})	2.04 - 2.30	2.15
Fertiliser N (kg N ha^{-1})	182 - 302	256
Recoveries in milk and livestock (%)	12 - 19	16
Surplus kg (N ha^{-1})	234 - 367	316
Surplus N (kg N 1000 l^{-1} milk)	29 - 44	36

Switzerland: Nutrient use has always been strongly orientated towards manures with 100 % of the manure used in agriculture and account being taken, at least partially, of nutrient content. For P, the proportion supplied of the total used in crop and grassland production from manure increased from 71 to > 77 % between 1990 and 2000. For N, the proportion used as manure is similar but difficult to quantify because of losses and organic N content. Between 1990 and 2000 N in livestock excreta decreased by *ca.* 12 % mainly because of a decrease in animal numbers, and mineral fertiliser N by 15 %. The decrease in fertiliser N, in spite of decreasing manure nutrients, resulted from a 1993 policy with direct payments to farmers making 'special ecological contributions'; > 90 % of farms participate in this voluntary programme. Farmers must comply with *ca.* 40 criteria including N and P balances based on recommended crop nutrient requirements with inputs in manure (according to guide values for excretion) and fertiliser. While 100% of P excretion is taken into account, unavoidable N losses in houses and during manure storage of 15-30 % and an availability of 60 % of the remaining N on grassland and 50 % on arable crops are assumed. Calculated inputs must not exceed recommended requirements by more than 10 %. Typical recommendations are 12 kg N t^{-1} dry matter (DM) for intensively managed grass, 6 and 0 kg N t^{-1} DM for medium intensive and extensive grassland and 110 kg N for silage maize, which is less than in many other European countries. The corresponding N uptake by the harvested crop is *ca.* 18-30 kg N t^{-1} DM for grassland with DM yield of up to 12 t ha^{-1} under favourable conditions and 200 kg N for silage maize. The relatively low rates recommended are because clover is usually present. For permanent grassland (84 % of total grassland, excluding alpine pastures), clover is typically 5-20 % of DM, and for sown grassland it is 20-50 %. Average N-fixation in the Swiss lowlands is estimated to be 59 kg N ha^{-1} (Boller and Nösberger, 1987).

As a consequence of the restrictions on nutrient balances, large surpluses are rare. The new policy has clearly sharpened the farmer's attitude towards nutrient cycles. Many farms now use even fewer nutrients than those permitted and fears of reduced yields were not confirmed. A recent representative survey showed that, on average, dairy farms use 47 kg ha^{-1} mineral fertiliser N, with a range of 0-196 kg ha^{-1} (Table 4, Reidy *et al.*, 2004). The rate decreases with altitude because of the lower yield. As well as the relatively low mineral N fertiliser use, inputs in concentrate feeds are also relatively low (average 400–500 kg cow^{-1} y^{-1}). At 112 kg ha^{-1}, the N surplus is considerably lower than in the UK and the utilisation efficiency (% of N inputs utilised in product see table 8, later) is in the same range as that (28 %) reported for Swiss farms by Thomet and Pitt (1997) (nearly twice that in the UK) and reaches values close to those reported as technically attainable for the Netherlands (Table 1).

4 Optimising nitrogen flows within and minimising losses from dairy farms

UK: There have been few detailed analyses of the internal recycling within, and flows of nutrients from, farms. Nitrogen losses were estimated for the six SW farms noted earlier by using modelling approaches (Table 6) and these ranged from 131-187 kg N ha^{-1} on a whole farm basis and represented the equivalent of between 55-75 (mean 66) % of the N fertiliser input, i.e., in line with other data for the UK and elsewhere. A number of options to change managements to reduce losses were considered which followed those proposed by Jarvis *et al.* (1996) as follows: A) improved slurry / fertiliser use, B) incorporation of forage maize, C) incorporation of clover based swards and with forage maize and D) combining (A) and (B) (Cuttle, 2002). This analysis clearly suggested that there are practical opportunities to reduce N losses and, on average, for all the farms it should be possible to reduce overall losses from

Table 6. N farm budgets for the alternative managements (averaged for 6 SW England dairy farms) kg N ha^{-1} over whole farm (Cuttle, 2002).

	Current	A	B	C	D
Total inputs (fertiliser)	366 (261)	288 (182)	329 (224)	182 (4)	271 (166)
Total outputs	59	59	58	53	58
N surplus	307	228	271	129	213
Efficiency (%)	16	21	18	29	22
Total estimated loss	170	102	160	64	105

A: improved slurry/fertiliser utilisation. B: incorporation of forage maize.
C: clover based swards with forage maize. D: combining A and B.

170 to between 64 and 160 kg N ha^{-1} depending upon the strategy taken. Surplus N decreased from, on average for all farms, 316 to 129-271 kg N ha^{-1} and overall efficiency increased from, on average, 16 to 18-29 %. The switch to clover was the most effective in terms of efficiency but reduced productivity. An analysis of effects on financial performances of the six farms (Cuttle and Turner, 2003) (Table 7) indicated that effects depended upon current

management and ranged from a reduction to an increase in financial margin. The desk study approach using farm information has a number of important functions: it i) raises awareness of real circumstances and issues, ii) expands a low base of knowledge of operational activities and decision making patterns on farms and iii) demonstrates real opportunities to make improvement with an assessment of economic impact. There is little comparable information for other nutrients in the UK which can be used for similar modelling purposes.

Table 7. Effect of alternative management on total N loss and financial performance of six farms in SW England (% change from the existing management)[1] (Cuttle and Turner, 2003).

Management	Total N loss (% change)		Financial margin[2] (% change)	
	range	mean	range	mean
A: improved slurry/fertilisers	-29 to -48	-39	-3 to -8	-6
B: maize forage	-3 to -8	-6	+2 to +11	+5
C: clover and maize	-28 to -54	-42	-4 to +26	+6
D: combining A and B	-29 to -45	-38	-4 to +11	+2

[1] based on 2002 costs and prices; [2]excludes capital costs

Studies by ADAS on experimental dairy systems incorporated combinations of management strategies to reduce emissions of N and P (Peel *et al*., 1997) on a site over a chalk aquifer with average winter drainage where leaching should be < 30 kg N ha^{-1} to meet the Nitrates Directive limit.

Table 8. Inputs, surplus and efficiency of N use in whole farm dairy systems at ADAS Bridgets (UK) 1994-2001[1], an average Swiss dairy and experimental dairy herds[2].

	UK			Switzerland	
	ADAS System 1 All grass 19 ha	ADAS System A Grass/Maize 19 ha	ADAS System C Grass/Maize 21 ha	Average dairy farms valley zone[2] 20 ha	Dairy herd Waldhof[2] 6.1 ha
N inputs (kg ha^{-1})					
Feed	106	90	85	22	20
Fertiliser	321	195	154	61	118
Atmospheric deposition	30	30	30	85	84
Total input	*427*	*315*	*269*	*168*	*223*
Total outputs (milk and meat) (kg ha^{-1})	*68*	*64*	*63*	*55*	*103*
Surplus (kg ha^{-1})	359	251	206	112	120
Utilisation (%)	15.9	20.3	23.4	32.9	46.3
l milk kg^{-1} N applied	20.5	32.7	42.6	133.1	137.8
Surplus (kg N 1000 l^{-1} milk)	54.6	39.3	31.4	13.9	7.4
N losses (kg ha^{-1})					
Nitrate leaching	45	16	10	-	-
Ammonia loss	NA[3]	19	13	-	-

[1] Source: adapted from Peel *et al.*, 1997 and Withers *et al.*, 2003 (dairy system 1 = conventional, grass based; system A = incorporation of maize silage + tactical fertiliser: system C = grass/maize, reduced intensity).
[2] Model dairy farm without arable crops and pigs; based on average values for valley zone (statistics: BFS, 2002a; representative survey, methodology described by Reidy *et al.*, 2004); [3] data not available.

System performance and nutrient flows within each system were carefully monitored, nutrient balances constructed and N and P losses measured or modelled. The combinations of measures adopted in the improved grass / maize systems (Table 8: A and C) reduced N surpluses compared with the conventional all-grass system, with corresponding improvements in indicators of efficiency. Losses by volatilisation and leaching were reduced to within EC limits without detriment to either forage or milk production (Table 8). Large reductions in fertiliser N were possible by taking account of N in manure, soil N supply and sward age. In ancillary studies, slurry provided all the nutrients required for optimum yield of maize. With rapid incorporation of slurry in spring before sowing maize, and using a trailing shoe applicator for applications to grassland, there was a 60 % reduction in NH_3 losses compared with broadcast applications. However, the improved systems A and C required a higher level of technical awareness and management skill than the conventional system (1). Furthermore, C was 10 % less profitable than A. Most of the extra costs were for storage but other techniques could be employed on commercial farms at nil or low relative cost.

Switzerland: In spite of a low N surplus and high N use efficiency, information from an experimental low-input herd shows that, under optimal conditions and good management, results can still be improved (Table 8). Compared with the average for dairy farms in the valleys, inputs on this farm were one third higher and outputs were approximately double. With the same N surplus ha^{-1}, this herd had a N efficiency of *ca*. 46 % (n.b. much of this difference results from exclusion of heifers in the calculations). Radical changes in dairy farming are difficult to achieve in Switzerland because i) of the strong dependence on farm-grown DM, ii) farms that sell their milk for cheese production (nearly 50 % the total milk produced) are not allowed to use silage and ii) farm structure and the financial situation strongly limit the potential for new buildings. The most promising future systems are i) a low input strategy with early spring calving and full grazing during summer and ii) a high yield strategy. The choice of option strongly depends on farm size, investment potential and milk marketing possibilities. Each of the two strategies was optimised on nine pilot valley and hill zone farms during 2000-2003 and both showed promising results and a considerable potential for improving the economic situation. Using a score card approach, the potential to reduce milk production costs between 2000 and 2010 was estimated at 40 % for the low-input farms and 46 % for the high yield farms (Durgiai and Mueller, 2004). For N, the two strategies mainly differed in inputs in concentrate which was 1.3 kg and 4.7 kg 1000 kg^{-1} of milk for the low-input strategy (9 values; range 0-2.8) and the high yield strategy (5 values; range 2.6-6.9), respectively. Fertiliser N use was 50 kg N ha^{-1} for the low input strategy and 65 kg N ha^{-1} for the high yield strategy. A full N balance is not possible because feed inputs for other livestock are not available, but estimates show that the high yield strategy farms have an advantage in N use efficiency. For mountain farms, both strategies are difficult to implement in a consistent way because of the short growth period and no possibility of using silage maize and other arable crops in the ration. With the low N surplus it can be assumed that NH_3 volatilisation is easier to reduce than leaching or denitrification losses. Because of the strict limits on N use, farmers understand the need to reduce volatilisation. Detailed estimates of the technically attainable and the feasible NH_3 abatement potential have been made (e.g., Menzi *et al.*, 1997). Model calculations show that the maximum technically achievable abatement potential could be as high as 60 % for valley farms and only about 30 % for mountain farms. Furthermore, the difference between the technically achievable and the reasonable abatement potential are of relatively higher importance for mountain farms. These differences result from low applicability of low emission spreading techniques (topography, no arable crops, short growth period). In absolute terms, the abatement potential for valley farms mentioned above would be equivalent to approximately 40 kg N ha^{-1}. The effect of such an abatement on the N use efficiency will depend on the effect this has on production and total N input and will only increase if N input is reduced without changing production or production is increased with the same N input. On average, for valley zone dairy farms given in table 8, the N use efficiency could be improved from 33 % to *ca*. 43% and 37 % for the low input and high yield strategies noted above, respectively.

5 Manure management

One of the key issues relating to improved N efficiency is understanding the contribution and effectiveness of use of supplies from manures and slurries. Manures are variable materials, with variable N supply rate patterns of which there is still only a limited appreciation and knowledge. Typically, each adult dairy cow generates *ca*. 60 kg of dung and urine per day; therefore during the housing period large quantities of slurry and solid manures are produced.

UK: UK dairy cow manure totals 30 million t y^{-1}, with those operating on straw-bedded and slurry-based systems estimated to contribute 34 % and 66 %, respectively, of this (Smith *et al*., 2001). Large volumes of dirty water (6-167 l cow d^{-1}) (Cumby *et al*., 1999) are generated in wash-waters from milking parlours, collection and other yard areas receiving rainfall. Increased farmer confidence in, and knowledge of, manure N content is essential in changing attitudes from manure disposal to one of nutrient management. At worst, farmers are encouraged to use average values for nutrients published in handbooks (e.g., HMSO, 2000). An improvement would be to persuade farmers to submit representative samples for analysis to help overcome variation in nutrient contents and avoid under-application and poor crop response or over-application and risk of transfer of N to air and water courses. Meters are available for estimating the plant available N content of manures and can be used on sub-samples of slurry prior to application: these tests take approximately 10 minutes to complete and are accurate and reliable at estimating NH_4^+-N contents of slurries (Williams *et al*., 1999). Hydrometers can be used because there is a good relationship between dry matter and nutrient contents and significant progress has also been made in quantifying nutrient contents in-line on slurry tankers. Knowledge of the total N content is only part of the requirement to match nutrient application to crop demand as only a proportion of that contained in manure is readily available to plants. For example, up to 90 % of the total N in cattle solid farmyard manure may be in the organic form and must be mineralised before it is available to plants (Chadwick *et al*., 2000). Chadwick *et al.* (2000) found that only 2 % of the organic N in one dairy slurry was mineralised within 199 days of application, whereas 19 % was mineralised from another. N availability was related to C: organic N ratios, which were 10 and 15, respectively. Generally, organic materials with a ratio > 15 will immobilise N, and those with ratios < 15 will release N. Some information on N supply from manures is made available to farmers in tables (HMSO, 2000). Increasingly, PC based decision support systems will be required to provide advice to farmers on the best time of year to apply manures to gain maximum utilisation of manure nutrients: one example of these is MANNER (Chambers *et al*., 1999).

Switzerland: *Ca*. 70 % of dairy cattle excreta are collected as slurry or liquid fraction manure. Solid manures are produced mostly in traditional farms, collected daily and stored in stacks outside tied housing buildings. Slurry is usually diluted with *ca.* 1 part excreta to 1 part wastewater from washing, uncovered surfaces draining into the slurry pit and sometimes household wastewater. Farms must have slurry storage capacity for at least 4-6 months to avoid application outside the growth period: *ca.* 80 % of slurry is stored in closed pits. Most of the slurry and liquid fraction manure is used on grassland in regular applications from early spring to autumn. Farmers are encouraged to use guide values rather than analyses because of difficulties in representative sampling, variable composition of manure and time lags between sampling and receiving reliable results. Guide values exist for nutrients in livestock excreta, amounts and composition of undiluted slurry and stored solid manure, waste water production, N availability, etc. (Walther *et al*., 2001; Menzi and Besson, 1997). Since the more or less mandatory requirement for nutrient balances, farm numbers using detailed fertiliser plans have decreased but awareness by farmers of good manure and nutrient management has increased. The new policy has achieved more than the previous decades of intensive extension work. Financial support to Swiss agriculture is one of the highest in the world, and this approach cannot be transferred directly to other countries, but any incentive approach based on strict nutrient balances might be considered to be promising in other circumstances.

6 The Nitrogen 'problem'

Nitrogen flows in agriculture are complex and difficult to control because the cycle is not a 'tight', closed system and has many opportunities for the escape of various forms of N at various stages. The whole cycle can be considered as a cascade (Galloway *et al*., 2003) with leakage of N throughout the complex series of transformation / transfer processes that regulate the fluxes of N until reactive N is eventually converted back to N_2. Figure 1 illustrates this effect with a dairy farming system at its centre and shows that the overall farm N cycle cannot be separated from other cycles at other scales, both larger and smaller. Indeed, contained within each of those in figure. 1 are other cycles, for example in the soil biomass within the soil cycle, in plants (and their component parts) at the field scale, within manures within the farm etc. Nitrogen can be incorporated in, on the one hand, and released from, on the other, stabilised (usually organic) forms at many stages of this cascade, usually with a change in N form which is more mobile and has potential for loss. At some stages there are mechanisms for recapture but there are some significant inefficiencies in utilisation at various stages in the overall system for which there is little room to improve (Table 1).

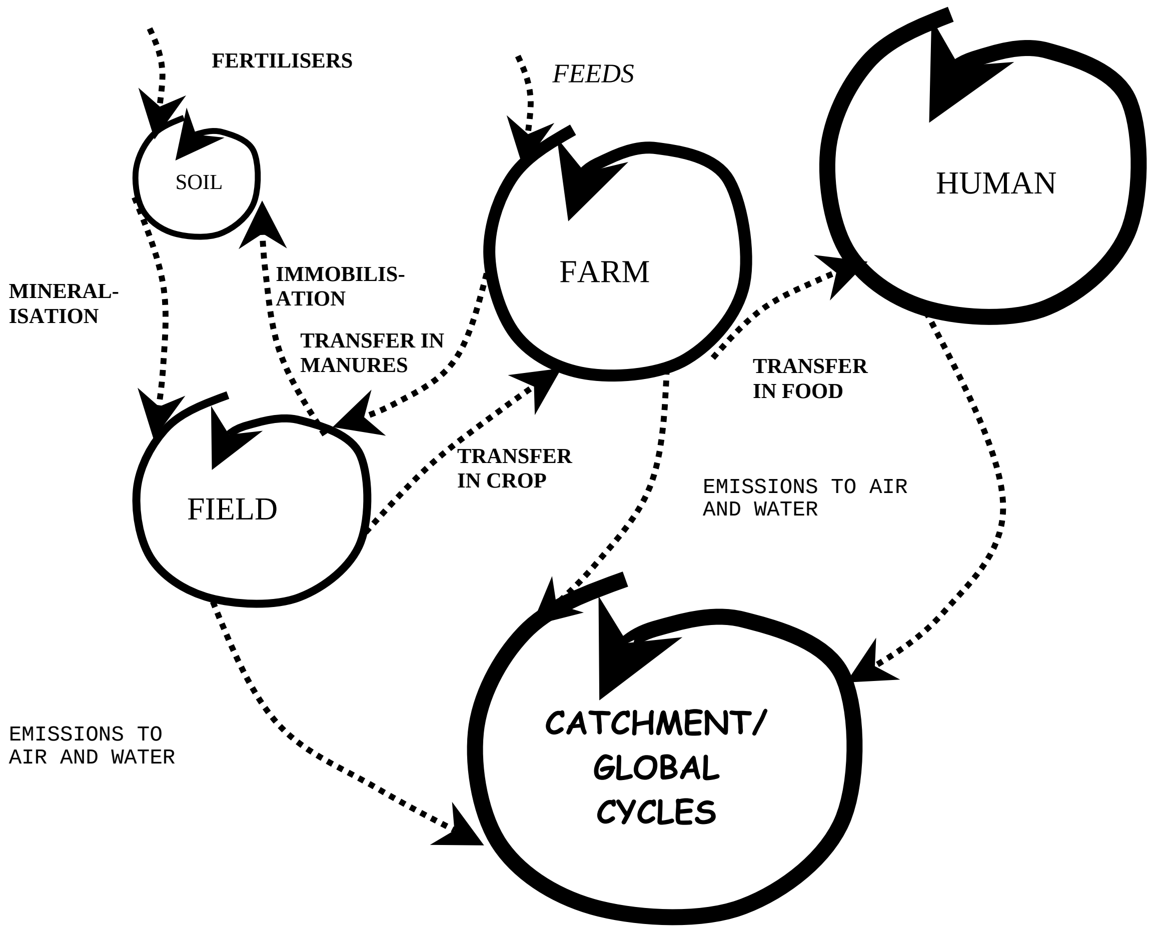

Figure 1. Nitrogen cycle cascades from livestock farms and component parts to global scales.

There are requirements and pressures to reduce and control losses from many points of view. Agricultural livestock and their excreta are important sources of N compounds (e.g., NH_3, and N_2O), as well as of methane and odours. There is increasing pressure for agriculture to reduce NH_3 emissions and changes in manure management could make a large contribution to the reduction required. Agriculture accounts for *ca.* 80 % of UK's and 90 % of Swiss emissions of NH_3 (currently estimated at 320,000 and 48,000 t), most of the remainder originating from wild animals and combustion processes (Defra, 2002). Emissions occur from grazing, housing, storage and treatment of all manures and their application to land. Inorganic N fertilisers, especially urea, are also a small source. The potential for NH_3 loss is greater from slurry than from FYM, and more cattle are housed on slurry systems than on straw-based FYM systems: slurry from cattle is therefore a major source. There are a number of options which can be used to reduce NH_3 losses but there is increasing evidence that measures taken to do this, e.g., by shallow injection, may increase losses of N_2O. Shallow injection decreased NH_3 emissions of the NH_4^+-N applied in slurry from 72 % (surface spreading) to 11 % (Chadwick, unpublished), but increased N_2O emissions from 2.8 % (surface spreading) of the NH_4^+-N applied to 10.2 %. The extent to which pollution swapping occurs is being assessed in a number of new studies.

7 Conclusions

Summary: The current understanding of N cycling in livestock systems can be summarised as follows. i) The key transformation processes are linked closely to the C cycle at all stages of the production system, ii) Rates of transformations and any subsequent transfers are determined by the intensity of input, i.e., the greater the N input, the faster the cycling and transfer and rate of loss, iii) Surplus N at the farm scale provides a key indicator for the potential for loss and improvement of efficiency and iv) Different efficiencies within different parts of the system control the flow and loss potential at each stage and the overall farm efficiency: some components of which have greater potential for improvement than others.

Research requirements: Our understanding of the way that N is utilised or lost at the larger, farm scale has increased substantially and there will be continuing demand for knowledge at this level. However, a number of research challenges still exist in order to optimise the sustainable use of grassland based systems from all perspectives: some of these challenges may be listed as follows. i) One of the current problems is how to determine the relationships between information obtained at different scales and how this may be utilised to optimise practical options at all phases of the system for a range of different requirements (see figure 2). Research is required to be able to extrapolate and interpolate information at different and relevant scales. ii) There are loopholes in many parts of livestock systems which present opportunities for loss throughout the whole production cycle. In particular, those associated with manure production and utilisation still present many problems. iii) Many options for improving efficiency have been suggested but the possibilities for 'pollution swapping' must be taken into account with any imposed changes in management: research which takes a life cycle approach is required to provide this information. iv) Many models of N cycling exist, but these must be linked with economic models in order to develop practical diagnostic tools for both policy makers and land mangers. v) Current drivers for information and change in practice will demand that tools are available to operate at different scales including those which are bigger than the farm *viz*. river basins for the objectives of the Water Frame Directive (EU, 2000).

Scale	Requirements	Deliverables and Diagnostics	Drivers and controls
A Soil 'micro'	: process understanding : mechanisms : model building	: biomass activities and outputs : location, rates, amounts and forms of N released	**A** **B** **C** **D** **E** **A** :texture :pore/micro structure ***CRUMB***
B Soil 'macro' (profile/ patch)	: process effects : loss process controls : soil quality : soil function	: amount and forms of N : rates of loss to the environment : rates of supply to plants : N budget (soil surface)	:agronomy :soil variability :drainage :hydrology ***SOIL BLOCK***
C Product-ion unit	: production potential : crop yield/quality : environmental impact/: sustainability	: crop yield responses : N exports to water and air : export of N in product : economic returns	:agronomy :crop rotation :local conditions :operator skills ***FIELD***
D Farming system	: economic return/stability : sustainable resource : minimal pollution	: economic returns : indicators : N budgets	:economic drivers :environmental legislation :management skills :knowledge transfer ***FARM***
E Region	: rural sustainability : environmental quality : soil/water/air	: 'clean' water and air : biodiverse systems : viable enterprises	: legislation : integration of activities : life cycle understanding : integration of knowledge ***CATCHMENT***

Figure 2. Scalar requirements for N understanding within dairy farming systems and beyond (modified from Jarvis, 1995).

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Challenges and tools to develop efficient dairy systems based on grazing: how to meet animal performance and grazing management

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Abstract

Utilisation of grazed grass should form the basis of sustainable dairying systems in the future. Grazed grass is the cheapest feed available for dairy cows and may also help to reduce the environmental impact of the most intensive systems while giving a natural image of farming. Efficient exploitation of grass by grazing will require the development of grazing systems designed to maximise daily herbage intake per cow while maintaining a greater quantity of high quality pasture over the grazing season. This paper discusses conditions for efficient exploitation of grass and outlines possibilities for future advances. There are opportunities to consume more grass by extending the grazing season in early spring and late autumn or by intentionally deferring grazing from a period of grass surplus in spring to a period of grass shortage in summer. The introduction of legumes in grass-based swards should also be seriously considered as an alternative option to pure grass swards to maximise cow performance. There are also opportunities to manage seasonal production of grass by plant selection, improved N fertilisation strategies and better grazing management. The opportunity to increase cow performance by decreasing stocking rates is rather limited because this practise is constrained by the necessity to maintain high quality swards over the grazing season, unless alternative strategies are adopted. Increasing leaf blades mass at the base of the sward by appropriate grazing management in early spring may play a major role in increasing herbage intake. This will result in a low residual sward height thus making grazing management easier. This requires a greater knowledge of the carryover effects of early season grazing management on mid-season pasture quality and the implication for milk output per hectare. In the future, development of reliable decision support methods and tools for short term rationing of grass at paddock level and long term budgeting of grass at farm level will give farmers more confidence in grazing and will undoubtedly contribute to optimising the proportion of grazed grass in the annual diet of the dairy cow.

1 Introduction

High milk price has encouraged dairying systems with high inputs of chemical fertilisers, concentrate feeds and mechanised methods for silage production at the expense of grazing. These were largely reinforced by the convenience of managing dairy herds indoors particularly with cows calving in autumn and fed with maize silage and by the inability of grazing to maximise individual milk yield. Thus, use of grazing for milk production has considerably decreased over the last 30 years (Bourgeois, 2002). The introduction of GATT reforms and the current changes in EU agricultural policy (mid term review) will decrease the level of protection enjoyed by EU countries especially for milk which is subjected to a production control system. This will enhance the necessity to improve the efficiency per litre of milk. At the same time, progress must be made in reducing the harmful negative impacts on the environment and on natural resources resulting from inappropriate management practices in dairy farming. The common agricultural policy (conditionality of direct payments, green box) and the introduction of new agri-environmental measures in the future will define new priorities for land use and environmental performances and will encourage better management of inputs to develop more environmentally friendly dairying systems.

Utilisation of grassland by grazing should form the basis of sustainable dairying systems in the future. Efficient exploitation of grass by grazing with limited inputs of supplementary feeds and fertilisers will require development of grazing systems designed to maximise daily herbage intake per cow while maintaining high quality and quantity of the sward over the grazing season. This also requires a reliable decision support systems as simple as possible to assist dairy farmers to organize the feeding program of the herd in time and space from an unstable feed resource. Such tools and methods will increase farmer reliance in grazed grass and will contribute to optimise proportion of grazed grass in the annual diet of the dairy cows. The aim of this paper is to discuss conditions for efficient dairy systems based on grazing and outlines possibilities for future advances. The paper directs attention to recent advances upon i) the opportunity to better fed highly productive cows and rationalize feeding practises at grazing, ii) the effects of grazing practices upon overall performances per animal and per unit area during the grazing season, iii) new decision support tools and methods to help farmers making decisions at the paddock level – mainly for feeding decisions – and at the system level for management decisions.

2 Cow and grass or how to increase grass intake and individual cow performance?

2.1 Herbage intake increases with the animal demand

Higher producing cows have a greater nutrient demand and this is reflected in increased grass intake. Because actual milk yield (aMY) is an output variable, Peyraud *et al.* (1996) proposed to use potential milk yield for predicting daily herbage intake (DHI). The cow potential is expressed by milk yield at peak (PMY) or expected milk yield (eMY) which take account of the time elapsed between the peak (assumed to be the sixth week of lactation) and the period of grazing that assumes a weekly persistence of 0.985 (eMY = PMY x $0.985^{(WIM-6)}$ with WIM is week in milk). From a series of experiments conducted in May and June with autumn calving cows the incremental increase of DHI averages 180 g kg^{-1} PMY or 250 g kg^{-1} eMY (Peyraud *et al.*, 1996; Delagarde *et al.*, 2001b). Kennedy *et al.*, (2002a) showed that the coefficient of regression between DHI and PMY was 190 g kg^{-1} during the fourth month of lactation which fit well with the French data. The coefficient fall to 120 g kg^{-1} during the eighth month of lactation. The coefficient of regression between DHI and aMY is higher than DHI and PMY (400 to 500 g kg^{-1}, Stakelum and Connelly, 1987; Peyraud, unpublished) which emphasized that the limitation of cow productivity at grazing is primarily due to low voluntary herbage intake.

The cow potential has a determinant effect on milk yield at grazing. From a series of trials involving 236 cows, Delaby *et al.* (2001) and Delaby and Peyraud (2003) have showed that milk yield for cow grazing in spring (April to early July) is strictly and linearly linked to the cow potential (Figure 1). The relationship is:

aMY = 6.3 + 0.59 eMY (n=236; rsd = 2.17; r^2 = 0.74) (Equation 1)

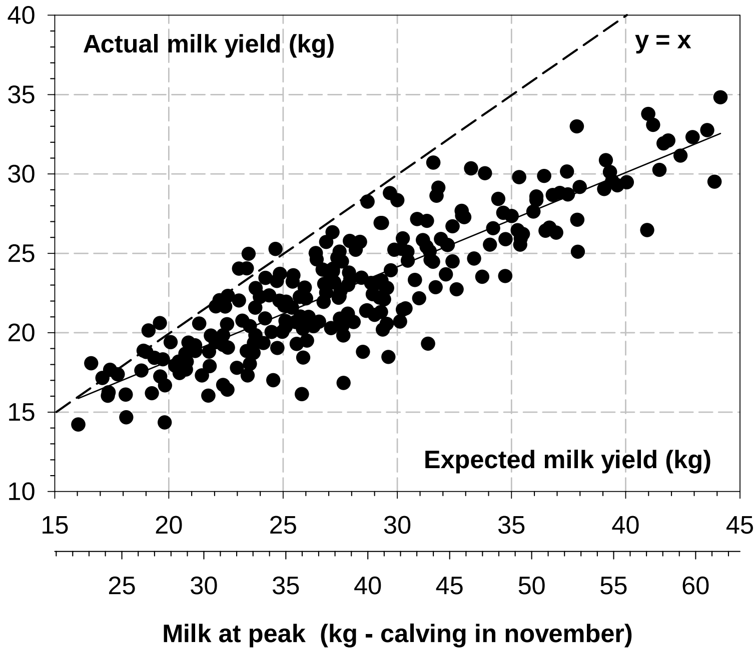

Figure 1. Milk yield at grazing in relation to the potential yield (expressed as expected milk yield or as milk at peak) of the cows.

According to the equation 1, the dairy cows were able to produce about 60 % of each kg of expected milk yield above 15 kg of milk with grass only. This slope is in reasonably good agreement with the marginal DHI increase with eMY (250 g kg^{-1}) which covers approximately two thirds of the additional energy requirements associated with the increase in eMY. This effects of cow potential on milk yield is recovered over the grazing season. Milk yield was 2 to 3 kg higher with high genetic merit cows than for those of medium genetic merit, which may lead to an extra milk output of 800 to 1200 kg y^{-1} cow^{-1} (McGilloway and Mayne, 1996; Buckley *et al.*, 2000; Kennedy *et al.*, 2002b). The equation 1 also shows that grass alone prevents high genetic merit cows to fully express their milk potential. However, the average milk production of 7400 kg y^{-1} cow^{-1} fed with only 320 kg concentrate (Kennedy *et al*., 2002b) indicates that relatively high milk production is achievable with high genetic merit cows in grass-based system; at least under area well suited for giving high yield of grass over prolonged grazing season.

2.2 Increasing herbage allowance to increase herbage intake

On rotational grazing, pasture allocation is commonly described in term of daily herbage allowance (DHA), which is the weight of herbage cut above a sampling height (i.e., kg pasture dry matter cow^{-1} d^{-1}). DHA is more often estimated at ground level or at a cutting height of 4 or 5 cm assuming that the material below that height is not available for the animal. From a comprehensive review of short term trials with dairy cows, Delagarde *et al*. (2001, 2004a) obtained a strong curvilinear relationship between DHI and DHA:

DHI = 18.4 (1 - $e^{-0.0466\ DHA}$); n = 92; r^2 = 0.87; rsd = 0,99 (Equation 2).

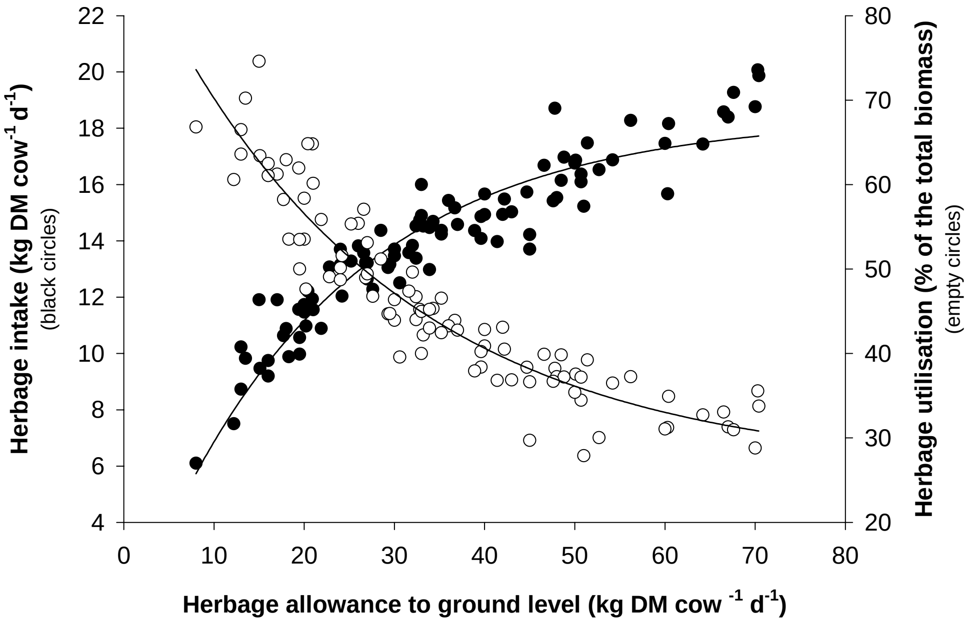

Figure 2. Influence of daily herbage allowance (DHA) to ground level on daily herbage intake (DHI) in rotationally grazed dairy cows (Delagarde *et al*., 2001b).

According to this relationships (Equation 2), DHI reaches a plateau for DHA higher than 60 kg d^{-1}. At this stage cows are able to satisfy their appetite. For DHA ranging between 25 to 40 kg DM d^{-1} to ground level, which is the range of variation generally found in European countries, the cows are far to satisfy their appetite, where DHI being lower than 80 % of the intake capacity. This explains why cows are not able to achieve their milk potential when fed grass alone. Within this range of DHA, the DHI increases on average 0.15 kg kg^{-1} DHA to ground level or 0.20-0.25 kg kg^{-1} when DHA is calculated at 5 cm. Because post-grazing sward height is a direct function to DHA, the additional increase of DHI with increased amount of DHA, which corresponds to 1 kg d^{-1} for 5 kg DHA is also roughly equivalent to 1 kg d^{-1} for one extra cm in post-grazing sward height (rising plate meter).

The additional increase of DHI with increased amount of DHA means that hardly one fourth of the extra amount of grass offered above 5 cm is actually eaten by the cows. This explains why post-grazing sward height rapidly increases with increasing DHA. Therefore, grazing too leniently in spring to increase DHA and / or cow performance results in deterioration of sward quality in mid and late season and also in a sharp reduction in animal performance in subsequent grazing rotations (Mayne *et al.*, 1987; Hoogendoorn *et al*., 1992). Thus the possibilities to increase DHI by increasing DHA are rather limited on a long term basis and alternative strategies must be developed to increase grass intake and milk production from grass.

2.3 Increasing herbage availability and quality to increase herbage intake

Herbage availability can be defined as the relative ease or difficulty with which herbage is harvested by the grazing animal. Herbage availability is a complex parameter that takes in account the qualitative and quantitative aspects of the sward and interactions with DHA. In continuous grazing, DHA is theoretically unlimited and herbage intake increases asymptotically with sward mass and / or sward height (SH). A comprehensive review from Delagarde *et al.* (2001) has shown good relationship between DHI and SH:

DHI = 12.1 (1 - e $^{-0.34\ SH}$) where maximum intakes are obtained for sward height averaging 9-10 cm but rapid decreases of intake when sward height was below 7 cm.

On rotational system, pre-grazing sward height is higher than on continuous grazing system and will decline during the grazing process as a function of herbage allowance. The herbage availability might be partly determined by the proportion of green leaf in the grazed horizons. Wade *et al.* (1989, 1995) first concluded that herbage availability increased with the proportion of green leaves in the bottom of the sward when the animal ceases to eat. This was further demonstrated by Parga *et al*., (2000) and by Delagarde *et al.* (2004b). Finally, DHI will be predicted more accurately when using the daily allowance of green leave (rsd = 1.46 kg d^{-1}) than with DHA (rsd = 2.02 d^{-1}). Therefore, increasing leaf blades mass at the bottom of the sward by appropriate grazing management in early spring may play a major role in increasing herbage intake while maintaining a low residual sward height over the entire grazing season.

Changing the botanical composition of the sward may also contribute to increase herbage availability and quality. Herbage intake and milk yield are higher within a mixed perennial ryegrass-white clover sward compared with a pure perennial ryegrass sward (Thomson *et al.*, 1985; Wilkins *et al*., 1994 and 1995; Ribeiro-Filho *et al.*, 2003). The higher is the clover content in the mixed sward the higher is the difference. The mixed swards should then be seriously considered as an alternative option to pure grasses swards to maximise cow performance. The introduction of legumes in grass-based swards also provides some economic and agronomic advantages. Conversely, the cow performance is only marginally affected by ryegrass cultivars having the same heading date (Hageman *et al.*, 1993; Gowen *et al*., 2003) and unlikely there is margin for further progress in maximising DHI by exploitation of ryegrass characteristics having similar agronomical properties.

3 Farmers and grazing management or how to improve grass utilisation by the dairy herd

3.1 Extending herbage growth season

Grass grows regularly from the spring to autumn in the western part of Europe (UK, Irish Republic, Britanny and Normandy in France). The most favourable regions with humid summer, have a DM yield potential of 15,000 kg DM ha^{-1} and of 20,000 kg milk ha^{-1} (Holmes, 1980). In other regions (large part of France, Galicia) the grass growth curves are usually characterised by having a summer drought during most of the years, which obliges farmers to house their animals (Mosquera-Losada and Rodríguez, 1999a). On the other hand, the reduction of grass growth due to cold temperatures happens later in the year in north Spain than in the North Europe. There is also large interannual growth curve variability. There is a challenge to extend the herbage growth throughout season.

Nitrogen (N) is a key nutrient in determining pasture productivity. The N fertilisation extents the grass growth in the season. The first N application is important to stimulate the early growth of grass in pasture-based systems. However grass growth response to this first application depends on climatic conditions. A study in Spain showed that the response is higher in areas closer to the cost, where temperature is steadily incremented at the start of the year than in higher altitude (Mosquera-Losada and Rodriguez, 1999b). Similarly, N fertilisation can be efficient when rain period starts in early autumn when the temperature and radiation are still high like in Spain.

A major objective of grass breeders is to increase the length of the growing season. Increased productivity of new ryegrass variety is mainly due to slightly longer growth period and there is no indication that any limit has been reached from continuous selection (Wilson, 1993). The use of other species such as cocksfoot and fescue or mixed white clover-ryegrass swards which are more resistant than ryegrass to high temperature and drought can increase seasonal production. Watering can extend the grazing season but at the price of sharply increased costs.

3.2 Extending the grazing season: an opportunity to consume more grass while increasing cow performance

Given the high feeding value of grass relative to conserved forages, there is interest to extend the grazing season as much as possible. In many situations moderate grass growth occurs in early spring and herbage growth in late autumn is almost entirely lost through senescence and grass death during winter. Experiments at Hillsborough (Sayers and Mayne, 2001) and Moorepark (Dillon and Crosse, 1994) have shown that access to grass between mid February to mid April or in November and December (Mayne and Laidlaw, 1995) during 3-4 hours d^{-1} increased milk yield by 2 to 3 kg d^{-1} and reduced grass silage intake by 4 to 6 kg d^{-1}. The effective use of late autumn grass as part of the diet of dairy cows was further confirmed under Britanny conditions (Chenais and Le Roux, 1996). Cow having access to grazing during daylight (6 hours d^{-1}) produced 1 kg d^{-1} more milk and consumed less 5.1 kg d^{-1} of maize silage than cows fully housed. There is considerable opportunity to extend the grazing season, thereby reducing cost associated with indoor feeding systems. During these transition periods daily grazing time and stocking rate should be adjusted according to the climatic conditions and soil types to avoid poaching and to limit the risk of nitrate leaching in autumn.

The grazing season could also be extended by intentionally deferring grazing from the period of production to a period of grass shortage. In area with dry summers, grazing can be deferred to a certain extend by changing the length of the grazing rotation. Paddocks are closed in spring for up to 50 or 70 days before being grazed in July / August. This requires mixed swards to maintain the sward quality for feeding dairy cows. The net energy value of ryegrass-white clover mixed sward averaged 0.75 UFL kg^{-1} DM after 70 days re-growth (Delaby and Peccatte, 2003) which is equivalent to values observed for good quality grass silage. Because sward height of deferred paddocks is high, it is recommended to strip grazed these paddocks.

3.3 Stocking rate and grazing systems have limited effects on cow performance

From 30 experimental responses, Delaby and Peyraud (unpublished) have shown the addition of one unit in the stocking rate (i.e., add one cow ha^{-1}) only marginally decreased milk yield per cow by 1 kg d^{-1} (i.e., 7 %) This demonstrates that decreasing stocking rate to increase intake and milk production per cow has limited application in dairy farms. Post-grazing sward height is affected by stocking rate. Several trials have reported a milk yield response averaging 1.0 kg milk d^{-1} cm^{-1} increase of post-grazing sward height (Hoden *et al.,* 1991; O'Brien *et al*., 1999; Delaby and Peyraud, 2003) which is the maximum room to manoeuvre without having to adopt alternative strategies to utilise residual herbage to a degree commensurate with maintaining sustainable high quality swards over the grazing season.

For a given stocking rate, studies comparing continuous grazing and rotational grazing systems have not shown one grazing system to be markedly superior to another (Ernst *et al*., 1980; Hoden *et al.*, 1987). However, continuous grazing system appears to be more sensible to drought conditions than rotational grazing system with a higher risk of decrease in grass growth during dry summers compared to rotation grazing (Hoden *et al*., 1987). This reflects a superiority of rotational grazing to maximise grass intake over the season where rainfall and / or temperature are limiting grass growth. Milk yield do not differ in rotational grazing systems in which fresh pasture is allocated either daily (strip grazing) or over several days (paddock system) (Hoden *et al.*, 1987). Splitting cows into leader and follower according to the milk yield at turnout has the objective to match grazing severity to the cows requirements. However the increase in milk yield reported for the leader cows is almost totally compensated by a decrease in low yielding cows (Mayne *et al.*, 1988). This more complex system of management is not justified due to the overall marginal effects on herd performance.

3.4 Improving grazing and feeding practices to improve grass utilisation

Well managed early spring grazing can have beneficial effects on sward quality as long as it does not affect DM production, in the period up to mid June. O'Donovan and Delaby (2004) compared grassland utilisation and milk production on swards that were previously allowed to graze in March (6 h d^{-1}) with swards not grazed before mid April. Higher post-grazing sward height and lower grass utilisation on late grazed swards showed that delaying spring grazing leads to large accumulation of herbage which can be difficult to graze and makes grazing management more difficult in subsequent rotations. Earlier grazing can also result in higher milk yield when early grazed swards are not too severely grazed (Table 1) and the total number of grazing days per unit area is similar or even higher than the number sustained on late grazed swards.

Table 1. Effect of early spring grazing and subsequent stocking rate during full grazing on milk yield and grass utilisation in May and June (O'Donovan and Delaby, 2004).

	Early grazing (March)		Late grazing (mid April)	
Stocking rate (cows ha^{-1})	4.5	3.9	4.5	3.9
DM production (kg ha^{-1} d^{-1})	66	67	65	58
DHA to ground level (kg OM d^{-1} cow^{-1})	34.6	42.3	40.1	48.5
Grass digestibility	0.80	0.80	0.76	0.76
Milk yield (kg d^{-1} cow^{-1})	19.3	23.3	21.1	23.0
Grass utilisation (% of DHA at 5 cm)	104	100	85	81
Post-grazing sward height (cm)	4.6	5.0	6.5	6.8
Total grazing days since March (ha^{-1})	427	366	350	284

Turnout date is critical for a good grass utilisation in subsequent rotations. Too early turnout is wrong when area available per cow and / or grass growth at this period growth are low. In this scenario, it will become impossible to have enough grass on the farm to feed the cows accordingly to the levels which are meaningful. From a computer simulation Delaby and Le Gall (2001) have demonstrated that when 2500 m^2 cow^{-1} (4 cows ha^{-1}) are available for grazing, early turnout date (1st March) will reduce the grazing period by 19 days until early July and will increase the consumption of supplementary feed (+ 85 kg cow^{-1}) compared to a latest turnout date (1st April). Conversely, too late turnout date will lead to an over-supply grass situation and some difficulties with managing tall swards later on.

The effect of feeding supplement on cow performance were recently reviewed (Peyraud and Delaby, 2001). Efficient response of one kg of milk to one kg concentrate is now currently reached when the amount of concentrate does not exceed 6 kg cow^{-1} d^{-1}. Therefore, feeding concentrate can be efficient to maintain good sward management, which allows the control of post-grazing sward height while achieving high milk yield per cow with high economic returns. Farmers often fed buffer forages to compensate the weekly variation in grazing conditions. In fact, giving conserved forages (grass silage, hay or maize silage) always results in high substitution rates with grazed grass, often over 1.0, and very low or negative milk responses (Leaver, 1985; Peyraud and Delaby, 2001; Chenais *et al*., 2001) when the offered amount of grass would have been sufficient to fed the herd. Buffer forages then contribute to a poor grass utilisation. Conversely, during periods of grass shortage, feeding buffer forages have two purposes. It maintains the intake level of the cow and milk yield because the substitution rate falls below 0.3. It also allows to recover a correct amount of available grass for subsequent grazing periods.

4 Methods and tools to give farmers more confidence in grazing

The challenge in grazing management is to find an optimum between the twin objectives of high performance by the herd and good grass utilisation.

4.1 Short term rationing of grass at paddock level

Sward height after grazing provides a measure of sward conditions which can be used on farms for management decisions in two purposes. For animal nutrition, low post-grazing height indicates an insufficient feed supply and that the average intake of grass by the herd was lower than it could have been. If a post-grazing sward height is high, it means that more grass could have been utilised. For grass budgeting, high post-grazing sward height indicates that forage will accumulate thus grazing management will be more difficult in subsequent rotation. Some post-grazing sward heights were proposed as indicator for bringing the cow out of the paddock in Britanny (Dequin *et al*., 1998). The target heights increase from 4.5 to 6.0 cm between early spring and summer. Similar approach was proposed in Ireland (Stakelum *et al.*, 1997) but with only one target height (5.5 cm). Since post-grazing sward height is partly related to pre-grazing height, DHI is predicted more accurately when post-grazing sward height is expressed as a proportion of pre-grazing height rather than as an absolute value (Delagarde *et al*., 2001a).

The pre-grazing sward height can be used as an indicator for management. Sward higher than 16 cm are difficult to graze and DHI will decrease (Peyraud *et al*., 1996). Optimal pre-grazing sward height is 12 to 14 cm. Stakelum *et al*. (1997) recommended that the pre-grazing yield of available grass (above 4 cm) in the next paddock for grazing should be around 2000 kg ha^{-1} DM (i.e., 12 cm).

For tactical feeding decisions, a predictive herbage intake model (Grazemore-HIM) was recently produced (Delagarde *et al*., 2004a) as part of the EU funded called ‘Grazemore project‘ (Mayne *et al*., 2004). Grazemore-HIM enables the prediction of DHI for a group of cows under rotational or continuous grazing, for a wide range of animals, grass and legume species, supplementary feeds (forages or concentrate) and grazing management practices. Grazemore-HIM take in account of herbage allowance (Figure 2) and pre-grazing sward mass on rotational grazing (or sward height on continuous grazing) and daily access time to the pasture.

4.2 Long term rationing of grass at farm level

Stocking rate was the first proposed criteria to make decisions for grazing and grassland management. High stocking rate is recommended in spring and decreases across the grazing season. Since stocking rates do not allow enough precise information at one specified farm, the method of Key Events (KE) was the next step to be developed. KE are the occurrence dates of relevant decision during the grazing season. The key events under consideration in spring are the turnout date, the start date of grazing night and day and the closing date of the silo. Later in the season, there are other events such as the reopening date of the silo, the beginning night indoors date, the end of grazing date. In Britanny, five typical management strategies have been defined by extension services specialists of grazing management for dairy cows (Dequin *et al*., 1998) to take in account local variations in area available for grazing and total length of the grazing season (from 0 to 180 days y^{-1}).

To take in account the magnitudes and the trends of quantities of forage, the concept of grass budgeting was firstly developed by Duru *et al.*, (1988). The grass budget corresponds to the total supply of available grass (above 5 cm) at a given time on all the paddocks. The grass budget state is expressed in term of 'days ahead' (DA) which is calculated as the total grass supply on farm divided by the number of cows and the mean level of grass intake per cow (i.e., 15 kg DM d^{-1}, Chenais *et al*., 2001). DA target values varied according to the available area for grazing and the season from 8-10 days at turnout (March, April), to 10-15 days later in spring and increases up to 25-60 days in late spring / early summer when grass growth is reduced. A similar method was developed in Ireland but the state of the farm total grass supply is expressed as the total amount of available grass (here above 4 cm) per hectare ('Farm Cover' – FC, Stakelum *et al*., 1997). The measurement of yield of grass available is done weekly by walking in the paddocks and assessing the yield by visual assessment or by measuring sward heights using a rising plate meter.

The previous methods / tools were rather static and do not take in account the complexity of interactions between management operations and its delayed effects on grass growth and herbage intake. Models have been developed (Pâtur'IN: Delaby *et al*., 2000; Sepatou: Cros *et al*., 2003; Grazemore: Mayne *et al*., 2004) to simulate the effects of different technical management options of feeding strategies and grassland management over a period of several months and their sensitivity to different weather patterns. All these models incorporate a plant sub-model to simulate herbage accumulation, a herd sub-model to simulate herbage intake and to predict milk response (Grazemore) and a decision sub-model that reproduces the implementation of a management strategy (grazing policy, stocking rate, fertilisers, cropping, feeding supplements etc.). The plant and animal sub-models are always designed to integrate strong interactions between the two components of the grazing system but the functionalities are different according to the model. At the present state of development, these models are not ready yet to be used on farm for tactical decision. They are powerful research tools for grazing systems. They also provide a framework for discussing and confronting management strategies. These models can be utilised for teaching grazing science to improve student's understanding of the component processes controlling production in grazing dairy systems. A first experiment has been developed in France (Delaby *et al*., 2002).

5 Conclusions: new challenges in grazing science to maximise grass utilisation while maintaining high animal performance

There is quite considerable scope to improve animal and grassland performances with grass based system given recent developments in our understanding of management factors influencing grass intake and grass growth.

These aims also bring new challenges in grazing science for the next ten years. i) The first challenge is to maximise daily herbage intake. To understand the regulation of herbage intake, studying the relationships between sward structure and intake per bite have now reached a plateau and we need to develop new insights into the relative effects of the physical constraints to prehend the grass, the rumen fill (e.g., rate of comminution, rate of digestion, rate of passage) and the cow metabolism. ii) The second challenge is to maintain a high proportion of green material within the sward canopy in order to increase herbage intake while maintaining a low residual height making grazing management easier. Here, there is a need to better understand how the carryover effects with early grazed swards would persist into later rotations and how long the early grazing can affect milk yield per hectare according to subsequent grazing management. iii) The third major area of progress is to control grass growth and grass availability on farm. This will extend the grazing season in early spring or late autumn or during summer time when grass growth is limited by climatic conditions. In addition, in area favourable to maize cropping, it could be interesting to avoid too much surplus grass in spring which must be ensiled with much higher cost than maize silage. In these area grass should mainly be grazed. There are opportunities to manage seasonal production of grass by plant selection (selection from existing grasses gene pools, creation of new hybrid material) and addition strategies as N fertilisation and grazing management. This also put forward new interests for the use of white clover-ryegrass mixed swards which grow slower than pure ryegrass sward in spring and can be grazed up to 50-60 days of re-growth while maintaining a relatively higher digestibility compared to pure ryegrass pasture. iv) The fourth area of progress is to develop reliable decision support methods and tools to encourage and facilitate increased reliance on pasture based systems. To be operational these tools / methods should require a time investment to record the indispensable inputs data as low as possible and the inputs should be readily available and be unambiguous. Management oriented models are support tools for research about grazing strategies. They allow simulations in many situations to better quantify the risks and consequences of technical choices. Finally, these simulations will help to develop, in connection between researchers and extension services, friendly tools and methods for the use of farmers and extension services.

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Mattenklee landraces, a valuable source of genetic variation for red clover breeding

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Abstract

Persistent Swiss landraces of red clover (*Trifolium pratense* L.) developed in the 19th and 20th centuries and became known as Mattenklee. This material served as starting point of the successful red clover breeding programme of our station. A collection of about 100 landraces, sampled in 1971 and 1972, is currently being regenerated. Here, we present results of the evaluation of a subset of 20 landraces in terms of agronomic performance and morphological descriptors. Plot trials showed inferior yields and persistence for most landraces when compared to the standard cultivar Milvus. However, there was great variation among the landraces, and the best old landrace performed almost like Milvus in terms of yield and persistence. The results show that the preserved Mattenklee landraces provide a valuable source of genetic variation for further breeding.

Keywords: *Trifolium*, Mattenklee, genetic resources, landrace, yield, persistence

Introduction

Red clover (*Trifolium pratense* L.) landraces used to be maintained and propagated on-farm by Swiss farmers in the 19th and 20th centuries. By consciously harvesting the seed in the last year of stand of a 3 to 4 year ley, the farmers improved persistence of these landraces which became known as Mattenklee, meaning 'clover of the leys' (Boller, 2000). Mattenklee landraces disappeared for the most part in the 1970s. In 1971 and 1972, samples of about 100 extant landraces were collected and subjected to preliminary evaluation (Nüesch, 1976). In order to assess the potential value of this genetic resource for future use in our breeding programmes, more detailed knowledge about morphological descriptors and agronomic performance is essential. Here, we report on yield and persistence, and on the variability of morphological parameters within a subset of 20 landraces. The results are interpreted in the light of their potential use in our red clover breeding programme, which is mainly based on material of the Mattenklee type.

Materials and methods

Landraces and cultivars. 20 landraces were chosen which represent the most important regions of origin of Swiss Mattenklee. Seed of 19 landraces, originating from the 1971/72 collection, was bulk harvested in the year 2000 on isolated 25 m^2 regeneration plots with at least 200 individual plants. Basic seed of the last still utilised landrace, Leisi, and of the cultivars Milvus and Mt.Calme was retrieved from cold storage. All seed lots used were of good quality, with at least 85 % germination.

Description of morphological characters. 60 seedlings per landrace or cultivar were raised in the greenhouse and transplanted to the breeding nursery at Zurich-Reckenholz in the spring of 2001 in six replicated rows of 10 individual plants. Time of flowering was determined and measurements of stem length, leaflet length and leaflet width were taken. Leaf shape was described as the ratio of leaflet length to leaflet width.

Agronomic evaluation. Standard plot trials with 6 × 1.5 m plots and three replications were established in the spring of 2001 at three locations in Switzerland: Zürich-Reckenholz, Ellighausen TG and Oensingen SO. Five landraces and the cultivars Milvus (Mattenklee type) and Mt.Calme (semi-persistent field clover type) were sown at all three locations, while 15 landraces were each sown at one of the three locations. Plots were harvested twice in the year of sowing, four times in the first and three times in the second year after the year of sowing, respectively.

Statistical analysis. The GLM procedure of SAS© (Statistical Analysis Systems) was used to estimate least squares means and the significance of contrasts among them. Cluster analysis of morphological and agronomic characters was performed with the Cluster procedure of SAS©, after adjusting variance of each character to the least significant difference obtained from the respective analyses of variance.

Results and discussion

Yield potential and persistence varied greatly among the landraces, but were mostly inferior to those of the current Swiss standard cultivar, Milvus (Table 1). The sum of dry matter yield harvested during the first 16 months after sowing (two cuts in late summer and autumn of the year of sowing, and two cuts during spring of the first year thereafter), was considered a measure of yield potential since the stands showed no significant injury due to biotic or abiotic stress until then. The ratio of the sum of yields of all later cuts to this initial dry matter yield was named ‘persistence ratio’.

Table 1. Yield and persistence of 20 Mattenklee landraces and cultivars Milvus and Mt. Calme.

Landrace/ Cultivar	DM yield first 16 months, t ha^{-1}	persistence ratio (DM yield second / first 16 months)	DM yield final 2 cuts in third year, t ha^{-1}
LR002	13.74^{cdef}	0.92^{cde}	3.92^{def}
LR008	13.26^{f}	1.09^{a}	4.53^{bcd}
LR075	14.81^{abc}	0.85^{cdef}	3.68^{efgi}
LR086	13.71^{def}	0.79^{f}	2.88^{k}
LR088	13.55^{def}	0.86^{cdef}	3.64^{efghik}
LR119	13.94^{cdef}	0.90^{cdef}	3.64^{efghi}
LR127	13.96^{cdef}	0.92^{cd}	3.89^{e}
LR140	13.90^{cdef}	0.81^{ef}	2.93^{hik}
LR160	13.93^{cdef}	0.85^{cdef}	3.29^{efghik}
LR163	14.27^{abcde}	0.88^{cdef}	3.91^{def}
LR189	14.01^{cdef}	0.91^{cd}	3.66^{efg}
LR239	13.40^{df}	0.95^{bc}	3.94^{cde}
LR300	13.87^{def}	0.94^{c}	3.83^{e}
LR311	14.05^{bcde}	0.84^{def}	2.92^{ik}
LR318	14.39^{abcd}	0.85^{cdef}	3.16^{fghik}
LR321	13.34^{f}	0.86^{cdef}	3.13^{ghik}
LR325	14.15^{bcde}	0.83^{ef}	3.44^{efghik}
LR352	13.48^{df}	0.92^{cde}	3.75^{efg}
LRDett.	14.72^{abc}	1.05^{ab}	5.01^{ab}
LRLeisi	15.09^{a}	0.94^{cd}	4.66^{abc}
Milvus	14.33^{abce}	1.10^{a}	5.18^{a}
Mt.Calme	13.95^{def}	0.87^{cdef}	3.53^{efghi}

Values within a column not followed by the same letter are significantly ($P < 0.05$) different.

During the initial 16 months of stand, only 4 landraces had a significantly inferior yield to the standard cultivar Milvus, and three of them had an even higher yield. Conversely, none of the landraces exceeded Milvus in persistence ratio or yield of the final cuts in the second year after the year of sowing, and 17 landraces had significantly lower values for both parameters of persistence. Nine and 7 landraces, respectively, had even slightly poorer persistence characteristics than Mt. Calme, a cultivar which is considered a short-lived type. However, there was great variation in agronomic performance among the landraces. The best performing landrace, LRDett. ('Dettenbühl'), showed a slightly higher initial yield and almost equal persistence characteristics when compared to Milvus.

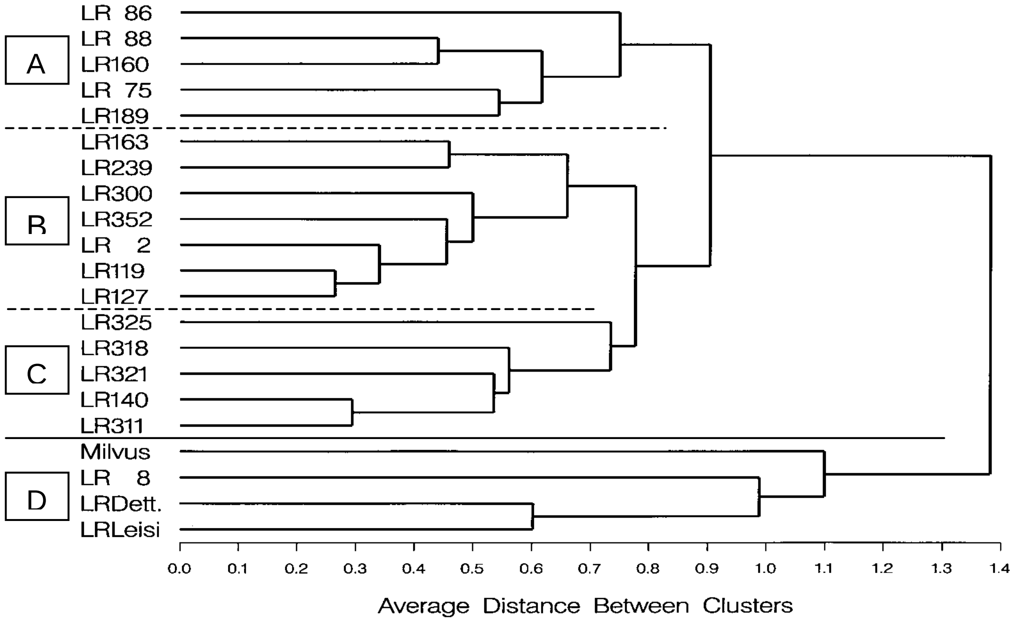

Figure 1. Cluster grouping of 20 Mattenklee landraces and cultivar Milvus based on 5 morphological descriptors and 5 agronomic characteristics.

Cluster analysis of five morphological descriptors (time of flowering, stem length, leaflet length, width and shape) and five important characteristics of agronomic performance (initial yield, persistence ratio, final yield, resistance against southern anthracnose and mildew) revealed that none of the landraces had a close relationship to Milvus, which represents our current Mattenklee breeding material (Figure 1). Conversely, the great majority of the landraces was grouped in often narrow sub-clusters. This confirms first results we obtained with AFLP markers (Kölliker *et al.*, 2002) on a small subset of the landraces and cultivars investigated here. That marker-based analysis of relationships among the landraces and their distance to cultivars and spontaneous red clover accessions is currently being continued and expanded.

Conclusions

Most of the preserved landraces showed inferior yields and persistence when compared to a current cultivar. However, the great variation among the landraces, the promising performance of the best, and their apparently wide genetic distance from the advanced cultivars underline their potential as valuable genetic resources for further breeding.

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Reducing the environmental impact of red clover (*Trifolium pratense* L.): physiological approaches underpinning germplasm improvement

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Abstract

Red clover (*Trifolium pratense* L.) is an increasingly important component of sustainable grassland agriculture and particularly organic farming. The red clover breeding programme at IGER aims to develop new varieties that are high yielding and persistent, particularly under grazing. It is also focusing on environmental traits, particularly those associated with nitrate leaching following defoliation, which is an increasingly important issue in the UK due to the recent implementation of NVZ (Nitrate Vulnerable Zones). While some of the traits associated with forage yield can be measured in the field, those associated with environmental impact are not amenable to this approach on the large numbers of plants required for a germplasm improvement programme. An experiment has been established in flowing solution culture (FSC) to measure the response of diverse red clover selection lines to cutting, with particular emphasis on nodule senescence, a key factor in nitrate leaching after defoliation. Cutting significantly influenced the growth and development of the different lines, reduced crown diameter and led to nodule senescence. Differences between selection lines in nodule number and nodule weight per plant after cutting were observed, indicating the existence of potentially useful genetic variation in nodule senescence. The relevance of these results for the development of improved red clover varieties for sustainable grassland agriculture are discussed.

Keywords: *Trifolium pratense* L., red clover, breeding, flowing solution culture

Introduction

Red clover (*Trifolium pratense* L) has historically played an important role in UK agriculture as a high yielding forage legume with valuable nutritional attributes. The 1960s saw a decline in its use (Rhodes and Ortega, 1996), but there has recently been a resurgence of interest in red clover as a consequence of an increased demand for traceable, home-produced high protein feed, particularly from the organic sector. Although the agronomic value of the species has been increased by recent improvements in techniques for ensiling red clover (Merry *et al*., 2001), there remain some aspects of red clover's growth and survival characteristics that are inimical to its widespread use in the UK. These include poor grazing tolerance and susceptibility to clover rot (*Sclerotinia trifoliorum*) and stem eelworm (*Ditylenchus dipsaci*), leading to crown deterioration and lack of survival. At IGER the red clover breeding programme aims to develop new varieties that are high yielding and persistent, particularly under grazing. It is also focusing on environmental traits, particularly those associated with nitrate leaching following defoliation, an increasingly important issue in the UK due to the recent implementation of NVZ (Nitrate Vulnerable Zones).

While some of the traits associated with forage yield can be measured in the field, many of them are not possible to assess on the large numbers of plants required for a germplasm improvement programme. This paper reports results of an experiment established in flowing solution culture (FSC) to measure the growth and development of diverse red clover selection lines after defoliation, with particular emphasis on nodule senescence, a key factor in nitrate leaching after defoliation.

Materials and methods

Four selection lines were chosen for their diverse morpho-physiological characteristics: the diploid early flowering variety Milvus (M); a line from within Milvus selected for survival within a cutting experiment (MC); and two selection lines from within the diploid, early flowering variety Sabtoron: Sabtoron grazing (SG), a selection line developed from survivors of a grazing experiment and Sabtoron cutting (SC), developed from survivors of a cutting experiment.

Forty-eight plants of each selection line were grown from seed in vermiculite. When they had 2 expanded leaves they were removed from vermiculite, roots washed and transferred (on 3 July 2002) to the FSC system. In this system plants are grown in large tanks containing closely controlled concentrations of the major plant nutrients. Depletion of nutrients is measured frequently and they are replenished automatically. A major advantage of FSC is that it allows root system size and function to be analysed more easily than is possible in soil-based growth media. Eight tanks were used, with six plants of each selection line per tank (total of 192 plants). On 1 August 2002, 6 plants of each line were destructively harvested. Half of the remaining 168 plants were cut to a height of 3 cm and the remainder left uncut. After 12, 26 and 40 days, 6 plants of each line from both the uncut and cut treatment were destructively harvested. At each harvest the plants were separated into leaf, stem, petiole, root and inflorescence. The number of stems and inflorescences were counted. Crown diameter was measured using callipers and the dry weights of all components were measured. Before the roots were dried, a sub-sample (approximately 10 % of the fresh weight) representative of the whole root profile was removed from each root sample. All nodules from the root sub-sample were removed, counted and weighed.

Results and discussion

The selection lines, which were selected on the basis of their morpho-physiological characteristics, differed at all harvest dates in stem number and above ground biomass, but no significant difference was observed in crown diameter or root growth (Table 1). Overall MC had more stems than SC and M and all had more than SG. SC had a significantly greater aerial dry weight than SG and M and MC had a significantly greater aerial dry weight than M.

Table 1. Morphological traits of uncut and cut plants of 4 selection lines of red clover, measured 40 days after cutting. Signficance: ns, not significant; *, $P < 0.05$; **, $P < 0.01$; ***, $P < 0.001$

Treatment	Selection line	Stem no. plant^{-1}	Crown diameter (mm)	Aerial dry weight (g)	Root dry weight (g)
Uncut	M	14.0	10.7	20.4	4.0
	MC	14.2	11.4	30.3	4.9
	SG	11.5	9.9	25.2	3.6
	SC	10.3	8.8	35.9	4.5
Cut	M	10.3	8.6	9.8	2.5
	MC	13.3	9.3	13.3	2.9
	SG	10.7	7.9	9.6	2.2
	SC	12.2	9.3	13.5	3.0
s.e.d. treatment (t)		0.61*	0.45***	2.04***	0.31***
variety (v)		0.87*	0.64ns	2.89**	0.44ns
t × v		1.23ns	0.91ns	4.08ns	0.62ns

Cutting had a significant effect on plant growth and development and generally all of the selection lines showed a similar response to cutting (Table 1). Cut plants had significantly fewer stems and a lower aerial and root dry weight than the uncut plants at all dates.

In this experiment cutting significantly reduced crown diameter of all of the selection lines, an effect observed at all harvest dates. At all harvest dates crown diameter was highly correlated with stem number over both treatments together (r = 0.91***) and separately under both the uncut (r = 0.96***) and cut treatments (r = 0.85***). Crown diameter has been identified as an important factor influencing the persistence of red clover and survival of spaced plants (Rhodes and Ortega, 1996). Rhodes and Ortega (1996) suggested that plants with larger crowns may have a competitive advantage under grazing but are less competitive under infrequent cutting, where they have a higher maintenance requirement. This suggests that the effect of cutting frequency on crown diameter should be studied in future experiments.

Table 2. Nodule number and weight (g) per plant of uncut and cut plants of 4 selection lines of red clover, measured 12 days after cutting. Signficance: ns not significant; *, $P < 0.05$; **, $P < 0.01$; ***, $P < 0.001$.

Treatment	Selection line	Nodules per plant	Nodule weight per plant (g)
Uncut	M	880	0.079
	M C	694	0.063
	SG	932	0.113
	SC	887	0.102
Cut	M	492	0.035
	MC	402	0.047
	SG	829	0.055
	SC	778	0.042
s.e.d. treatment (t)		131.4ns	0.0137**
variety (v)		185.8ns	0.0193ns
t × v		262.8ns	0.0273ns

This experiment also confirmed that cutting resulted in nodule loss from the roots of red clover. Comparisons of nodule size and number on the roots of cut and uncut plants following cutting showed significant variation between the selection lines in the extent of nodule loss (Table 2). Nodule loss after cutting was greater in M and MC than in SG and SC, although this was not statistically significant. However, cutting significantly reduced nodule size in all lines. Nodule loss after defoliation is one of the causes of nitrate leaching in legume swards and FSC will be used in future studies to examine variation in this important environmental trait at the genotypic level.

Acknowledgement

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Breeding white clover (*Trifolium repens* L.) for Europe: successes and challenges

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Abstract

White clover is used to improve the nutritive value of pastures and is an important component of environmentally-sustainable grassland ecosystems. In 1991, a white clover breeding program involving two New Zealand companies (AgResearch and Midlands Seed) and a European company (Barenbrug), was initiated to develop new varieties for European agricultural systems. This collaborative international program has resulted in a range of improved varieties being released and listed in Europe. This paper summarizes the agronomic performance of these varieties in the UK and of 21 experimental synthetics tested in three European countries.

Keywords: plant improvement, genetic relationships, agronomic performance

Introduction

White clover is used worldwide to improve the grazing value of pastures in temperate animal production regions and to provide low-cost nitrogen from nitrogen fixation. It is also increasingly seen as an important component of environmentally-sustainable grassland ecosystems because of its persistence under grazing, its ability to improve soil structure and its potential to reduce methane emissions.

In 1991, a white clover breeding program involving two New Zealand companies (AgResearch and Midlands Seed) and a European company (Barenbrug), was initiated to develop new varieties that were better adapted to European agricultural systems. This brought together the extensive agronomic testing network of Barenbrug, the breeding expertise and genetic resources of AgResearch and the seed production capability of Midlands Seed. This paper summarises the agronomic performance of white clover selections and varieties at three locations in Europe, and examines the genetic relationship of these new white clover varieties with industry standards such as Huia, Milkanova and Aran using microsatellite DNA markers.

Germplasm Development and Testing in Europe

The initial gene pool consisted of 100 lines that had been developed through intensive selection under grazing in New Zealand. This gene pool was evaluated at Wolfheze (Netherlands) and at Mas Grenier in Southern France. Several candidate varieties were identified and entered into National List Trials in France and the United Kingdom. This resulted in five varieties (Crusader, Barblanca, Milton, Triffid and Makuri) achieving National List and/or Recommended List status since 2000. Crusader and Barblanca have performed exceptionally well in UK National List Trials run by NIAB (Figure 1), with Crusader significantly outperforming all other small and medium-leaved varieties. Triffid, Milton and Barblanca also performed well in France and have been listed.

Jahufer *et al*. (2003) looked at the genetic relationship among 32 white clover varieties including four of the new European varieties (Crusader, Barblanca, Milton and Triffid). There was a strong relationship between the clustering of varieties based on the allelic variation using 39 microsatellite markers and their known pedigree and geographical origin. For example, all of the ladinos clustered together as did the varieties that contained a high proportion of Southern French germplasm (e.g., Crusader and Milton). Barblanca, which contains more Spanish and Portugese parentage clustered with other varieties with Mediterranean parentage. Control varieties such as Aran, Demand, Huia and Milkanova all clustered in a major branch containing varieties originating predominantly from Northern and Central Europe.

Genetic improvements have been shown in white clover performance (Woodfield *et al*., 2001), in beef production under grazing in USA (Bouton *et al*., 2004) and in sheep production under grazing in New Zealand (Chapman and Caradus, 1997). There is similar potential in Europe to enhance livestock production and on-farm profitability given the strong performance of new persistent and productive white clover varieties such as Crusader. While most varieties have been bred for a specific climatic zone there is clearly some overlap. New Zealand varieties have historically performed well in parts of Europe, and both Crusader and Barblanca which were developed for Europe also perform well under grazing in New Zealand (Woodfield *et al*., 2001).

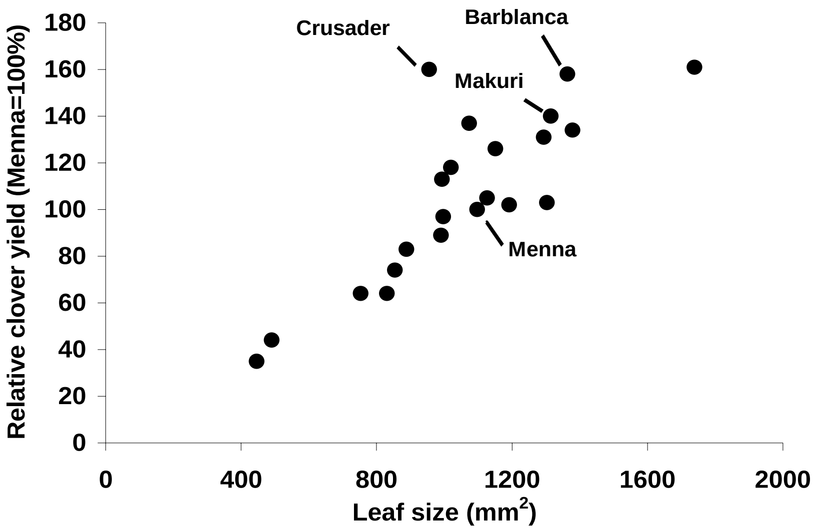

Figure 1. Clover yield in the third year of 22 white clover varieties in UK recommended list trials relative to the yield of Menna (= 100 %). (Adapted from NIAB 2003).

Following the initial evaluations at Mas Grenier and Wolfheze, selections were made from both sites and then progeny tested in Southern France, Netherlands and Northern Ireland (Loughgall). A minimum of 100 new families have been generated and progeny tested at Wolfheze annually since 1993, with an additional 50 to 100 new families entering evaluation biannually at Mas Grenier and Loughgall. Twenty-one synthetic populations, resulting from selection for agronomic value at each site, were established at all three sites in 2000. At the Loughgall site two managements (low and high defoliation) were imposed to provide an additional environment. The 21 synthetics and four control varieties (Aran, Avoca, Alice and Huia) were evaluated over 3-years and an analysis of variance on the clover content in the second and third years was conducted to test for significant differences ($P < 0.05$) among lines within each environment. Pattern analysis (cluster analysis and ordination) was conducted using the means from the within environmental analyses. The resulting biplot (Figure 2) indicates the presence of 3 main clusters. Within these clusters there are synthetics with superior performance to the 4 control varieties at each site. Synthetics with broad adaptation across environments were also identified.

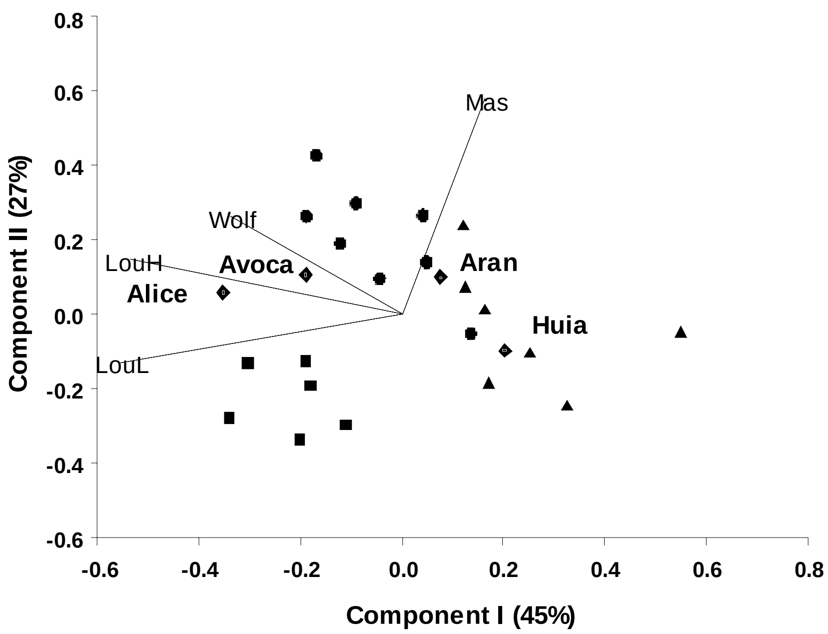

Figure 2. Biplot of variation among 21 white clover populations for mean clover content during years 2 and 3 in four environments. The symbols indicate 3 clusters and the control cultivars based on mean clover content. The vectors indicate the 4 environments: Wolfheze (Wolf); Mas Grenier (Mas), and Loughgall under either low defoliation (LouL) or high defoliation (LouH).

Challenges and Opportunities

New white clover varieties for Europe have to undergo National List testing before they can be marketed. This process, which involves evaluating performance at a range of geographical locations under cutting, is very expensive and fairly slow. The results provide an indication of climatic suitability and identify important pest and disease problems, however, they do not adequately predict performance under grazing. Breeding programmes currently target the National List testing system rather than the actual management systems used by European farmers. This creates opportunities for varieties that can combine adaptation to grazing with acceptable performance in the testing system.

The proposed reductions in international agricultural subsidies and the growing pressure to use environmentally sustainable agricultural practices should increase demand for components of less intensive grazing systems such as white clover. Even in heavily subsidised European farming systems there is a growing economic push towards implementation of more sustainable grazed pasture systems. Any reduction in subsidies is likely to increase this trend.

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Adaptation of white clover (*Trifolium repens* L.) to a cool and short growing season

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Abstract

A joint breeding project between Iceland and Norway has been initiated with the aim of developing cultivars of white clover (*Trifolium repens* L.) with good winter survival and yield when grown under cold climatic conditions. Crosses between winter hardy, low yielding populations from northern Norway and high yielding, commercial cultivars of more southerly origin are being tested reciprocally under field conditions in the two countries. Spaced plants were transplanted into a smooth meadow grass (*Poa pratensis* L.) sward. Morphological characters associated with yielding capacity have been measured and stolon material has been collected three times during the autumn in order to study the role of unsaturated fatty acids and vegetative storage proteins in the development of winter hardiness. Results from the morphological measurements obtained so far at the experimental site in Iceland showed no significant correlations between survival and traits associated with yielding ability such as leaf size. A number of promising crosses have been identified, which combine good survival and slow growth during the establishment year, large leaves and thin stolons.

Keywords: breeding, morphology, spaced plants, white clover, winter hardiness, yield

Introduction

The lack of winter hardy and productive cultivars of white clover (*Trifolium repens* L.) has restricted the agricultural use of this species in northern regions. In an attempt to increase the yield potential of white clover adapted to the short and cool growing season prevailing in the north, a number of crosses between indigenous Norwegian populations and more productive 'southerly' cultivars have been carried out. The parental populations used in the Icelandic part of the programme have already been described in detail in terms of biomass production, morphology, and rates of stolon extension and leaf appearance (Helgadóttir *et al.*, 2001). The observed variation suggested that it should be possible to improve the harvestable yield potential without sacrificing winter hardiness. Further, analyses have shown that the Norwegian populations produced greater amounts of unsaturated fatty acids at lower temperatures than the 'southerly' populations (Dalmannsdóttir *et al.*, 2001). This seems to coincide with improved winter hardiness under field conditions in Iceland.
The breeding project is carried out both at the Agricultural Research Institute, Iceland and by Graminor, Norway. The progeny are currently being tested reciprocally under field conditions in the two countries. Here we only present results obtained so far from the Icelandic part of the project.

Materials and methods

Reciprocal crosses were made between three Norwegian populations, HoKv9238 (62°55' N), Norstar (HoKv9262) (62°50' N) and Snowy (HoKv9275) (61°20' N), on one hand and selected populations of AberHerald (47°17' N), AberCrest (47°23' N) and Undrom (63 10' N) that had survived one to three winters in experimental plots in Iceland, on the other (Helgadóttir *et al.*, 2001). The AberHerald and AberCrest populations were classified as 'southern' populations and were characterised by high yields, large thick leaves, long petioles and thick stolons. The three Norwegian populations, on the other hand, had small leaves, thin stolons, low biomass production, and high rates of leaf and node appearance. Undrom was intermediate in yield, leaf size and stolon diameter, but was characterised by general leafiness and short petioles. Progeny from a total of 99 crosses were transplanted as spaced plants into a smooth meadow grass (*Poa pratensis* L.) sward at Korpa Experimental Station (64°30' N) in July 2001. The experimental design is a randomised block with three replicates. Crosses form subplots within each block, each made up of six genotypes. Each cross is thus represented by 18 genotypes in total. In autumn 2001 the vigour of the plants was visually estimated on a scale 0, 1 and 2. In summer 2002 the plants were scored for survival and detailed morphological measurements were carried out on the survivors according to Collins *et al*. 2001. Results for individual attributes were first analysed by standard statistical methods and then subjected to Canonical Variates Analysis (CVA).

Results and discussion

Severe winter kill occurred in the field and only 55 % of the plants survived the first winter (Table 1). Less than half of the progeny of crosses involving AberHerald and AberCrest survived, compared to over 70 % of the progeny of Undrom. Progeny of Snowy survived significantly worse than progeny of the other two Norwegian populations. The differences in winter survival of the various parental combinations partly reflect the geographic origin of the parental populations and their observed winter hardiness under field conditions. This is particularly the case for Undrom versus the two Aber cultivars. The difference between the Norwegian populations, on the other hand, is more surprising and can't be explained by their geographic origin.

Table 1. Mean survival (%) and s.e. of progeny from different parental combinations of northerly (HoKv9238, Norstar, Snowy) and southerly (AberHerald, AberCrest, Undrom) populations of white clover after one winter in the field (n indicates the number of crosses for each parental combination).

	n	HoKv9238	n	Norstar	n	Snowy	n	Mean
AberHerald	10	51.4 ± 1.10	9	69.4 ± 0.44	11	29.2 ± 1.05	30	48.7 ± 0.99
AberCrest	16	60.5 ± 1.06	9	47.6 ± 0.67	18	42.6 ± 0.87	43	50.3 ± 0.62
Undrom	9	73.4 ± 0.94	6	75.0 ± 0.58	11	67.3 ± 0.14	26	71.2 ± 0.29
Mean	35	61.2 ± 0.70	24	62.6 ± 0.60	40	45.7 ± 0.75		

A number of significant correlations were found between the individual morphological characters (Table 2).

Table 2. Simple correlations between survival and various morphological characters of progeny grown under field conditions (* = $P < 0.05$, ** = $P < 0.01$, d.f. = 98).

	VI	SU	FH	PH	PS	IL	SD	LS
Vigour (VI)	1.00							
Survival (SU)	0.22*	1.00						
Flower height (FH)	0.08	0.05	1.00					
Plant height (PH)	-0.06	-0.15	0.15	1.00				
Plant spread (PS)	0.20*	0.32**	0.37**	0.09	1.00			
Internode length (IL)	-0.07	0.09	0.37**	0.29**	0.54**	1.00		
Stolon diameter (SD)	0.08	-0.18	0.18	0.16	0.22*	0.35**	1.00	
Leaf size (LS)	0.04	-0.17	0.17	0.20*	0.12	0.15	0.28**	1.00

Only plant spread was positively correlated with survival (r = 0.32, $P < 0.01$), whereas no significant correlations were found between survival and morphological characters associated with yielding ability such as leaf size. This is an important observation as it shows that it should be possible to select simultaneously for good winter survival and morphological characters that influence yielding ability. Results of CVA are shown in figure 1. The first two axes explained around 76 % of the total variation. The main discriminatory variable on CV I was leaf size (-ve), but, vigour in autumn (-ve), stolon diameter (+ve) and survival (+ve) were of lesser significance. On CV II the main discriminatory variables were again leaf size (+ve), survival (+ve) and vigour (-ve). The analysis shows that a number of crosses, mainly involving Norstar, seem to combine good survival with slow growth during the establishment year, thin stolons and large leaves. The first two traits are characteristic of the Norwegian parent and are associated with winter hardiness, whereas large leaves are inherited from the more southerly populations. On the other hand, almost all of the progeny from HoKv9238 maintain their northern characteristics.

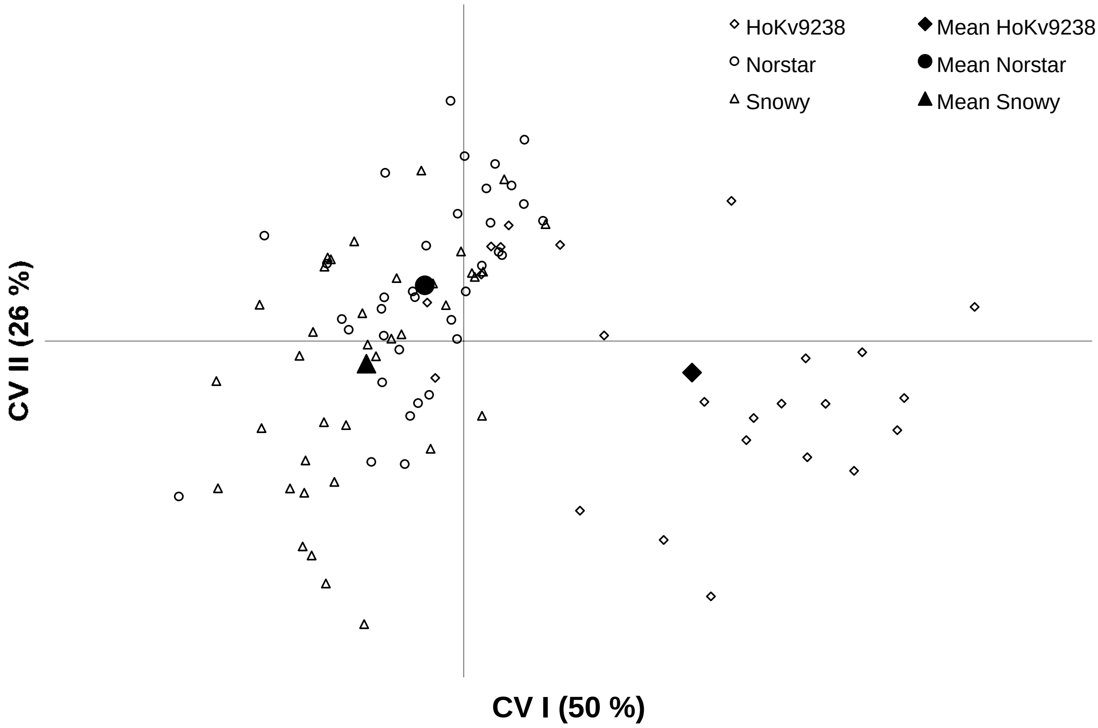

Figure 1. Canonical Variates Analysis using all measured traits classified by the Norwegian parent. Mean values are shown with black symbols.

The accumulation of unsaturated fatty acids and vegetative storage proteins in stolons during autumn is currently being measured for crosses involving HoKv9238 and Norstar. The results will be used to underpin the selection of the most promising crosses for further development of new varieties for the northern marginal areas.

Conclusions

The results obtained so far have identified a number of promising crosses, which combine good survival and slow growth during the establishment year, large leaves and thin stolons.

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Identification of interspecific hybrids of *Trifolium ambiguum* × *Trifolium hybridum* by inter-SSR fingerprinting

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Abstract

Wide hybridization has been carried out to improve alsike clover, *T. hybridum* L., by introducing disease resistance and the rhizomatous root trait from the wild clover species *T. ambiguum* Bieb. In making such hybrids it is important to be able to identify them at an early stage in their development; and for this purpose we have applied inter-SSR fingerprinting as a tool for their discrimination. Anchored primers of simple-sequence repeats, composed of tetra, tri and dinucleotide motifs were used in the polymerase chain reaction (PCR) to obtain DNA profiles of *T. ambiguum* and *T. hybridum* and their hybrids. The size of the amplified fragments varied within the range 0.4-2.5 Kb. Tetranucleotide primers, $(AGAC)_4GC$, $AC(GACA)_4$, $(GACA)_4GT$ and $(ACTG)_4GA$, gave unique profiles for the parent species, but, in most cases, the fingerprints of the hybrids were identical to that of *T. ambiguum*. The trinucleotide primer $(TCC)_5GT$ also produced discriminative specific fragments for the parents, and these specific fragments were retained and followed in most of the hybrids, although some individuals again showed fingerprints identical to *T. ambiguum*. Similar data was obtained when the dinucleotide primer $(GA)_8CT$ was used. The $(TCC)_5GT$ and $(GA)_8CT$ primers were found to be the most suitable for the identification of interspecific hybrids of *T. ambiguum* x *T. hybridum*.

Keywords: *Trifolium hybridum*, *Trifolium ambiguum*, interspecific hybridization, inter-SSR fingerprinting

Introduction

Wide hybridization plays an important role in the development of novel forage grass varieties. It is a means of combining useful traits from both parents, and both intergeneric and interspecific hybrids have been successfully applied in forage grass breeding. Clover breeders are now adopting a similar strategy to improve the cultivated species *T. pratense* L., *T. repens* L., and *T. hybridum* L. by introgressing into their genomes valuable traits from their wild relatives. Wild *T. ambiguum* Bieb. has useful agronomic traits of persistency, the capacity to form rhizomes, as well as drought and disease resistance; while *T. nigrescen*s Viv. could contribute high seed yield and resistance to nematodes (Meredith *et al.*, 1995). Data on interspecific hybridisation of clovers has been available for some time, but there are still no varieties produced by such means.

Cytological analysis of clover hybrids is rather complex, and recently new molecular tools have been increasingly used for investigations of population polymorphism, the identification of species and varieties, and for marking individual genotypes and traits (Marshall *et al.*, 2003). There is also some data on rDNA polymorphism and specific markers for individual chromosomes (Ansari *et al*., 1999). The objective of our study was to identify SSR primers suitable for discriminating between *T. ambiguum* and *T. hybridum* and their hybrids, and to employ these primers to identify interspecific hybrids at an early stage of their development. The inter-SSR approach has already been successfully used for species discrimination in *Lolium* and *Festuca* grasses (Pašakinskienė *et al*., 2000).

Materials and methods

The materials used were *T. ambiguum* Bieb., x = 7, 2n = 16, 32, 48, which is rhizomatous, persistent, and disease resistant; and *T. hybridum* L., 'Daubiai' 2n = 2x = 16, which is high-yielding, susceptible to diseases, and tolerant of acid soils.

Plants were grown in a greenhouse and transferred into a climatic chamber prior to flowering (22-25 °C, 13,000 lux, 16 h photoperiod). Hybrids were obtained using embryo culture. DNA was extracted from young leaves following the CTAB-based extraction protocol (Doyle *et al*., 1990). PCR was performed in an Eppendorf Gradient Mastercycler using the following primers: $(AGAC)_4GC$, $AC(GACA)_4$, $(GACA)_4GT$, $(ACTG)_4GA$, $(TCC)_5GT$ and $(GA)_8CT$. PCR products were separated on 1.5 % agaroze gel in 1 x TAE buffer.

Results and discussion

The number and size range of PCR-amplified fragments in the two parent species and their hybrids varied within the size range 0.4-2.5 Kb, as shown in table 1.

Table 1. Number and size range of PCR-amplified DNA fragments in *T. ambiguum* Bieb., *T. hybridum* L. and their hybrids.

Primer code	Oligonucleotide sequence	Number of bands (MW range, Kb) in *T. ambiguum*	Number of bands (MW range, Kb) in *T. hybridum*	Hybrid profiles compared to parental species
77H	$(AGAC)_4GC$	4 (0.40-2.00)	3 (0.70-1.90)	Identical to *T. ambiguum*
78H	$AC(GACA)_4$	3 (0.75-1.30)	7 (0.40-2.50)	Identical to *T. ambiguum*
104H	$(GACA)_4GT$	5 (0.60-1.30)	7 (0.55-1.90)	Identical to *T. ambiguum*
GO2	$(ACTG)_4GA$	5 (0,55-1.30)	5 (0.65-2.40)	Identical to *T. ambiguum*
GO3	$(TCC)_5$ GT	3 (0.75-1.40)	2 (0.90-1.10)	Fragments of *T. ambiguum* and *T. hybridum* are present
105H	$(GA)_8CT$	5 (0.65-1.70)	3 (1.00-1.40)	Fragments of *T. ambiguum* and *T. hybridum* are present

Using the $(AGAC)_4GC$ primer, fragments marking *T. ambiguum* fell within the range 0.4-2.0 Kb, and bands specific for *T. hybridum* appeared within a slightly smaller interval. The 0.4 Kb fragment appeared as unique marker for *T.ambiguum*. The $AC(GACA)_4$ primer generated different DNA profiles for the two parent species: *T. hybridum* is distinguished by a strong specific band of 2.5 Kb together with four faint and specific fragments of different sizes. When the $(GACA)_4GT$ primer was used completely different profiles were obtained, and one specific fragment was identified for each species. The $(ACTG)_4GA$ primer also generated polymorphic profiles. The tetranucleotide repeats, $(AGAC)_4GC$, $AC(GACA)_4$, $(GACA)_4GT$ and $(ACTG)_4GA$ all gave polymorphic profiles for the parental species, but the fingerprints of the hybrids were, in most cases, identical to that of *T. ambiguum*.

Fragments amplified with $(TCC)_5GT$ were close in size. A specific fragment of 1.1 Kb was obtained for *T. hybridum* and one of 0.75 Kb for *T. ambiguum*. These specific fragments were retained and followed in most of the hybrids, but some individuals showed fingerprints identical to *T. ambiguum*.

$(GA)_8CT$ amplified fragments within the range 0.65 Kb and 1.7 Kb. *T. hybridum* had a strong specific band of 1.0 Kb and *T. ambiguum* was characterized by three faint specific fragments, 0.65 Kb, 0.9 Kb and 1.0 Kb. The hybrids displayed specific fragments from both parents in most of the cases, but in some individuals some parental bands were not expressed. In total, from the results with $(TCC)_5GT$ and $(GA)_8CT$, most of the hybrids (96.1 %) had DNA fragments from both parental species, and only a small number of them (3.9 %) were missing some characteristic fragments.

Conclusions

Tetranucleotide repeat primers, $(AGAC)_4GC$, $AC(GACA)_4$, $(GACA)_4GT$ and $(ACTG)_4GA$, generated different fragments for *T. ambiguum* and *T. hybridum*, but in the hybrids these primers only displayed fragments of the female parent, *T. ambiguum*.

The $(TCC)_5GT$ and $(GA)_8CT$ repeats provided species-specific fragments from both *T.ambiguum* and *T. hybridum* which could be followed and identified in the hybrids.

Acknowledgements

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Forage productivity of some Bulgarian lucerne cultivars in mixtures with grasses

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Abstract

During the period 1994-1997 a field trial was carried out in the north central region of Bulgaria. The objective of the study was to establish the forage productivity of some Bulgarian lucerne (*Medicago sativa* L.) cultivars in pure stand and in double component mixtures with the grasses, cocksfoot and tall fescue, each in proportion 1:1. The lucerne cultivars Obnova 10, Pleven 1 and Victoria were used. It was found that Victoria was the most productive in all tested stands. The average annual dry matter (DM) yield in the pure stand was 15,673 kg ha^{-1} and in the mixture with cocksfoot 16,809 kg ha^{-1}. There were no significant differences between the yields of the cultivars in the mixtures with tall fescue. The DM yield was higher in the mixed stands by 8.8 %.

Keywords: lucerne, cocksfoot, tall fescue, mixtures

Introduction

Lucerne is the highest yielding perennial forage legume crop and it is most widely grown in warm temperate areas. Cocksfoot and tall fescue are forage species capable of flexible utilization, i.e., cutting and grazing (Tomov and Petkov, 1989). These species are suitable components for legume-grass perennial mixtures and can be used as sown swards (Gibson and Newman, 2001). In agronomic terms compatibility in lucerne-grass mixtures resulted in higher DM productivity than monocultures (De Santis *et al.*, 1992), due to the more effectively utilised abiotic factors by complementation of seasonal growth patterns of the species and their persistence (Tomov and Petkov, 1989).
The aim of this study was to test new lucerne cultivars in pure stand and in mixture with perennial grasses in order to establish the most suitable as well as the highest yielding mixture wherein lucerne shows its valuable crop characteristics to the greatest extent.

Materials and methods

From 1994 to 1997 three Bulgarian lucerne cultivars (Obnova 10, Pleven 1 and Victoria) were tested in pure-sown stands and in mixtures with perennial grasses. The lucerne monocultures were sown at 25 kg ha^{-1} as were cocksfoot (cv. Dabrava) and tall fescue (cv. Albena) mixtures. The experiment was designed as a block method with four replications and plot size 10 m^2. The first three treatments were pure lucerne stands (LPS) of the above mentioned cultivars in the same order. The treatments 4 to 6 were mixtures with cocksfoot (MC), and the treatments 7 to 9 with tall fescue (MT). The sowing ratio in mixtures between legume and grass components was 1:1. The swards were cut at early flowering stage of the lucerne. Three cuts were obtained during the first, second and fourth years and four during the third. Data were analysed using MS Excel, ANOVA LSD at $P = 0.05$.

Results and discussion

The lucerne played a prominent part in all studied swards. In the LPS it had the lowest proportion in the first cut but with later cuts its proportion in the sward increased (Figure 1).
The lucerne proportion in first and fourth cuts of MC was lower than in second and third cuts. Cocksfoot started to re-grow earlier than lucerne prior to the first cut because of its lower temperature start point for growth and then reproductive stems emerged and it made up a significant part of the sward. In the next two cuts the lucerne proportion increased because cocksfoot only produced leaves. In the fourth cut at the end of the vegetation period the daily temperature decreased which led to more active grass growth.
The sward component distribution in MT stands was different from that of MC. Lucerne dominated in all cuts including the first and the fourth. Tall fescue had less aggressive potential than cocksfoot especially in the first cut but also the last since it needs higher temperatures at the end of the vegetation period.

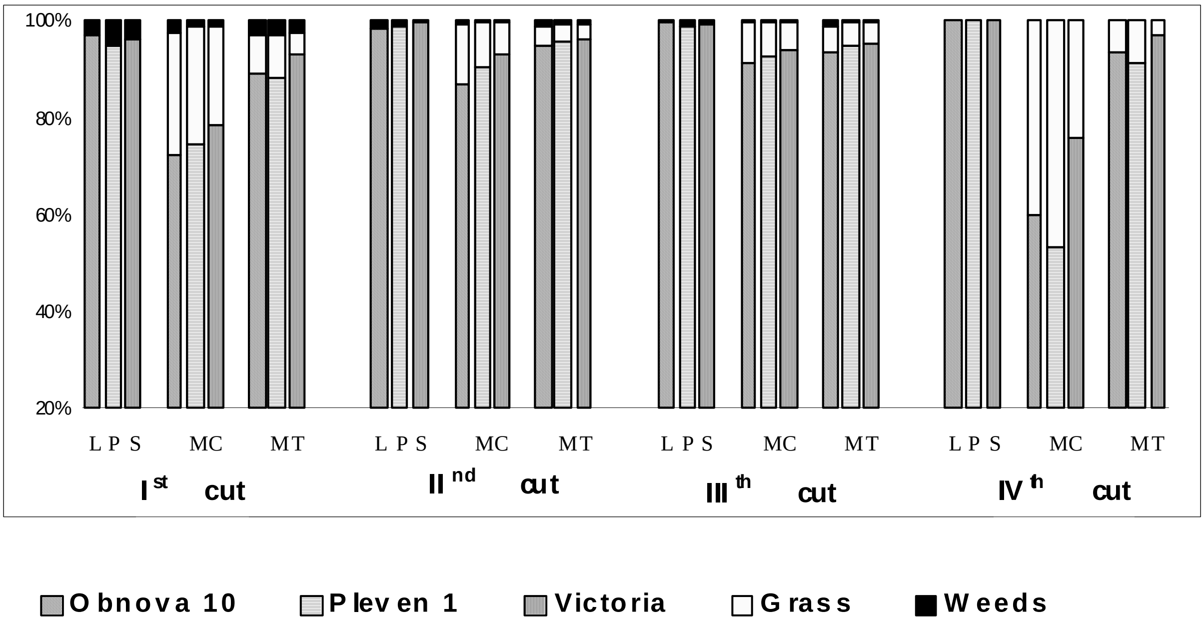

Figure 1. Botanical composition of the swards averaged over the period, 1994-1997. LPS-lucerne pure stand, MC-Mixture with cocksfoot; MT-Mixture with tall fescue

The DM productivity depended on the lucerne cultivar as well as on the type of the stand – pure-sown or mixture (Table 1). The highest average annual yield was obtained from Victoria for LPS and exceeded the control (Obnova 10) by 7.7 %. It was due to the DM productivity obtained from the first two cuts. The same tendency was observed in MC. The highest average annual yield was obtained from the Victoria mixture again and exceeded the pure-sown Victoria by 7 %. It was due to the DM productivity obtained from all cuts.
Irrespective of the good yields of Victoria in the first cut there were no significant differences between the yields of the tested cultivars in MT. This result could be due to the specific relationships between the components, which reflected on the cultivar productivity.

Table 1. Average dry matter yield for the period 1994-1997 (kg ha^{-1}).

Treatments		1st cut	2nd cut	3rd cut	4th cut	Annual average yield
				Pure lucerne stand		
1	Obnova 10	5.757	5.705	2.706	378	14.546
2	Pleven 1	5.910	5.844	2.551	398	14.702
3	Victoria	6.386	6.040	2.855	393	15.673
	$\bar{x}$	6.018	5.863	2.704	389	14.974
	LSD ±	414	246	310	56	342
				Mixture with cocksfoot		
4	Obnova 10	7.065	5.515	2.646	469	15.695
5	Pleven 1	7.027	5.839	2.794	377	16.037
6	Victoria	7.517	5.803	2.935	555	16.809
		7.203	5.719	2.791	467	16.181
		266	274	158	106	376
				Mixture with tall fescue		
7	Obnova 10	6.371	5.575	2.986	398	15.331
8	Pleven 1	6.148	5.639	2.922	361	15.070
9	Victoria	6.703	5.532	2.990	413	15.639
	$\bar{x}$	6.408	5.582	2.96	391	15.346
	LSD ±	248	267	201	63	321
						LSD ± 1.184

Conclusions

The lucerne cultivar Victoria produced the highest yield in all tested types of stands. The yield in pure stand exceeded that of Obnova 10 (control cultivar) by 7.7 %.
The lucerne mixture with cocksfoot was more productive than the pure stand under the cutting regime adopted due to the compatability of the included species. The MC mixtures averaged 16,181 kg ha^{-1} DM which was 8.5 % greater than the average yield from the LPS stands.

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Variability of yield and its components in lucerne cultivars

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Abstract

The aims of this study were to estimate the variability of yield and its components in 18 lucerne cultivars of different origin, and is use in breeding. Three Czech, nine Iranian and six Serbian cultivars were analysed. The cultivars differed significantly in all examined traits. The highest yields in the first year (2001) were achieved by the Serbian cultivars Mediana (17.43 t ha^{-1}) and Banat (17.29 t ha^{-1}), while the lowest yielding was Iranian Yazdi (10.23 t ha^{-1}). In 2002 the highest yields were achieved by the Iranian cultivar Hamadany (19.04 t ha^{-1}) and Banat (17.56 t ha^{-1}), while the lowest yielding was Nikshahry (6.64 t ha^{-1}). The Serbian cultivar Bačka was the tallest (71.4 cm), and the Serbian cultivars Novosađanka, Zaječarka 83 and Hamadany had the largest internode number (13 in all three cases). The shortest internodes were measured in the Iranian cultivar Nikshahry (4.9 cm), the Czech cultivar Jarka (5.0 cm) and the Serbian cultivars Novosađanka (5.0 cm) and Mediana and Bačka (5.8 cm). The genotypes with a high proportion of leaves were Baghdady (50 %) and Niva and Jarka (49 % in each), while Nikshahry had the fastest re-growth rate (41.8 cm).

Keywords: lucerne, cultivar, yield components, morphology

Introduction

High yields and nutritional value make lucerne the most important forage legume. Lucerne is grown on over 3×10^7 ha worldwide and on around 2.1×10^5 ha in Serbia and Montenegro. According to Vavilov, this plant species has its origins in the Middle Eastern gene centre, which incorporates Asia Minor, Transcaucasia, Iran and the highlands of Turkmenistan (Michaud *et al*., 1988). Dry matter yield, re-growth rate, plant height and internode length and number are the crop's economically important quantitative traits and they are correlated with the yield and quality of its forage (Čobić *et al*., 1989; Katič, 2001). The variability of these quantitative traits depends on the environmental and genetic factors and genotype × environment interactions (Borojevič, 1992).
The objective of this paper was to analyse the production and morphological traits of some domestic and foreign lucerne cultivars in order to identify those best adapted to our country's conditions and include them in a breeding program to develop new cultivars with higher yields and dry matter quality.

Materials and methods

The quantitative traits (i.e., dry matter yield, plant height, internode number and height, proportion of leaves and re-growth rate) of nine Iranian (Ghareh Yon Geh, Nikshahry, Bamie, Yazdi, BK3, Makojaran, Ghar Galog, Hamadany and Baghdady), six domestic (NS Banat ZMS II, NS Mediana ZMS V, Novosađanka H-11, NS Slavija, Zaječarka 83 and NS Bačka ZMS I) and three Czech (Zuzana, Jarka and Niva) cultivars were analysed in this study. Re-growth rate was assessed by measuring plant height 14 days after cutting. Five measurements per replicate were made in the centre of each plot. The trial was carried out on a non-calcareous chernozem during 2001-2002 at the Rimski Šančevi Experiment Field of the Institute of Field and Vegetable Crops in Novi Sad using a randomized block design with four replications with plot size of 5 m^2 (5 × 1 m). Analysis of variance of a three-factorial trial (A-cultivar, B-cut, C-year) was performed for the morphological traits and that of a two factorial trial

(A-cultivar, B-cut) for dry matter yield. Differences among the treatments were determined by the LSD test.

Results and discussion

Hay yields were higher in 2001 (the second year of the crop), as a result of favourable environmental conditions during that year. In the third year (2002), a severe drought reduced yields. The domestic cultivars produced significantly higher dry matter yields than the foreign ones (Lukič *et al*., 2001). Serbian lucerne cultivars are characterized by a high potential for good quality dry matter yield (Đukič, 2002). Mediana (17.44 t ha^{-1}), Banat (17.30 t ha^{-1}) and the Iranian cultivar Yazdi (10.23 t ha^{-1}) produced significantly lower yields in 2001. In 2002, above-average yields were produced by the Iranian cultivar Hamadany (19.05 t ha^{-1}) and the domestic cultivars Banat (17.53 t ha^{-1}) and Bačka (17.34 t ha^{-1}), while the lowest yield was recorded in Nikshahry (6.65 t ha^{-1}) (Table 1).

Table1. Plant height, internode number and length, proportion of leaves, re-growth rate in 2001-2002, and DM yield (per year) in 2001 and 2002 of 18 different lucerne cultivars.

Cultivar	Plant height (cm)	Internode number	Internode length (cm)	Proportion of leaves (%)	Re-growth rate (cm)	2001 DM yield (t ha^{-1})	2002 DM yield (t ha^{-1})
	Mean 2001-2002	Mean 2001-2002	Mean 2001-2002	Mean 2001-2002	Mean 2001-2002		
Zuzana	63.5	12	5.4	48	30.6	16.66	12.87
Jarka	59.9	12	5.0	49	33.0	17.12	14.68
Novosađanka	62.8	13	5.0	48	34.3	15.92	13.93
Yazdi	52.8	10	5.2	46	36.8	10.23	9.34
BK 3	52.0	10	5.1	49	38.2	11.83	9.84
Makojaran	63.3	11	5.7	43	34.5	16.40	16.66
G. Y. Geh	63.6	12	5.4	47	38.5	15.85	15.21
Baghdady	61.7	12	5.3	50	38.5	13.82	7.95
Mediana	67.8	12	5.8	45	38.8	17.44	16.70
Slavija	60.9	12	5.2	46	33.5	16.08	13.60
Nikshahry	51.8	11	4.9	44	41.8	10.94	6.65
Banat	68.3	12	5.5	46	38.0	17.30	17.53
Ghar Galog	64.7	12	5.4	45	30.3	17.21	15.61
Niva	61.2	11	5.4	49	32.5	13.96	12.72
Bamie	64.6	12	5.2	46	40.1	15.59	17.21
Zaječarka 83	67.9	13	5.5	45	38.2	16.29	14.06
Hamadany	70.5	13	5.6	42	38.7	16.81	19.05
Bačka	71.4	12	5.8	44	39.8	16.80	17.34
LSD (0.05)	12.16	2.38	0.88	8.60	11.48	1.20	0.34
LSD (0.01)	16.09	3.15	1.17	11.37	15.19	1.59	0.45

The re-growth rates of the cultivars differed significantly after cutting (Katič, 2001). The highest rates were found in the Iranian cultivars Nikshahry (41.8 cm) and Bamie (40.1 cm) and the domestic cultivar (39.8 cm) and the lowest in the Czech cultivars Zuzana (30.6 cm), Niva (32.5 cm) and Jarka (33.0 cm), the domestic cultivar Slavija (33.5 cm) and the Iranian cultivar Ghar Galog (30.3 cm) (Table 1). Plant height at cutting also varied significantly (Katič, 2001). The tallest plants were those of the domestic cultivars Bačka (71.4 cm) and Banat (68.3 cm) and the Iranian cultivar Hamadany (70.5 cm). The shortest plants were recorded in the Iranian cultivar Nikshahry (51.8 cm) and the Serbian cultivar Slavija (43.0 cm). The Czech cultivars were ranked between the Serbian and Iranian ones with respect to plant height (Jarka 59.9 cm, Niva 61.2 cm and Zuzana 63.5 cm) (Table 1). Internode number also varied (Rumbaugh *et al*., 1988). The domestic cultivars Novosađanka and Zaječarka 83 and the Iranian cultivar Hamadany had more internodes (13), while the Iranian cultivars Yazdi and BK 3 (10) and the Czech cultivar Niva (11) had fewer. (Table 1). The

Iranian cultivars Baghdady (50 %) and Bamie (49 %) had a higher percentage contribution of leaves to yield. A high contribution was also found in the Serbian cultivar Novosađanka (49 %), which is an indirect indication of higher quality. Short internodes combined with thicker stems reduce lodging in lucerne (Katić, 2001). In our study, short internodes were found in the domestic cultivars Novosađanka (5.0 cm) and Slavija (5.2 cm), the Iranian cultivars Nikshahry (4.9 cm) and BK 3 (5.1 cm) and the Czech cultivar Jarka (5.2 cm). The domestic cultivars Bačka (5.8 cm) and Mediana (5.8 cm) and the Iranian cultivar Makojaran (5.7 cm) had long internodes (Table 1).

Conclusions

The highest dry matter yields in the study were produced by the Serbian cultivars Mediana and Banat in 2001 and Bačka, Banat and the Iranian cultivar Hamadany in 2002. The Iranian cultivars Nikshshry and Bamie had the highest re-growth rates after cutting, especially under the drought conditions of 2002. Bačka, Banat and Hamadany had tall plants at flowering (cutting), while Baghdady, Novosađanka and Bamie were characterized by a high percentage contribution of leaves to yield. The cultivars Yazdi, BK 3 and Niva were characterized by having fewer internodes and Nikshahry, Novosađanka and Jarka by having short internodes. The domestic cultivars Banat and Mediana were among the top performers in terms of yield and should form the basis of future lucerne breeding for higher yields and quality. In order to broaden the genetic base of such future breeding efforts, the domestic cultivars should be combined with the Iranian cultivars Hamadany, Ghar Galog and Bamie as well as with the Czech cultivars, especially Jarka and Niva.

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Variability in dry matter yield and morphological characteristics of lucerne cultivars depending on geographic origin

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Abstract

Fifteen lucerne genotypes of different geographic origins (five cultivars from France, three from Czech Republic, two from Iran, one from Serbia and four experimental populations developed by individual selection from the cultivars NS Banat ZMS II, Orca and Europe) were studied for variability in yield and morphological characteristics. The genotypes differed significantly in DM yield, proportion of leaves, plant stature, internode length and crop growth rate. In the second year, the highest yields were achieved by the cultivar NS Banat ZMS II and the population BS1183 derived from it with 19.40 t ha^{-1} and 19.51 t ha^{-1}, respectively. These genotypes also had a higher crop growth rate (35.2 cm), height (66.7 cm) and a lower proportion of leaf in dry matter yield (45.3 %). Cultivars with a high proportion of leaf such as Lifeuil had a lower crop growth rate (28.0 cm), short stature (60.6 cm) and significantly lower yields of dry matter. The French cultivars were lower yielding than the domestic ones, but they had a higher proportion of leaf, i.e., better quality.

Key words: lucerne, cultivar, DM yield, morphological characteristics

Introduction

Lucerne is grown on more than 30×10^7 ha, on all continents and from sea level to 2000 m asl (Michaud *et al*., 1988). To fit such a wide array of growing conditions, as well as to meet the requirements of the various utilization methods, numerous cultivars have been released and new cultivars continue to be developed. Local cultivars and ecotypes are more productive than introduced ones, because they are better adapted to specific growing conditions and utilisation methods (Degaldo *et al.,* 2003). Morphological characteristics of lucerne are significantly correlated with yield and quality of dry matter (DM) (Katić *et al.,* 2003). Information on variability of DM yield and morphological characteristics of lucerne genotypes of different geographic origins is needed for the establishment of divergent germplasm for the development of superior lucerne cultivars.

Materials and methods

A three-year field trial (2001-2003) was conducted at the experiment field of the Institute of Field and Vegetable Crops in Novi Sad. The trial included the cultivars Orca, Pecy, Milfeuil, Lifeuil and Europe (France), Zuzana, Jarka and Niva (Czech Republic), Ghareh Yon Geh and Baghdady (Iran), NS Banat ZMS II (Serbia and Montenegro) and experimental populations 02431073 and 0151065 (derived from Orca), ESC 41128 (derived from Europe) and BS1183 (derived from NS Banat ZMS II). The following characteristics were observed: DM yield (t ha^{-1}), stature (cm), proportion of leaves (%), number of internodes, length of internodes (cm) crop growth rate (cm). The obtained data were processed by ANOVA, using a two - factorial (cultivar and year) randomized block design with five replicates. The size of experiment unit was 5 m^2 (5 m × 1 m). Differences were tested by the LSD test.

Results and discussion

Significant variability existed among the tested cultivars in DM yield and years (CV 14.10-19.30). The highest yields were obtained from the domestic cultivar Banat (15.24 t ha^{-1}) and the populations selected at Novi Sad Institute (Table 1).

Table 1. Dry matter yields (t ha^{-1}) of lucerne cultivars during 2001-2003.

Cultivar	Dry matter yield (t ha^{-1})			
	2001	2002	2003	Mean
NS Banat ZMS II	7.62	19.40	18.69	15.24
BS 1183	6.80	19.51	19.21	15.17
Pecy	6.41	16.98	12.10	11.83
Milfeuil	7.79	16.23	13.38	12.47
Lifeuil	7.67	14.05	12.90	11.54
Orca	6.92	16.11	13.27	12.11
02431073	9.90	16.93	16.31	14.38
0151065	7.05	17.09	16.67	13.60
Europe	6.39	16.62	12.18	11.73
ESC41128	8.10	17.80	16.34	14.10
Zuzana	9.74	18.15	13.84	13.91
Jarka	7.14	17.58	14.26	12.99
Niva	6.26	15.38	13.70	11.78
Ghareh Yon Geh	6.29	16.54	19.64	14.16
Baghdady	5.75	9.23	6.10	7.03
LSD (0.05)	0.57	0.36	0.44	0.46
LSD (0.01)	0.75	0.48	0.58	0.60
CV (%)	14.12	14.10	19.30	15.84

This was an indication that these genotypes were best adapted to the local conditions. Closest in yield performance to the Serbian cultivars were those from Czech Republic, followed by those from France and Iran (Table 1). On average, differences in yield performance were larger among genotypes of different geographic origin (Rumbaugh *et al*., 1988) than among genotypes of the same origin. However, the largest difference was registered between the Iranian cultivars Baghdady and Ghareh Yon Geh (7.03 t ha^{-1} and 14.16 t ha^{-1}, respectively). The French and Iranian cultivars had the largest proportion of leaves, followed closely by the populations selected in Novi Sad. The lowest proportion of leaves in DM yield, was found in the cultivar Banat, which is widely grown in Serbia. The highest crop growth rates and tallest plants were registered for the Iranian cultivar Ghareh Yon Geh, the selected populations from Serbia and the cultivar Banat. The lowest crop growth rates were observed in the French cultivars and the Iranian cultivar Baghdady. The tested cultivars exhibited small differences in the number of internodes but the differences in the length of internodes were significant. The French cultivars had the shortest internodes (Table 2). Regardless of geographic origin, the cultivars with high DM yield had taller plants, higher crop growth rates and longer internodes than the cultivars with low DM yield. The cultivars with high proportion of leaves, i.e., with better quality (Julier *et al.,* 2001), had lower crop growth rates and shorter internodes than the cultivars with low proportion of leaves. The populations derived from the French cultivars Europe and Orca had higher DM yield but lower proportion of leaves and shorter internodes than the original cultivars. Fonseca *et al*. (1999) warned that breeding for quality may lead to reduced vigour in lucerne.

Table 2. Variability of morphological traits (proportion of leaves, height, crop growth rate, internode number and length) in lucerne cultivars.

Cultivar	Proportion of leaves (%)	Height (cm)	Crop growth rate (cm)	Internode number	Internode length (cm)
NS Banat ZMS II	45.3	66.7	35.2	12	5.7
BS 1183	48.1	66.7	34.0	12	5.5
Pecy	48.1	65.0	26.5	13	5.2
Milfeuil	47.0	64.3	29.3	11	5.7
Lifeuil	50.1	60.6	28.0	12	5.3
Orca	44.8	66.4	28.2	12	5.8
02431073	46.7	69.5	31.1	12	5.9
0151065	47.6	66.9	30.2	12	5.5
Europe	47.9	60.6	26.9	12	5.3
ESC41128	48.1	68.9	30.0	12	5.7
Zuzana	43.6	67.5	28.7	12	5.9
Jarka	47.6	64.6	30.1	11	5.7
Niva	47.7	64.0	28.4	11	5.7
GharehYon Geh	47.4	67.8	37.1	12	5.7
Baghdady	47.4	67.8	37.1	12	5.7
LSD (0.05)	0.51	1.38	1.39	0.45	0.20
LSD (0.01)	0.67	1.82	1.83	0.59	0.26

Conclusions

DM yields of the tested cultivars differed significantly with respect to geographic origin. Significant differences also existed among cultivars of the same origin. The domestic cultivars and the populations selected in Novi Sad were highest yielding, obviously due to better adaptation to the ecological conditions of the test site. The cultivars with high DM yield had faster crop growth rates, taller plants and longer internodes than the cultivars with low DM yield. The cultivars with higher proportion of leaves in DM yield (better quality) had shorter internodes and lower crop growth rates.

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Evaluation of morphological traits of domestic population of birdsfoot trefoil (*Lotus corniculatus* L.)

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Abstract

In our research, 21 domestic populations of birdsfoot trefoil collected from different locations in Central Serbia were investigated. The average production of populations in their third and second years of exploitation were compared to standard cultivars K-30 and K-37. Morphological analyses were made in the second cut. The following parameters were monitored: plant height, number of stems per plant, green and dry matter yield per plant, number of internodes, stem thickness and regeneration after cutting. Investigated material demonstrated high variability in regard to the monitored parameters between and among investigated populations. Yield of green matter was highly variable (cv 44.3 %) and varied from 18.7 to 395.6 g per plant (5.2-90.1 g dry matter per plant). Higher variations, from 18 to 245, were recorded for the number of stems per plant (cv. 44.0 %). Lower variability was recorded for plant height (cv. 17.5 %), number of branches (cv. 15.2 %) and for stem thickness (cv. 20.4 %). Investigated populations had high variability for the majority of traits and can be used for further selection processes.

Keywords: birdsfoot trefoil, morphological characteristics, population

Introduction

Birdsfoot trefoil is very important fodder leguminous plant in hilly-mountainous regions of Serbia. It is a widely distributed species that is adapted to a broad range of environments. Much of birdsfoot trefoils wide range of adaptation is due to its highly variable genetic diversity. The range of phenotypes found in birdsfoot trefoil is believed to have developed as a result of adaptation to the environments in which it is found and through continual intraspecific hybridisation (Steiner, 1999). Because of this, birdsfoot trefoil has a good variability for most traits and excellent adaptability to different agro-ecological conditions (Gatarić *et al.*, 1996; Barlan *et al.*, 2002). For these reasons, birdsfoot trefoil can be called a universal legume (Mijatović *et al.*, 1986). Birsfoot trefoil has been reported to be polymorphic for most traits (Mijatović *et al.*, 1986; Papadopoulos and Kelman, 1999). This forage crop is extremely important for animal husbandry development in mountainous and hilly areas. There are great possibilities in Serbia for the further spread of this species, in mixtures with grasses. One of the conditions for a faster expansion of this species is a continual improvement of the material available and the selection of new varieties. A common problem with the genetic improvement of many forage species has been the limited genetic base used for the cultivar development. But the wild population of birdsfoot trefoil found in natural pastures is a rich source of genetic diversity for plant breeders (Greene, 1999). Domestic populations of birdsfoot trefoil in Serbia represent great source of initial selection material for obtaining highly productive and persistent genotypes (Mijatović *et al.*, 1986; Radović *et al.*, 2003).
The aim of this paper was to determine the productivity and morphological traits of domestic populations in order to find the genotypes with good agronomical traits, so that they can be included in the future breeding process and improve the varieties of birdsfoot trefoil available.

Materials and methods

The research was carried out on the demonstration field of the Centre of Forage Crops in Kruševac on degraded alluvial soil. In our research, 21 wild populations of birdsfoot trefoil collected from different locations in Central Serbia were investigated. Collected seeds were sown apart at a distance 60 × 60 cm. Plants were cut in full bloom. Morphological analyses were made on 60 plants of each population in the second cut in the second and third year of exploitation. The following parameters were monitored: plant height (cm), number of stems per plant, green and dry matter yield (GMY and DMY) in g per plant, number of branches, stem thickness (mm) and regeneration after cutting (regeneration ten days after cutting). The cultivar Krusevacki 37 was used as a standard. The results were subjected to ANOVA and the differences between genotypes were tested by the LSD test. The variability among and within populations for the chosen characteristics was expressed by the coefficient of variation (CV).

Results and discussion

Results indicate significant differences between investigated populations for the majority of traits (Table 1).

Table 1. Mean values and coefficient of variation for green matter yield (GMY), dry matter yield (DMY), plant height, number of stems per plant, number of branches per stem and stem thickness in investigated populations of *Lotus corniculatus*.

Variety	GMY (g per plant)	CV (%)	DMY (g per plant)	CV (%)	Plant hght. (cm)	CV (%)	No. stem	CV (%)	No.of bran-ches	CV (%)	Stem thick. (mm)	CV (%)
1. Radocelo 1	143.8	21	39.1	42	41.5	15	102.1	54	8.9	15.2	1.6	17.3
2. Soko Banja	159.5	22	43.0	18	45.8	6	132.0	21	8.8	12.5	1.9	12.1
3.Vlasina	155.4	43	40.0	42	37.5	20	127.3	28	9.7	7.1	1.4	30.7
4. Vlasina 1	172.0	51	43.5	43	39.0	19	132.1	39	8.7	14.6	1.9	19.0
5.Cajetina	171.5	45	42.4	40	42.3	7	117.1	33	9.6	15.8	19	21.3
6. Zajecar	175.0	31	43.4	31	44.0	10	116.1	29	10.6	15.8	2.0	14.9
7. ZZA	119.7	53	32.6	56	37.2	15	153.2	33	9.5	13.4	1.7	19.2
8. Ploce	121.5	32	33.0	28	38.5	13	72.4	33	8.8	9.3	1.6	8.4
9. Mitrovo polje	118.0	39	32.4	38	34.5	18	78.5	40	8.5	15.1	1.6	23.6
10. Novi Pazar	108.4	57	32.9	45	34.8	12	61.1	34	8.7	17.3	1.7	20.9
11. Sjenica	83.7	55	23.7	56	32.3	14	56.4	41	7.9	9.7	1.5	13.3
12. Rudno 1	162.3	43	45.8	40	37.5	15	105.5	33	8.4	11.5	1.7	24.4
13. Rudno 2	106.0	39	28.6	36	33.1	13	76.5	35	8.3	16.9	1.4	12.9
14. Ozren	103.2	31	29.1	29	29.6	13	90.1	27	7.8	9.9	1.3	5.0
15. Radocelo 2	124.1	39	29.9	48	36.5	7	89.0	59	8.3	8.0	1.3	5.3
16. Uzice	108.1	34	29.3	32	35.1	15	82.1	16	8.5	11.1	1.7	16.5
17. Zlatibor	147.1	44	39.7	41	31.2	14	113.7	44	8.7	13.6	1.6	21.3
18. Aleksinac	157.7	36	38.4	28	33.5	10	95.1	36	9.4	13.2	1.5	14.9
19. Banja	161.7	40	40.7	36	31.5	7	122.8	51	9.2	18.6	1.5	6.6
20. Goc	151.3	51	37.7	49	34.5	20	91.5	53	7.8	18.6	1.4	11.4
21. K-37	181.0	14	45.6	14	40.6	7	121.8	25	8.7	9.2	1.6	11.2
LSD 0.05	43.94		10.70		3.91		39.88		0.97		0.22	
LSD 0.01	57.90		14.10		5.16		52.57		1.28		0.29	

Populations of Vlasina 2, Cajetina and Zajecar achieved high average yields of green and dry matter, relative to the standard cultivar K-37. The population from Sjenica gave the lowest yield of biomass. Plant growth was highest in populations of Soko Banja and Vlasina1. The shortest plants were grown in the population of Ozren. Significant differences were found in the number of stems per plant. The strongest cluster was found in populations of Soko Banja and Vlasina 2 (132 stems per plant), whereas the lowest number of stems per plant was found in the population of Sjenica (56.4 stems). Average number of internodes per stem varied from 7.8 in the Ozren population to 10.6 in the Zajecar population. Moderate differences were registered for stem thickness (1.3 to 2.0 mm).

Differences among individual plants within a population were significantly higher and are presented as variability coefficients (Table 1). The highest variation in individual plants was determined for green and dry matter yield (cv 44.3 %) and number of stems per plant (cv 44 %), but, was lower for plant height (cv 17.5 %), stem thickness (cv 20.4 %) and number of internodes per plant (cv 15.2 %). Green matter yield of individual plants varied from 18.7 to 395.6 g per plant (5.2 to 90.1 g DM per plant), and plant height varied from 20 to 53 cm. Great differences within a population were registered for the number of stems per plant, varying from 18 to 245. The variation of individual plants was lower with regard to number of internodes per stem (5.6 to 14.3) and stem thickness (1 to 2.7 mm).

High variability in dry matter yield, plant height, number of steam and number of branches in domestic populations of birdsfoot trefoil was found by Mijatović *et al.* (1986). Gatarić *et al*. (1996) found high variability for the number of stems per plant (45.7 to 136.3) and for stem thickness (1.72 to 3.15 mm). Similar results were registered by Papadopoulos and Kelman (1999) and Barlan *et al.* (2002). The lowest variability of individual plants was registered for the cultivar K-37, which is a consequence of the selection process in creating this cultivar. High variability among individual plants in investigated populations of birdsfoot trefoil for major agronomical traits indicate that domestic populations in Serbia represent a rich source of variability necessary for successful selection of varieties with desired traits.

Conclusions

Investigation of wild populations of birdsfoot trefoil collected at different locations in Serbia has demonstrated significant differences for the majority of estimated parameters. Populations 4, 5 and 6 have realized similar dry matter yield compared to the standard cultivar K-37. Populations 2 and 6 have demonstrated somewhat higher and upright plants compared to other material. Plants with a great number of stems per plant that form large clusters were characteristic of population 7, as well as populations 2, 3 and 4. Population 11 (Sjenica) gave the worst results in the majority of monitored parameters. Recorded differences among populations, as well as high variability of individual plants within populations, indicate that wild populations of birdsfoot trefoil are rich source of variability for creating new varieties of this species for different purpose. It is necessary to continue with the research of wild populations in order to determine their tolerance to different agro ecological conditions.

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Inducing *in vitro* mutations on *Vicia faba* L. to obtain variation in amino acid content

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Abstract

The paper presents data regarding the change of some biochemical and morphological indices of *Vicia faba* L. as a result of the *in vitro* treatment with chemical mutagens (diethyl sulphate and dimethyl sulphate). The biological material consisted of two genotypes: 'Cluj 84' and 'Linia 401'. These genotypes belong to the *Vicia faba* L. species, the *eu-faba* subspecies, and *equina* variety.
The results indicate that the treatment effect differed with genotype and dose rate. The neoplantlets regenerated from the *in vitro* mutagen treatments also revealed a change of biochemical activity, especially of the amino acid content and of the isoenzymatic activity. This aspect is particularly interesting as the species is known to have a low content of sulphur amino acids (Zaki, 1996) and thus mutagen treatment offers the potential for improvement.
The enzymatic activity of the two untreated controls presented the same type of enzymogram, while the two descendants of the genotypes 'Cluj 84' and 'Linia 401' differed. The esterase of the ungerminated Fava bean seeds might represent a biochemical marker, which would reflect the influence of mutagens upon the polymorphism of this species (Susso, 1982).

Keywords: *Vicia faba* L., *in vitro*, mutagens, biochemical and isoenzymatic activity

Introduction

Vicia faba L. is a leguminous plant that has been cultivated since ancient times for both animal and human nourishment. Although this plant has high protein content (over 35 %) it is also an excellent source of Lysine, unlike the graminae, which are deficient in this amino acid. Under good conditions for growth seed production may reach 4000-4500 kg ha^{-1} (Bond, 1994). The seed is an excellent animal feed but the plant can also be used in the green state before lignification of the stem has taken place.
There are complex interactions between genotype and the environment which causes production to be highly variable both within and between years. Improvements in seed quality are focussed on the increase in amino acid content and the reduction of anti-nutritional qualities such as Tannin content.

Materials and methods

The research was carried out between 2001 and 2002. The plant materials used in the study were Fava bean genotypes 'Cluj 84' and 'Linia 401', belonging to *Vicia faba* var. *equina*. Diethyl sulphate (DES) and the dimethyl sulphate (DMS) were used as the mutagen substances and these were applied at two concentrations: 2 ppm and 0.2 ppm, to 100 seeds of each genotype under aseptic conditions.
All seeds were grown in an identical environment for the first 48 hours, allowing the initiation of germination. They were then transferred to the mutagen and control environments in growth rooms for the next 72 hours. Immediately following this period of mutagen treatment the plantlets were removed to a common, balanced nutritional environment which would enable the full development and expression of the mutagen effect. The plants were grown to maturity and the biochemical determinations were carried out on the seed produced by the regenerated plants. The amino acid content is displayed in table 1. Significant differences are

indicated in the table where the treated values differ from the control value within each genotype.

Table 1. Amino acid content of seeds (g g^{-1} dry matter) of two genotypes of *Vicia faba* var. equina following treatment with DES and DMS at two concentrations.

Amino acid	'Cluj 84'			'Linia 401'		
	control	0.2 ppm	2 ppm	control	0.2 ppm	2 ppm
Aspartic acid	1.628	1.536	1.570	1.859	1.483*	1.372***
Threonine	0.680	0.656	0.610	0.598	0.496	0.496
Serine	0.935	0.864	0.940	0.962	0.902	0.792
Glutamic acid	3.331	3.032	3.204	3.302	3.032	2.704***
Cysteine	0.804	0.790	0.790	0.830	0.466	0.738
Proline	1.814	1.290	1.206***	1.778	0.964***	1.770
Glycine	0.885	0.922	0.852	0.854	0.848	0.756
Alanine	1.251	0.950	1.068	1.200	1.106	0.832***
Valine	1.510	1.446	1.542	1.464	1.080*	1.560
Methionine	0.845	0.608	0.742	0.324	0.358	0.608**
Isoleucine	1.181	1.062	1.118	1.028	0.958	1.004
Leucine	1.533	1.364	1.550	1.544	1.446	1.318*
Tyrosine	1.436	2.538***	1.752*	1.632	1.470	1.576
Phenylalanine	2.307	2.040	2.236	2.100	1.538**	2.046
Histidine	1.972	1.272	1.758	1.126	2.276***	1.870
Lysine	1.748	1.604	1.752	1.862	1.486*	1.654*
Arginine	2.420	1.980	2.370	2.236	1.220***	2.030*
Total g g^{-1} dry matter	26.280	23.954***	25.060***	24.689	22.078***	23.126***

* $P < 0.05$; ** $P < 0.01$;*** $P < 0.001$.

Results and discussion

One of the effects induced at the protein level by radiation treatment is the change of sulphur amino acids (Methionine, Cysteine, etc.). These amino acids play an important antioxidant role under the action of the radicals released through the radiation effect. Inducing genetic variability within *Vicia faba* L. is likely to be of practical significance as the levels of these important amino acids are considered to be low in this species. The antioxidant effect was more obvious at 'Linia 401', whose basic amino acid level was lower. In general there was a decrease in the amino acid content associated with the application of the mutagen. A differential reaction was observed between the two genotypes. 'Linia 401' was much more susceptible to the mutagen treatment than 'Cluj 84' with 11 and 2 amino acids showing significant deviation from the control values respectively. However, some amino acids did show significant increases after mutagen treatment. Theses were Tyrosine in 'Cluj 84' and Methionine and Histidine in 'Linia 401'.

The ratio between the different types of amino acids is displayed in table 2. There were no significant differences between controls and the treated variants in the case of both genotypes. However, changes in the ratios indicated that deviation from the control values occurred between basic and acid amino acids, as well as between the essential amino acids (Threonine, Methionine, Lysine, Valine, Isoleucine, Leucine, Arginine, Histidine) and the unessential amino acids (Glutamic acid, Glutamine, Proline, Alanine, Aspartic acid, Tyrosine, Serine, Glycine, Cysteine). In both genotypes the mutagen treatment, given at the 2 ppm dose rate, increased the proportion of essential amino acids.

Table 2. Ratio of amino acids following treatment with DES and DMS at two concentrations.

Specification	'Cluj 84'			'Linia 401'		
	control	0.2 ppm	2 ppm	control	0.2 ppm	2 ppm
Lysine / total amino acids	0.066	0.067	0.070	0.075	0.067	0.063
Methionine / total amino acids	0.032	0.026	0.030	0.013	0.016	0.023
(Methionine + Cysteine) / total amino acids	0.062	0.058	0.061	0.046	0.037	0.052
Basic amino acids / acid amino acids	1.042	0.894	1.029	1.036	1.003	1.118
Essential amino acids / unessential amino acids	0.826	0.716	0.840	0.813	0.812	0.941

The enzymatic activity of the two genotypes was similar as each presented a similar type of enzymogram consisting in two isoesterases with intense activity and one esterase with reduced activity. After treatment with the mutagen agents we observed an overall reduction in enzymatic activity.

Conclusions

The *in vitro* mutagen treatments can change the amino acid content, as well as the ratio of different amino acids. There was a differentiated reaction of the two genotypes as 'Linia 401' was much more susceptible to the mutagen treatment than 'Cluj 84'.

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Study of genetic diversity in *Dactylis* L. regarding phenolic spectra

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Abstract

Spectra of phenolic substances were used to study genetic affinity in the polyploid complex of *Dactylis* L.. The content of 9 free phenolic acids was determined after the extraction of dried herbage with 2 *M* HCl, using reverse phase and gradient elution of mobile phases, on the HPLC HP 1100 with DAD detection. The diploid subspecies demonstrated distinct differences from the tetraploids as a clearly specialized group. Caffeic acid dominated, followed by ferulic and p-coumaric acids. The presence of rosmarinic acids is of special interest. Phenolic profiles are sufficiently specific for single groups in *Dactylis* L. and they can be used in chemo-taxonomical research in grasses even at lower taxonomic levels.

Keywords: plant phenolics, polymorphism, genetic diversity, markers, chemo-taxonomy

Introduction

Besides the broad utilisation of DNA-based technology for the research of genetic diversity of species and lower taxonomy units, the products of secondary metabolism might be considered. An array of various compounds, e.g., phenolics, terpenes, and alkaloids possessing extreme diversity, is made up by gradual reactions from these primary molecules in a plant. Being encouraged by the results of Jay *et al*. (1996) we tried to use the wide diversity of plant phenolic profiles to distinguish subspecies of *Dactylis* from a chemo-taxonomical point of view.

Materials and methods

Herbage samples of 35 cocksfoot ecotypes (*Dactylis glomerata* ssp. *glomerata*, 2n = 28), 5 ecotypes of *D. glomerata* ssp. *galiciana* (2n = 14), 3 ecotypes of *D. glomerata* ssp. *lusitanica* (2n = 14), 7 Czech cultivars of *D. glomerata* ssp. *glomerata* (2n = 28), and 1 cultivar of *D. glomerata* ssp. *Polygama* cv. 'Tosca' (2n = 14) were collected from a field trial (Míka *et al*., 2002) at the Jevíčko site in the 1st cut in 2002. The content of 9 free phenolic acids (Table 1) was determined after herbage extraction (desiccated at 55 °C) with 2 *M* HCl on the fexIKA-Werke 50®extractor, reverse phase on Hypersil BDS C18 sorbent and gradient elution of mobile phases on the HPLC HP 1100 with DAD detection. The identification of substances was carried out by the comparison of retention times with retention times of standards and by comparison with library of spectra. The contents (in µg g^{-1}) of phenolics were evaluated by the procedure of hierarchical cluster analysis. *Dactylis* groups (indicated in Figure 1 as 1, 2, 3, 4 and 5) are explained in the heading of table 1.

Results

Caffeic acid dominated among free phenolic substances in *Dactylis* sp., followed by ferulic and p-coumaric acids. The presence of rosmarinic acid (Table 1) is of interest. The weight of phenolic acids used as chemical markers of genetic diversity decreased in the order: ferulic acid > p-coumaric acid > vanilic acid > vanilin acid > p-hydroxybenzooic acid > caffeic acid > chlorogenic acid > rosmarinic acid > protocatecheic acid > p-hydroxybenzaldehyde >

sinapic acid. Phenolic profiles are sufficiently specific for single groups of *Dactylis*, so that according to Euclidean measure the affinity, from a taxonomical point of view, can be distinctively determined. *D. glomerata* ssp. *polygama* is separated in the dendrogram from other tested diploid and tetraploid subspecies. Out of them are very close *D. glomerata.* ssp. *glomerata* ecotypes and cultivars. Relatively close are also diploids of *D. glomerata* ssp. *galiciana* and *D. glomerata* ssp. *lusitanica*.

Table 1. Characteristics of the sub species of *Dactylis glomerata* (mean ± s.d.)

	Dactylis glomerata ssp. *glomerata* ecotypes	*Dactylis glomerata* ssp. *galiciana* ecotypes	*Dactylis glomerata* ssp. *lusitanica* ecotypes	*Dactylis glomerata* ssp. *glomerata* cultivars	*Dactylis glomerata* ssp. *polygama* cultivar
n =	35	5	3	7	1
Marked in Figure 1 as:	1	2	3	4	5
Vanillic acid	9.2 ± 3.1	6.7 ± 3.1	5.3 ± 0.7	8.1 ± 2.9	14.4
Chlorogenic acid	11.5 ± 5.3	11.1 ± 8.4	14.7 ± 2.9	14.7 ± 6.6	56.0
Caffeic acid	203.4 ± 103.6	133.8 ± 137.5	192.8 ± 50.0	163.4 ± 69.7	228.1
Vanilline	1.8 ± 0.9	2.2 ± 1.0	1.5 ± 0.2	2.3 ± 0.9	6.6
p-Coumaric	37.8 ± 20.7	25.1 ± 25.5	17.3 ± 3.5	46.5 ± 22.2	86.6
Ferulic acid	110.2 ± 64.5	69.9 ± 86.4	52.5 ± 6.4	144.9 ± 75.9	300.7
Rosmarinic acid	7.2 ± 3.6	6.2 ± 3.1	10.8 ± 4.4	11.3 ± 6.2	29.3
Cinnamic acid	0.8 ± 0.4	0.8 ± 0.2	0.7 ± 0.3	0.8 ± 0.5	1.2

Discussion

The species *Dactylis glomerata* is very differentiated in both its morphological and physiological traits with different taxonomic subspecies possessing different economic values. Basically it is a complex polyploid with a diploid cytotype. The diploid subspecies is separate from the tetraploid one, not only according to isozyme and flavonoid polymorphism (Casler *et al*., 1996), but also according to phenolic profiles (Figure 1). The diploid subspecies demonstrate distinct differences as a clearly differentiated and specialized group (similarly to Jay *et al*., 1996). This picture fully corresponds to the position of tested diploid and tetraploid subspecies in the frame of the Eurasian morpho-geographical group, enunciated recently according to cytogenetic, morphological, geographic and ecological criteria (Lumaret, 1988). Phenolic profiles can commonly be used in chemo-taxonomic research for grasses and legumes, as we found out with *Festuca* sp., *Bromus* sp. and *Lotus* sp. (Míka, unpublished results).

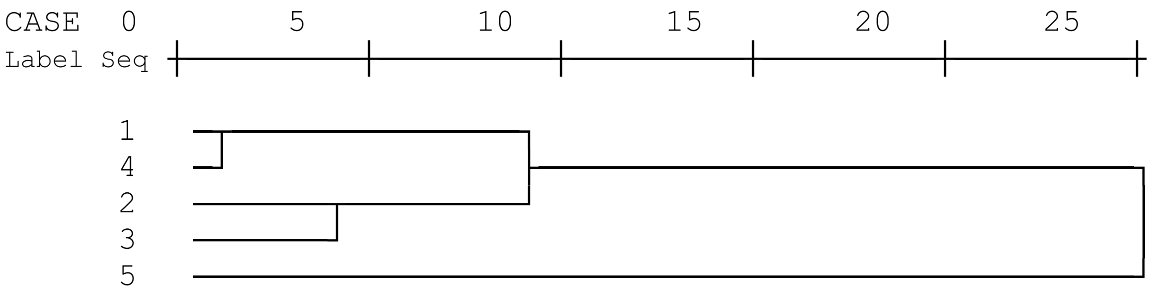

Figure 1. Dendrogram using Ward Method.

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The value of foreign cultivars of *Festuca pratensis* Huds. in Polish conditions

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Abstract

On the basis of the experiments in the years 1999-2002, significant inter-specific differences were found in yield potential of the examined varieties. Pradel cultivar was found the most productive, especially in the last (third) year of its utilization yielding an average of 118 % of dry matter crop of the standard variety of Skra (PL). The examined cultivars were found to interact with habitats. In the first re-growth, the foreign cultivars were characterised by higher contents of fibre in comparison with the standard Skra cultivar, which was accompanied by a lower concentration of crude protein. The examined foreign cultivars achieved more favourable results of crude protein and fibre content in the second re-growth.
In addition, the examined foreign varieties also exhibited good winter hardiness, especially between the second and third year of utilisation as well as a rapid rate of re-growth in spring (in particular Preval and Darimo).

Keywords: *Festuca pratensis* Huds., cultivars, re-growth energy, yield, feed energy

Introduction

In Poland, *Festuca pratensis* is a basic component of mixtures for permanent grasslands as well as for field cultivation. Its proportion in meadow communities makes up from 20 to 30 % of sward botanical composition, whereas in the case of pastures this figure is 15 to 35 %. In Great Britain, *Festuca pratensis* is considered to be the best grass species for making silages and for cultivation with lucerne grown for seeds on arable land (Domański, 1997). Long-term breeding programs regarding *Festuca pratensis* should take into account increased sward density, very good winter hardiness, rapid plant re-growth after defoliation and ensuring high yields and high nutritive value (Carlen *et al*., 2002; Falkowski, 1982; Kölliker *et al*., 1998; Kozłowski and Kukułka, 1993; Sawicki, 1999).

Materials and methods

In years 1999-2002, in eight experimental stations of the Research Centre for Cultivar Testing, distributed in different regions of Poland, 10 cultivars of *Festuca pratensis* bred in Holland, Germany, Poland and Switzerland were investigated. In two series, 16 simulated pasture experiments (5-6 cuts annually) in four repetitions were carried out according to the method of random blocks. In years of full utilisation, the following fertilisation was applied: 60 kg N ha^{-1} per re-growth and in spring one dose of 40 kg P_2O_5 ha^{-1} and 80 kg K_2O ha^{-1} in two equal doses (in spring and after the first cut). The obtained results were subjected to statistical analysis performing a full analysis of variance including cultivar-environment interactions (C $\times$ S). Concentrations of crude protein and crude fibre were determined in samples of dried plants. In addition, feed energy yield was calculated for individual cultivars.

Results

The obtained results of the analysis of variance associated with cultivar yields of the *Festuca pratensis* species indicated those cultivars which, in the years of utilisation, were characterised by yields significantly higher than average yields for the examined cultivars (Table 1).

Table 1. Analysis of experimental series of *Festuca pratensis* Huds. cultivars in multi-cutting utilisation (with all cuts and years).

	Cultivars									
	Preval	Darimo	Pradel	Premil	FP 4	ZFP8715	Swift	Lifelix	Wanda	Skra #
DM yield (dt ha^{-1} y^{-1})	132.7	125.9	135.0	128.2	130.1	122.9	125.5	121.6	121.4	119.2
Main effect	6.44**	-0.34	8.75**	1.97	3.82	-3.33	-0.75	-4.66**	-4.83**	-7.07**
F value (C × S)	1.5	2.62**	4.76**	4.27**	7.55**	4.20**	2.43**	3.67**	4.31**	10.6**
Regression coefficient	0.02	-0.01	0.04	0.03	0.08	-0.02	0.02	-0.01	-0.08	-0.06
Determin. co-efficient (%)	2.5	1.0	0.8	3.1	12.2	2.1	3.4	0.3	22.2	5.2
MES	29.6**	NS	28.1**	NS	11.6*	NS	NS	NS	NS	-

NS = Non-significant, ** significant at $P < 0.01$, MES - the result of testing of the Main Effect when comparing with the Standard as well as interactions in comparison with sites. # cv. Skra – standard.

Preval, Pradel, Premil and Darimo cultivars produced yields significantly higher than the remaining ones and they were subjected to further detained evaluation investigations in the subsequent studies. Dry matter yields of the examined cultivars in individual experimental stations varied in the result of differences in agro-meteorological conditions occurring in them. Almost all cultivars revealed a significant C × S interaction. The cultivars Preval, Pradel and Darimo were characterised by considerable re-growth energy, whereas in the second and third re-growth, Preval and Pradel cultivars bred in Switzerland were characterised by very good winter hardiness (Table 2).

Table 2. Major useful traits of *Festuca pratensis* Huds. cultivars (in 9^{o} scale).

Treatment	Cultivar					
	Skra	Premil	Preval	Pradel	Darimo	Wanda
Over wintering in year:						
first	8.7	8.7	8.9	8.9	8.5	8.9
second	8.3	8.5	8.6	8.5	8.4	8.2
third	7.9	8.2	8.3	8.3	8.3	7.6
Re-growth energy:						
in spring	7.7	8.2	8.8	8.4	8.7	7.6
after first cut	7.6	7.6	7.6	7.9	7.5	7.6
after second cut	7.9	8.2	8.2	8.4	8.0	7.8
after third cut	7.7	7.9	8.1	8.2	7.9	7.6

Yields of the examined cultivars, in consecutive years of utilisation, exhibited a declining tendency and the highest yields were recorded in the case of cultivars derived from Switzerland (Table 3). Cultivars Pradel and Preval were characterised by exceptionally high total feed energy content (Table 4).

Table 3. Dry matter yields of *Festuca pratensis* Huds. cultivars in multi-cutting utilization.

Year of utilisation	Cultivar					
	Skra – standard ($t\ ha^{-1}\ y^{-1}$)	Premil	Preval	Pradel	Darimo	Wanda
		in comparison with the standard cultivar Skra (%)				
1	12.7	105	107	110	103	101
2	10.0	108	112	114	106	101
3	8.3	108	108	118	107	105

Table 4. Yields of feed energy of *Festuca pratensis* cultivars in multi-cutting utilization.

Year	Cultivar					
	Skra - standard ($UF * ha^{-1}\ y^{-1}$)	Premil	Preval	Pradel	Darimo	Wanda
		in comparison with the standard cultivar Skra (%)				
2000	12584	107	105	110	103	103
2001	11274	109	114	117	108	103
2002	10777	107	109	115	107	106

* UF – unit feed.

Concentrations of crude protein of the examined cultivars (included in the register of original cultivars in Poland) were the highest in the second re-growth reaching, on average, 20 % and were higher in comparison with the standard cultivar Skra. Cultivar Pradel contained the highest level of protein in the first re-growth (18.6 % DM). On the other hand, the content of crude fibre in the first re-growth ranged from 22-23 % and 23.5-24% DM in the second one. The smallest quantities of crude fibre in the first re-growth were recorded in the Skra cultivar, while in the second re-growth in Premil.

Conclusions

The results obtained confirmed considerable progress in the breeding work on cultivars of *Festuca pratensis* achieved in Europe. The obtained cultivars are characterised by considerable productivity, good winter hardiness, high dynamics of growth in spring as well as the ability for rapid growth after the second cut (during summer). Therefore, in natural conditions occurring in Poland, the registration of new foreign cultivars – Preval, Pradel and Premil – increases the amount of valuable cultivars of *Festuca pratensis*, which can find considerable application, primarily in mixtures for pastures.

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Persistence and production ability of *Dactylis glomerata* L., *Dactylis polygama* Horvat, *Festuca arundinacea* L. and genus hybrids in 1986-2003

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Abstract

At the Jevíčko site in the Czech Republic (CR) we observed 19 grass varieties in accurate trials which were sown in 1986 and evaluated production ability and persistence of five varieties of *Dactylis glomerata* L. (DG), one variety of *Dactylis polygama* Horvat (DP), two varieties of *Festuca arundinacea* L. (FA) and two inter-generic hybrids. The trials were established by grassland renovation in 1986 (335 m above sea level, temperature 7.5 °C, average annual precipitation 629 mm). Grass species were sown as simple legume-grass mixtures with red clover and white clover, fertilised (240 kg N ha^{-1} + $P_{35}K_{100}$) and cut three times. Evaluation of the system comprised determining dry matter production, botanical composition of the stand and forage quality with the use of NIRS. *Dactylis glomerata* L., *Festuca arundinacea* L. and Festulolium hybrids were among the most productive, *Dactylis polygama* Horvat was less productive but the most persistent grass species under the conditions in the CR. These species are the basis of permanent grass / legume mixtures for grassland renovation and strip seeding into grassland.

Keywords: *Dactylis glomerata* L., *Dactylis polygama* Horvat, *Festuca arundinacea* L., *Festulolium* hybrid, persistence, yields

Introduction

FA has spread significantly in developed forage countries in the last decades due to its advantageous qualities, e.g., production ability, persistence, good health (Buckner and Bush, 1979). DG, FA and Festulolium hybrids are among the most persistent and productive grasses of the grasses used in the Czech Republic (Kohoutek *et al*., 2000). Selection of ecologically compatible grass and clover species for grassland renovation is an objective of long-term research in the Czech Republic.

Materials and methods

Nineteen grass species were sown at the Jevíčko site in 1986, in a trial to evaluate species of *Dactylis glomerata* L., (cv. Niva, Rela, Milona and two newly bred varieties VV-24/75 and VV-126/81 (cv. Dana, 1992)), *Dactylis polygama* (syn. *Dactylis Aschersoniana* Graeb. - cv. Tosca since 1998), *Festuca arundinacea* L. (cv. Lekora and newly bred HŽ-BI (cv. Kora, 1989)) and Festulolium genus hybrids (two newly bred varieties, MRK-HŽ I (cv. Felina, 1988) and MRK-HŽ III/3). They were sown at the Jevíčko site in 19 simple grass / legume mixtures (60 % grass species, 25 % *Trifolium pratense* L., 15 % *Trifolium repens* L.) with 4 replications in small plots (10 m^2). They were studied in a 3-cut system. Grass / legume mixtures and pure cultures were fertilised with nitrogen rates of 120 kg ha^{-1} (1987), 180 kg ha^{-1} (1988 and 1989) and 240 kg ha^{-1} (1990-2003). The dry matter production of the species was calculated as dry matter production × % of proportion of sown grass in the grassland, from an evaluation of botanical composition, divided by 100. The quality of forage dry matter in 1995-2002 was evaluated with the NIR Systems 6500 instrument equipped with a spinning sample module, in reflectance range 1100-2500 nm, band width 2 nm, measured in small ring cups, 2 × 2 replications (i.e., 2 fillings of each sample and double scanning of each cup filled). The parameters used were crude protein, fibre, NEL (net energy of lactation), NEV (net energy of fattening), PDIE (ingested digestive protein allowed by energy) and PDIN (ingested digestive protein allowed by nitrogen).

Results

Dry matter (DM) production (Figures 1 and 2) of the evaluated grasses was similar even in the trial years, the differences between years are caused by rainfall.

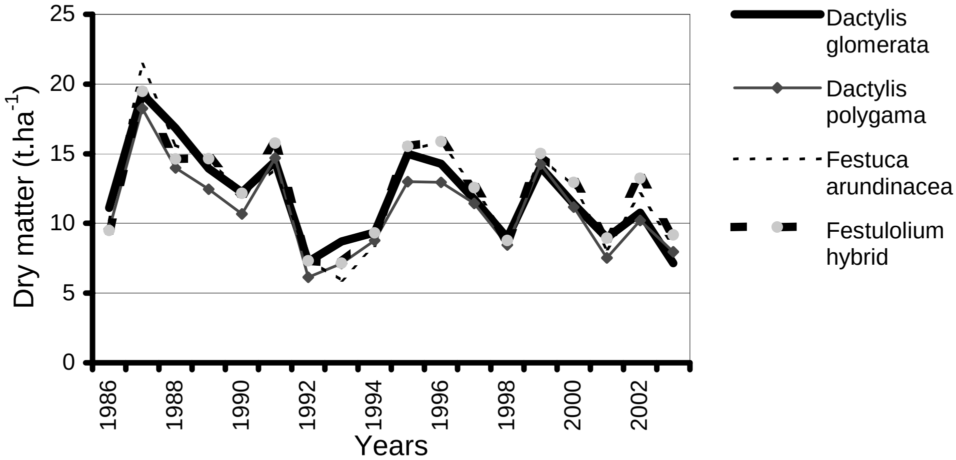

Figure 1. Dry matter production (t ha^{-1}) variants of DG, DP, FA and Festulolium hybrid at the Jevíčko site in 1986-2003.

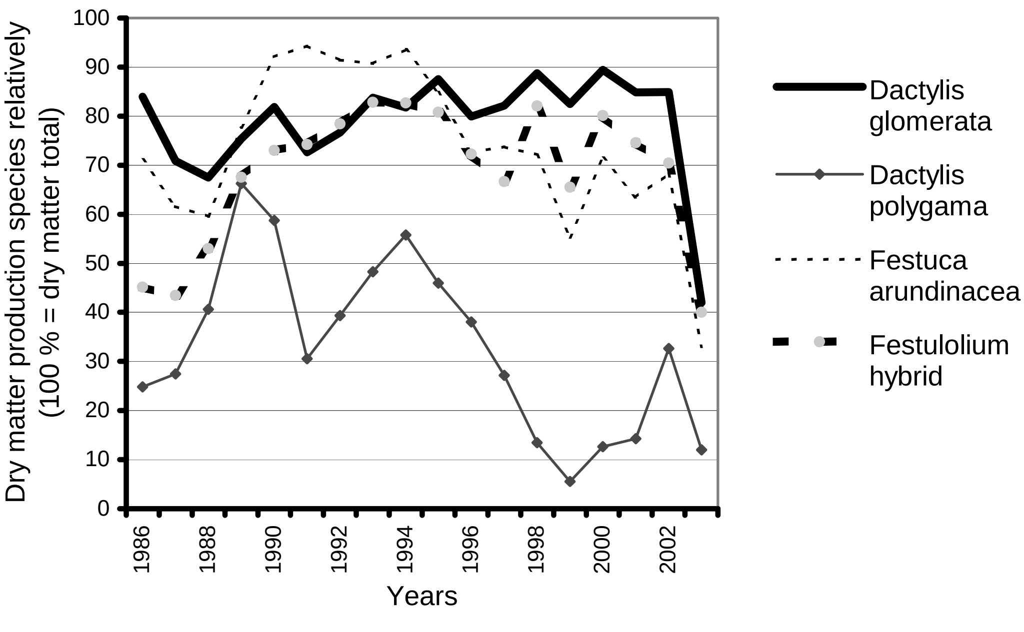

Figure 2. Relative dry matter production of sown species DG, DP, FA and Festulolium hybrid at the Jevíčko site in 1986-2003.

The annual yields of DG were 80-90 % of sown species and had a tendency to increase, which shows high persistence and competitiveness of DG. The DP, which is less competitive, had a gradually decreasing proportion of dry matter production, from the first five years after sowing (50-60 %) to 10-30 % in the last five years. Native species penetrated gradually into this grassland. FA increased its proportion from the initial 60-70 % after sowing to 80-90 % in the first ten years, while in the last five years of evaluation its proportion in the grassland was between 60-70 %. Festulolium hybrids were less competitive after sowing than FA, which is favourable for sown legumes in the first two to three years after sowing. After the fifth year their proportion in the grassland was steady at 70-80 %. In the year 2003, due to strong winter frosts without snow cover, there was deep sod freezing which resulted in a lower share of the species being recorded in the DM yield. In the following period the species regenerated and their vigour improved. However, the persistent dry weather caused low DM-yield in second cut. The DM yield in the third cut was negligible due to lasting dry weather, and that in total resulted in the profound decline of DM production species annual yield by 40 % in comparison to the previous years.

The forage quality (Table 1) of evaluated grasses was similar, the concentration of crude protein being in the range 160.3-168.7 g kg^{-1} and the concentration of NEL and NEV in the range 5.68-5.73, and 5.51-5.54 MJ kg^{-1}, respectively. The values of PDIE and PDIN were in the range 83.0-84.6, and 97.0-102.2 g kg^{-1}, respectively.

Table 1. Parameters of forage quality of four grass species in the average of years 1995-2002.

Species	Crude protein (g kg^{-1} DM)	Fibre (g kg^{-1} DM)	NEL (MJ kg^{-1} DM)	NEV (MJ kg^{-1} DM)	PDIE (g kg^{-1} DM)	PDIN (g kg^{-1} DM)
Dactylis glomerata	166.1	256.9	5.73	5.54	84.5	99.7
Dactylis polygama	168.7	256.8	5.71	5.54	84.6	102.2
Festuca arundinacea	162.8	254.7	5.70	5.53	83.3	98.3
Festulolium hybrid	160.3	255.9	5.68	5.51	83.0	97.0
$LSD_{0.05}$	5.7	8.4	0.05	0.04	2.1	3.3
$LSD_{0.01}$	6.5	10.2	0.07	0.06	2.5	4.2

Discussion

The importance of *Festuca pratensis* Huds. and *Lolium perenne* L. among the typical grassland species in the conditions of the Czech Republic has decreased in the last 10-15 years, because they have poor persistence. *Festuca arundinacea* L. together with inter-generic hybrids of the festucoid type have started to gain importance, as was the case in the USA, France and other countries in the 1970's and 1980's (Buckner and Bush, 1979). FA and DG are grasses of the central European region which may have a significant role in the period of global warming, because they are potentially the best at tolerating drier conditions. FA is also suitable, because of its over-growing capacity and availability in a prolonged grazing season (leaves are green until December).

Acknowledgements

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Yield and ensilability of diploid / tetraploid *Lolium perennne* varieties and *Trifolium repens f. hollandicum / giganteum* in mixtures

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Abstract

In the last few years, tetraploid varieties of *Lolium perenne* have become important for fodder production. The advantage of these tetraploid varieties is a higher yield and a higher content of water-soluble carbohydrates. At the same time, biological N_2-fixation rate of *Trifolium repens f. giganteum* is high, which is interesting in view of the usually low nitrate contents of grassland growth. Therefore, the water-soluble carbohydrate / buffering capacity (WSC / BC) ratio), and the nitrate concentrations of diploid / tetraploid varieties of *Lolium perenne* and *Trifolium repens f. hollandicum / giganteum* in mixtures with other grasses, were analysed over two years. The first cut was divided into two harvest times, the other cuts were all harvested at the same time. The results show that mixtures with tetraploid *Lolium perenne* varieties and *Trifolium repens f. giganteum* often had higher DM yields. *Trifolium repens f. giganteum* mixtures mostly had lower contents of water-soluble carbohydrates. However, because of different buffering capacities, there was no major effect on the WSC / BC-ratio. The *Lolium perenne* varieties had no great effect on ensilability, with the exception of the first growth in 2001 the growth did not show sufficient nitrate levels.

Keywords: ensilability, tetraploid, *Lolium perenne*, *Trifolium repens*, nitrate

Introduction

For a good silage quality high contents of water-soluble carbohydrates, and nitrate concentrations higher than 0.05 % in DM (Weissbach and Honig, 1996) are necessary. In extensive grassland systems low nitrate concentrations are often problematic for silage production (Sterzenbach, 2000). Therefore *Lolium perenne* is one of the interesting grass species. In recent years tetraploid varieties have become important in seed production. In 2001, 37 out of 106 (35 %) *Lolium perenne* varieties, which figure in the registered list of varieties, are tetraploid. The advantage of these varieties is a higher concentration of water-soluble carbohydrates, therefore they are important for silage production (Opitz v Boberfeld, 1994). The N_2-fixation rate of *Trifolium repens f. giganteum* is high, useful in order to achieve higher nitrate concentrations and therefore a better ensilability. The results that can be found in the relevant literature often stem from examinations of monocultures, which is why in this trial the ensilability of diploid / tetraploid *Lolium perenne* varieties and *Trifolium repens f. hollandicum / giganteum* was analysed in mixtures with other grasses.

Materials and methods

To analyse their yield and ensilability, four mixtures of diploid / tetraploid *Lolium perenne* varieties (six cv per ploid level) and *Trifolium repens f. hollandicum / giganteum* (two cv per white clover type) were sown with other grasses in a trial as a latin rectangle with four replications (Table 1). The forage was harvested in five (2001) and four (2002) cuts per year. The first cut was divided into two harvest times (middle and end of May), the other cuts were harvested at the same time. The DM-yield per ha was calculated on the basis of the FM yield and the DM content after the growth had been dried at 103 °C. To characterise ensilability, the contents of water-soluble carbohydrates (Yemm and Willis, 1954), the buffering capacity (Weissbach, 1967) and the nitrate concentrations (Anonymous, 1997) were analysed.

Table 1. Variants, designed as latin rectangle.

	Mixture 1	Mixture 2	Mixture 3	Mixture 4
Lolium perenne (diploid) (seed rate 14 kg ha^{-1})	ANTON LABRADOR AUBISQUE TWINS CASTLE TRIVOLI	ANTON LABRADOR AUBISQUE TWINS CASTLE TRIVOLI		
Lolium perenne (tetraploid) (seed rate 14 kg ha^{-1})			BARANNA LIPRINTA LIPERRY SALEM LIPONDO LIVREE	BARANNA LIPRINTA LIPERRY SALEM LIPONDO LIVREE
Trifolium repens f. hollandicum (seed rate 2 kg ha^{-1})	LIREPA MILKANOVA		LIREPA MILKANOVA	
Trifolium repens f. giganteum (seed rate 2 kg ha^{-1})		L.F.G. GIGANT ZERNO		L.F.G. GIGANT ZERNO
Festuca pratensis (seed rate 6 kg ha^{-1})	COSMOS 11	LIFARA		
Phleum pratense (seed rate 5 kg ha^{-1})	LIROCCO	THIBET		
Poa pratensis (seed rate 3 kg ha^{-1})	LATO	LIMAGIE		

After that the WSC / BC-ratios were calculated. All data were analysed separately for every cut and year with the help of analysis of variance. The LSD test was made at 5 % significance level. Figure 1 shows the annual DM yield; and figures 2 and 3 present the results of the first cut.

Results and discussion

The results show that mixtures with tetraploid *Lolium perenne* varieties and mixtures with *Trifolium repens f. giganteum* genearlly have higher DM-yields (Figure 1). This agrees with the results of Opitz v Boberfeld (1994), who found that *Trifolium repens f. giganteum* has the highest yields of the white clover varieties. In contrast to the results of this examination Lütke Entrup (2000) found no differences in the DM yield of diploid / tetraploid *Lolium perenne* varieties. Contrary to the results of Nösberger and Opitz v Boberfeld (1996), this examination shows that mixtures with tetraploid *Lolium perenne* varieties do not have higher contents of water-soluble carbohydrates than diploid varieties.
Thus, there is no effect on the WSC /

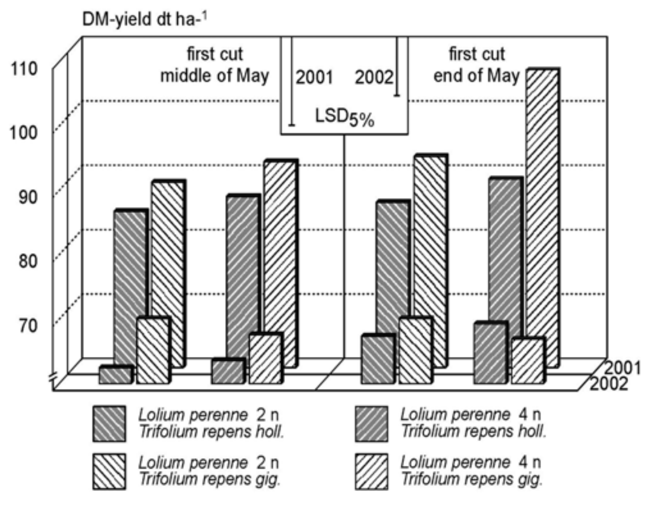

Figure 1. DM yield dependence on year, cutting date and *L. perenne / T. repens* variety.

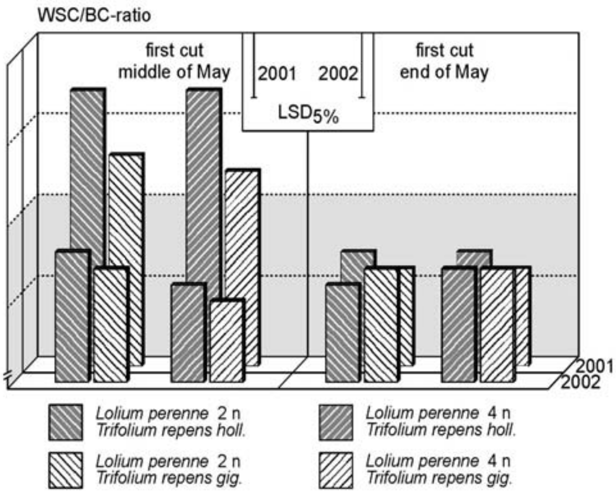

Figure 2. WSC / BC-ratio dependence on year, cutting date and *L. perenne / T. repens* variety.

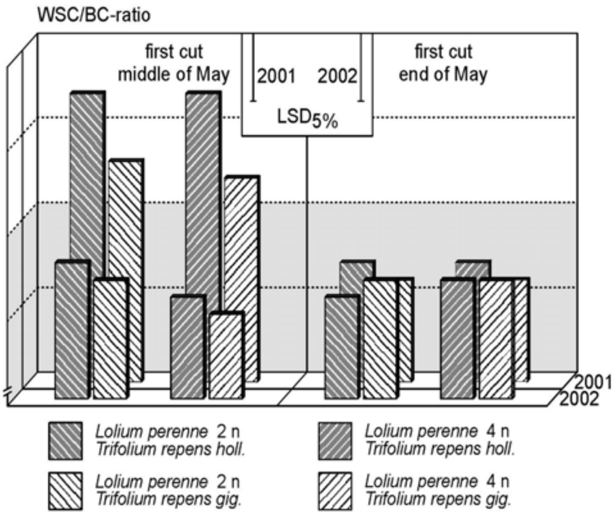

Figure 3. Nitrate-concentration dependence on year, cutting date and *L. perenne / T. repens* variety.

BC-ratio, (Figure 2). The reason is that the other grasses in the mixture equalize the contents of water-soluble carbohydrates. *Trifolium repens f. giganteum* mixtures often have lower contents of water-soluble carbohydrates; because of different buffering capacities there is no great effect on the WSC / BC-ratio. One reason for the lower contents of water-soluble carbohydrates could be higher contents of crude protein. On the other hand white clover has more carbohydrate in the form of starch, which does not possess a high degree of water-solubility (Opitz v Boberfeld, 1994).

With the exception of the first cut in 2001, i.e., the first cut after sowing the mixtures, the nitrate concentrations are comparable to the low results of Sterzenbach (2000). Thus, *Trifolium repens f. giganteum* does not have a positive effect on nitrate concentration.

Conclusions

Based on this trial data, it can be stated that tetraploid *Lolium perenne* varieties and *Trifolium repens f. giganteum* have generally higher DM yields, but in mixtures they do not have a positive effect on ensilability. Due to the low nitrate concentrations in the growth it is recommendable to use nitrate / nitrite additives to reduce the risk of butyric acid fermentation.

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Productivity and yield quality of *Festulolium* and *Lolium* x *boucheanum* varieties

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Abstract

Field trials were established with the aim of studying winter hardiness, productivity and forage quality of six *Festulolium* and *Lolium* x *boucheanum* ryegrass foreign varieties under agro-ecological conditions of Latvia. Swards were developed on a sod-podzolic soil and fertilised with N ($120_{(60+60)}$, and $180_{(60+60+60)}$ kg ha^{-1}), P (40 kg ha^{-1}) and K (150 kg ha^{-1}). Swards were cut three times during the growing season.
Swards were sown in May and dry matter (DM) yield and quality parameters (CP, CF, NDF, ADF and IVOMD) were determined on the first cut in the following season. Differences between varieties in winter hardiness and DM yield were highly significant. Some parameters of quality were influenced by genotype.

Keywords: *Festulolium*, *Lolium* x *boucheanum*, productivity, yield quality

Introduction

Intensification of agricultural production is related to the development of new varieties. Improvements in yield, quality and persistence of hybrids between *Lolium multiflorum* x *Lolium perenne* are being made using new genetic resources. Generally, hybrid ryegrass is very palatable with good digestibility and intake properties, leading to more efficient animal production. It also incorporate high levels of winter hardiness, drought tolerance and disease resistance. The aim of hybrid ryegrass is to combine the best attributes of Italian and perennial ryegrass. Italian ryegrass is less winter hardy but higher yielding than perennial ryegrass (Adamovich and Adamovicha, 2003; Humphereys and Jones, 1988).
Greater sward productivity may be obtained through use of hybrid combinations of contrasting grass species. Thus, ryegrass and fescue were crossed in order to improve the over-wintering of perennial ryegrass. For a long time breeders have been trying to put together valuable traits of these genera by crossing. Important requirement for *Festulolium* is combining such characters of ryegrass as productivity, growth potential and feeding quality, and from fescues, stress resistance in wintering and resistance to drought during the growth period (Sliesaravicius, 1997; Lysczarz, 2000).
Lolium x *Festuca* hybrids have better persistence, disease resistance and winter hardiness than ryegrasses, and better season-long productivity and higher forage quality than fescues. Some varieties are more like the ryegrasses and some more like fescues, depending on the breeding effort following the cross. *Lolium* x *Festuca* hybrids have good agronomical potential especially in adverse environments. (Veronesi, 1991; Nesheim and Bronstad, 2000)

Materials and methods

Field trials were conducted in Latvia to study crop productivity processes and yield quality in *Festulolium (Lolium ssp.* x *Festuca ssp.)* and hybrid ryegrass *(Lolium* x *boucheanum)*. Stands on Sod-Podzolic soils ($pH_{(KCl)}$ = 7.1, P = 253 and K = 198 mg kg^{-1}, organic matter content = 31 g kg^{-1} of soil) were established.
Swards were composed of: perennial ryegrass ‘Spidola’ (control), festulolium – ‘Perun’ *(Lolium multiflorum* x *F. pratensis)*, ‘Punia’ *(Lolium multiflorum* x *F. pratensis)*, ‘Lofa’ *(Lolium multiflorum* x *F. arundinacea)*, ‘Felina’ *(Lolium multiflorum* x *F. arundinacea)*,

‘Hykor’ *(Lolium multiflorum* x *F. arundinacea)*, hybrid ryegrass – ‘Tapirus’ *(Lolium multiflorum* x *L. perenne)* and ‘Ligunda’ (*Lolium multiflorum* x *L. perenne*).
The total seeding rate was 1000 germinating seeds per m^2. Trials were sown in the beginning of May. The plots were fertilised with P (78 kg ha^{-1}), K (90 kg ha^{-1}) and N ($120_{(40+40+40)}$ and $180_{(60+60+60)}$ kg ha^{-1}). Swards were cut three to four times per season.
Chemical composition of plants was determined only on the first cut by the following methods: crude protein (CP) – modified Kjeldahl; crude fibre (CF), neutral detergent fibre (NDF) and acid detergent fibre (ADF) – Van Soest (1980); *in vitro* digestibility of the organic matter (IVOMD – De Boever *et al.* (1994).

Results and discussion

Unfavorable weather conditions with lasting ice in 2002-2003 did not cause winter-killing of the studied cultivars, except for cv. Ligunda. The average productivity of *Festulolium* accounted for 16.2 t ha^{-1} DM and 1.6 t ha^{-1} CP at the 120 kg N ha^{-1} fertiliser dose. When 180 kg N ha $^{-1}$ was applied there was a DM yield increase of 1.5 t ha^{-1} (10 %). The highest DM yields were found with the DLF-Trifolium cultivars Hykor, Perun and Felina – 18.2, 17.5 and 16.4 t ha^{-1}, respectively (Table 1).

Table 1. Productivity and yield quality of *Festulolium* and *Lolium* x *boucheanum* swards.

Nitrogen levels (kg ha^{-1}) (F_A)	Varieties (F_B)	Winter hardiness (1-9)	DM yield		Content in DM (g kg^{-1})			Digestibility *in vitro* (%)
			t ha^{-1}	%	CP	ADF	NDF	
N 120	Spidola (LV)	7.8	11.09	100	107.4	318.7	561.7	65.5
	Lofa (DLF)	6.5	14.30	128	97.2	357.6	580.9	61.0
	Felina (DLF)	7.5	15.96	143	108.6	388.4	664.5	49.5
	Hykor (DLF)	7.0	17.55	158	113.0	384.4	654.6	52.5
	Perun (DLF)	7.5	16.61	149	85.8	353.8	578.6	61.5
	Tapirus (DSV)	6.8	13.43	121	74.8	333.0	548.4	62.0
	Punia (LT)	8.0	16.58	149	98.4	386.7	642.2	56.0
N 180	Spidola (LV)	7.8	12.91	100	125.6	314.9	544.5	67.2
	Lofa (DLF)	6.5	15.73	121	110.2	336.9	554.7	64.8
	Felina (DLF)	7.5	16.86	130	112.6	398.7	675.4	48.4
	Hykor (DLF)	7.0	18.88	146	121.6	354.8	620.5	58.7
	Perun (DLF)	7.5	18.46	143	106.0	356.6	604.3	60.2
	Tapirus (DSV)	6.8	15.07	116	95.8	336.1	548.9	63.3
	Punia (LT)	8.0	18.46	142	102.2	379.0	625.0	59.8

$LSD_{0.05}$ for DM yield: F_A = 0.32; F_B, F_{AB} = 0.46; Trial = 0.61

The average DM yields of *Festulolium* cultivars was improved by 4.9 t ha^{-1} (35 %), and those of hybrid ryegrass by 2.3 t ha^{-1} (19 %) when compared to perennial ryegrass.
Compared to perennial ryegrass, the 1st cut DM yield had higher NDF and ADF contents, thus negatively affecting DM digestibility. For *Festulolium* cultivars, the average ADF and NDF content was 315-374 g kg^{-1} DM and 616-624 g kg^{-1} DM, respectively. For the hybrid ryegrass cultivars it was 333 and 548 g kg^{-1} DM, respectively. The average DM digestibility for the studied cultivars was 57.2 %, which was 5.4 % lower when compared to perennial ryegrass. The lowest DM digestibility was observed with cv. Felina.
Drought resistance, a most significant trait, was particularly well expressed under conditions of drought. Under such adverse growing conditions the 2nd cut productivity of the studied cultivars depended on the fertiliser doses, and was on average increased by 1.66-2.19 t ha^{-1} (269-329 %) when compared to perennial ryegrass ‘Spidola’.

Conclusions

Cultivars of *Festulolium* and *Lolium* x *baucheanum* in Latvia are promising species of fodder grasses. Due to its quality and competitive productivity *Festulolium* may be equally ranked with the main forage grasses timothy and meadow fescue grown in climatic zone of Latvia. Further research results will show the possibilities of using *Festulolium* and hybrid ryegrass in grassland development

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Impact of water deficit on growth and productivity of *festololium* hybrid

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Abstract

Growth and productivity of a grass sward monoculture based on an intergeneric hybrid *(Festuca pratensis* Huds. x *Lolium multiflorum* Lam.) were studied in the warm dry region of south Slovakia (Nitra, 145 m asl) during two years (1999-2000) which differed in the amount of rainfall during the growing season (366 and 195 mm, respectively). Water deficit (53 %) reduced leaf area index (LAI), net assimilation rate (NAR) and other growth parameters. In 2000, the mean LAI and NAR values decreased to 37 and 38 %, respectively of the values for 1999. The most drastic decline (14 % of the 1999 value) was evident for crop growth rate (CGR). The shortage of rainfall in 2000 influenced yield of dry matter, which was reduced from 10.9 t ha^{-1} (1999) to 5.3 t ha^{-1} (2000), representing a reduction of 52 %. The existence of reduced dry matter production in the summer period (summer depression) was confirmed.

Keywords: water deficit, grass monoculture, intergeneric hybrid, growth analysis, productivity

Introduction

Global changes in the earths atmosphere are leading to increases in air temperature and reduction in rainfall. It has been concluded that in Slovakia in the last 100 years the air temperature has increased by 1 ^{o}C and rainfall has decreased (Špánik *et al*., 2001). Water deficit influences the basic processes connected with grass productivity (Jones, 1988) and aspects of this continue to be studied in detail (Assuero *et al*., 2002). The main aim of our study was to analyse the influence of water deficit on the growth and productivity of a grass sward monoculture under field conditions.

Materials and methods

The field experiment was established in the dry warm region of south Slovakia (Nitra, Luzianky 145 m asl). The concentration of basic soil elements (brown soil, 0–15 cm, pH = 6.7) is as follows: C_{ox} = 14.2 g kg^{-1}, N_{tot} = 1.1 g kg^{-1}, P = 33 mg kg^{-1}, K = 89 mg kg^{-1} and Mg = 267 mg kg^{-1}. Over the growing period the average temperature was 16.3 ^{o}C and rainfall was 327 mm. The data for both years, given in table 1 show a 44 % decline in rainfall for 2000. The intergeneric hybrid (IGH – *Festuca pratensis* Huds. x *Lolium multiflorum* Lam. cv. Perun) was sown at 45 kg ha^{-1} in plots of 14.5 m^2 in 4 replicates. The rate of nitrogen fertilisation was 150 kg N ha^{-1} (75 + 50 + 25 kg ha^{-1} for individual re-growth periods) and rate of P and K application was 30 and 60 kg ha^{-1}, respectively. Samples (250 × 250 mm) were taken at the beginning (t_0,W_0 and A_0) and the end (t_1,W_1 and A_1) of individual re-growth periods (three cuts) and the following growth parameters were calculated (Gáborčík, 1986): leaf area index (LAI), net assimilation rate (NAR), relative growth rate (RGR), leaf area growth rate (RGR_A) and crop growth rate (CGR).

Results and discussion

In the first year (1999) cv. Perun comprised 99.6 % of the herbage, but was reduced to 70.3 % in the following year (Table 2). Meteorological data (Table 1) show the severe decline in rainfall in 2000 (53.3 %) and an increase in daily temperature (4.7 %) over the growing period.

Table 1. Monthly and total rainfall (R, mm) and average daily temperature (t_d, ^oC) over growing period in two successive years.

Year	Parameter	Month						Growth
		April	May	June	July	August	September	period
1999	t_d	12.1	15.6	18.5	20.6	19.0	18.1	17.3
	R	59.6	30.0	131.5	90.6	47.1	7.1	365.9
2000	t_d	13.0	17.2	19.9	19.0	22.1	15.4	17.8
	R	26.8	27.6	6.2	60.9	21.5	52.3	195.3
Mean	t_d	10.1	14.8	18.3	19.7	19.2	15.4	16.3
(30 year)	R	43.0	55.0	70.0	64.0	58.0	37.0	327.0

Table 2. Botanical composition (%) of the sward.

Year	Component	Cut			Mean
		1st	2nd	3rd	
1999	cv. Perun	98.9	100.0	100.0	99.6 ± 0.6
	Weeds	1.1	0.0	0.0	0.4 ± 0.6
	Bare ground	0.0	0.0	0.0	0.0
2000	cv. Perun	91.8	66.7	52.5	70.3 ± 19.9
	Weeds	8.2	13.3	20.0	13.8 ± 5.9
	Bare ground	0.0	20.0	27.5	15.8 ± 14.2

The good growing conditions in 1999 (temperature and rainfall + 12 % and + 8 %, respectively in comparison to the 30 year average) resulted in a high leaf area index (LAI) and net assimilation rate (NAR). Average LAI of the cv. Perun sward was 4.7 g m^{-2} d^{-1} and NAR reached 4.05 g m^{-2} d^{-1} (Table 3). These parameters decreased to 2.02 and 1.58 g m^{-2} d^{-1} in 2000 (37 % and 40 %), respectively. Due to the lower LAI and NAR, crop growth rate was also reduced from 26.2 g m^{-2} d^{-1} to 3.7 g m^{-2} d^{-1} (14 %) in 2000. Another important growth parameter, relative growth rate (RGR), was also influenced by water shortage in 2000. In comparison to the year 1999 RGR dropped from 0.06 to 0.02 g g^{-1} d^{-1}, which represents only 33 % of the 1999 value.

Table 3. Growth parameters and primary production of cv. Perun swards over two years.

Cut	Year	RGR ($g\ g^{-1}\ d^{-1}$)	RGR_A ($m^2\ m^{-2}\ d$-^{1})	NAR ($g\ m^{-2}\ d^{-1}$)	CGR ($g\ m^{-2}\ d^{-1}$)	LAI ($m^2\ m^{-2}$)	DM yield ($t\ ha^{-1}$)
1st	1999	0.09	0.03	6.40	53.8	8.25	8.438
	2000	0.04	0.01	2.48	8.27	3.34	1.945
	Mean ± sd	0.07 ± 0.04	0.02 ± 0.01	4.44 ± 2.77	31.04 ± 32.19	5.80 ± 3.47	5.192 ± 4.59
2nd	1999	0.07	0.03	3.88	20.24	5.22	1.277
	2000	0.02	0.02	1.75	1.86	1.09	1.200
	Mean ± sd	0.05 ± 0.007	0.25 ± 0.017	2.82 ± 1.51	11.05 ± 13.0	3.16 ± 2.92	1.238 ± 0.05
3rd	1999	0.03	0.01	1.87	5.49	2.94	1.183
	2000	0.01	0.02	0.55	0.84	1.63	2.128
	Mean ± sd	0.02 ± 0.014	0.015 ± 0.007	1.21 ± 0.93	3.17 ± 3.29	2.29 ± 0.93	1.656 ± 0.07
Mean	1999	0.06 ± 0.03	0.02 ± 0.01	4.23 ± 2.27	26.5 ± 24.8	5.66 ± 2.66	10.90
± s.d.	2000	0.02 ± 0.03	0.02 ± 0.01	1.59 ± 0.97	3.66 ± 4.03	2.02 ± 1.17	5.27
	Mean ± sd	0.04 ± 0.03	0.02 ± 0.00	2.91 ± 1.87	15.1 ± 16.2	3.84 ± 2.57	8.09 ± 3.98

RGR = relative growth rate, RGR_A = relative growth rate of leaf area, NAR = net assimilation rate, CGR = crop growth rate, LAI = leaf area index, DM = dry matter.

The changes in these parameters, especially LAI and NAR, resulted in a decline in dry matter production. In the first year (1999) total dry matter yield was 10.90 t ha^{-1} but only 5.27 t ha^{-1} in 2000 (52 % or less).

Deficit in rainfall in Slovakia which has been detected in recent years (Špánik *et al*., 2001) can induce a short- and / or long-term physiological response in grasses. Durand *et al*. (1995) found reduced leaf extension rate (LER) of grass leaves under water stress and Huang and Gao (1999) confirmed that photosynthesis and transpiration declined under these conditions. Our previous results (Gáborčík, 1986) confirmed that leaf growth rate (RGR_A) and leaf area index (LAI) were more sensitive to moisture stress than net assimilation rate (NAR) in a range of tall fescue cultivars and ecotypes (*Festuca arundinacea* Schreb.). Under water deficiency the allocation of assimilates was also affected. All of these factors were responsible for a decline in dry matter production of the monoculture sward of cv. Perun studied in this experiment.

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Role of storage carbohydrates in hardening and resistance of timothy genotypes to frost and *Typhula* spp.

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Abstract

Timothy (*Phleum pratense* L.) is one of the grass species which is most resistant to abiotic winter stress factors, but susceptible to biotic winter injuries caused by *Sclerotinia borealis* and *Typhula* species. 200 timothy genotypes were tested against cold and snow mould at two conditions. For further tests and analysis of carbohydrates, 25 genoptypes possessing different levels of freezing tolerance and resistance to *Typhula ishikariensis* were selected. The survival of timothy genotypes in the *Typhula* test varied from 0 to 100 % (mean 53.8 %) and the LT_{50} values in the freezing test from -13.8 to -21.8 ^{o}C (mean -18.1 ^{o}C). The amount of fructans in different timothy genotypes increased with decreasing temperatures during the whole hardening period in both conditions. There was a positive correlation between resistance to *T. ishikariensis* and the fructan content of the genotypes. No significant correlation was found between LT_{50} values and fructan contents of the genotypes. However, there was a positive correlation between LT_{50} values and the amount of total non-structural carbohydrates. Several genotypes displayed both high LT_{50} values and good resistance to *T. ishikariensis*. Some genotypes were either tolerant of freezing or resistant to *Typhula* blight.

Keywords: timothy, *Phleum pratense*, hardening, storage carbohydrates, cold, *Typhula* spp.

Introduction

Timothy is resistant to abiotic winter stress factors, but susceptible to biotic winter injuries caused by *Sclerotinia borealis* and various *Typhula* species. Resistance to low-temperature fungi and tolerance to freezing have been considered to be due to different mechanisms. However, a positive correlation between cold tolerance and resistance to snow moulds has been found, for example in timothy and meadow fescue (*Festuca pratensis*) (Årsvoll, 1977). Hardening and increased amounts of reserve carbohydrates improve both resistance to snow mould and freezing tolerance. Falling temperatures and changes in radiation in autumn are factors that launch a genetically regulated hardening process in plants (Hay, 1990; Mahfoozi *et al*., 2000). Sacharose and fructans, polymers of fructose, are the main storage carbohydrates of several plant species, especially in the temperate zone grasses (Chatterton *et al*., 1989). The aim of our study was to test snow mould resistance and freezing tolerance of different timothy genotypes and to investigate differences in the accumulation of reserve carbohydrate composition during hardening.

Materials and methods

Initially, 200 timothy genotypes were tested for resistance to cold and *Typhula ishikariensis* at two research stations of MTT Agrifood Research Finland. For further tests and analysis of carbohydrates, 25 genoptypes possessing different levels of freezing tolerance and *Typhula* resistance were selected.
In cold hardiness tests, timothy plants were grown in a greenhouse and then transferred into a cold chamber for cold acclimation. Tests for cold hardiness were conducted using a

programmable cold bath. After three weeks the survival of plants was recorded and LT_{50} values were calculated according to Gudleifsson *et al*. (1986). In testing resistance to *T. ishikariensis,* seedlings were grown in a greenhouse and transferred outdoors for normal hardening in autumn. The plants were infected by a pathogenic strain of *T. ishikariensis*. Infected plants were covered by moistened cellulose cotton wool and plastic sheets and kept in the dark at +1 to +2 ^{o}C until the disease had reached the desired level of severity. Surviving plants were counted after recovery intervals of one, two and three weeks.
For analysing the accumulation of reserve carbohydrates, samples of crowns and bases of timothy shoots were taken three times at 7 to 10 day intervals during hardening.

Results and discussion

There were large differences between genotypes in tolerance to freezing and resistance to *Typhula* snow mould. The survival of plants of different genotypes in the *Typhula* test varied from 0 to 100 % (mean 53.8 %) and the LT_{50} values in the freezing test ranged from -13.8 to -21.8 ^{o}C (mean -18.1 ^{o}C).

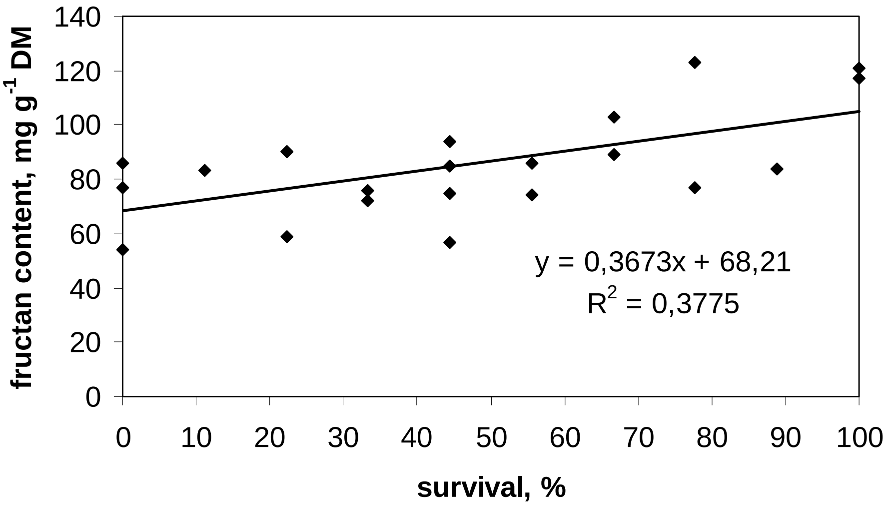

Figure 1. Correlation between the fructan content and resistance to *Typhula ishikariensis* in timothy genotypes.

The amount of fructans in different timothy genotypes increased with decreasing temperatures during the whole hardening period. The absolute fructan content at the end of the hardening period was a little higher in laboratory conditions (mean 100.8 g kg^{-1} DM) than in natural conditions (mean 81.4 g kg^{-1} DM). There was a positive correlation (r^2 = 0.38, P < 0.015) between resistance to *T. ishikariensis* and the fructan content of the genotypes (Figure 1). No significant correlation was found between LT_{50} values and fructan contents of the genotypes. There was a significant positive correlation (r^2 = 0.56, P < 0.003) between LT_{50} values and amount of total non-structural carbohydrates (Figure 2). Several genotypes displayed both high LT_{50} values and good resistance to *T. ishikariensis*. Conversely, some genotypes were either tolerant of freezing or resistant to *Typhula* snow mould. No significant correlation was found between *Typhula* resistance and water-soluble carbohydrate content. Results correspond to those found in winter wheat, where accumulation of mono- and disaccharides has been found to be greatest in cold hardy genotypes (Yoshida *et al.*, 1998), but where accumulation of fructans has correlated with snow mould resistance (Yoshida *et al.*, 1998; Kawakami and Yoshida, 2002).

The content of soluble carbohydrates in crown tissue of timothy increased rapidly during the first weeks of acclimation. However, a subsequent decrease was observed because non-structural carbohydrates were used as a source material for fructan synthesis. The large variation between genotypes was related to the their latitude of origin (Hay, 1990).

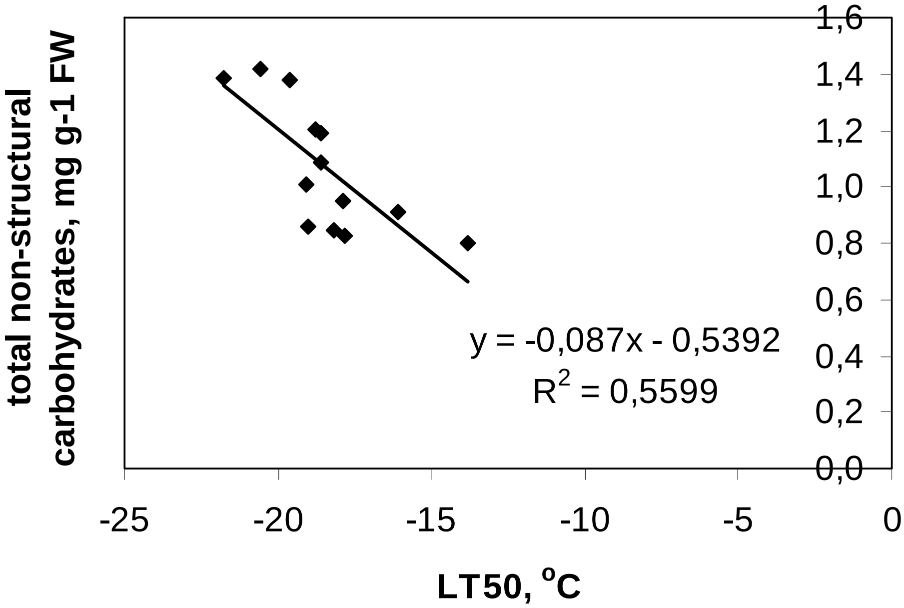

Figure 2. A correlation between the LT_{50} values and the amount of total non-structural carbohydrates of the timothy genotypes.

Conclusions

According to the results of the present study, it is possible to analyse the traits affecting winter survival of timothy. The correlation between resistance to *Typhula ishikariensis* and fructan content was positive. No correlation was found between LT_{50} values and fructan content, but between LT_{50} values and amount of the total non-structural carbohydrates the correlation was positive. Our next step is to use specific molecular markers, so that knowledge of genotype variation and resistance to frost and fungi can be consolidated. This is necessary to promote the development of timothy breeding.

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Study of morphological traits and yield of tall oatgrass populations from Serbia

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Abstract

The perennial grass tall oatgrass (*Arrhenatherum elatius* (L.) P. Beauv. ex J. Presl & C. Presl.) is widespread in Serbia. High and stable yield classifies tall oatgrass among the perennial grasses to consider when designing mixtures especially suitable for drought and poor soil. Fodder quality of this species is somewhat lower and therefore in some countries this species is neglected. In Serbia tall oatgrass has maintained its place in the production of livestock food.
Twenty-nine populations of tall oatgrass originating from Serbia were investigated, in order to characterize and select genotypes which stand out in regard to quality and yield of fodder. Morphological traits affecting quality and dry matter production (plant height in first and second cut, number, width and length of leaves, number of tillers) and dry matter yield were investigated in a two-year spaced plant trial. Significant variability within and between populations for investigated traits was found.

Keywords: tall oatgrass, populations, morphological traits, DMY, variability, breeding

Introduction

Tall oatgrass (*Arrhenatherum elatius* (L.) P. Beauv. ex J. Presl & C. Presl.) is an indicator species of the association *Arrhenatheretum elatioris* that is considered to be the highest quality natural low meadow in Europe. In Serbia, this association is of anthropogenic origin and it is mostly located at lower altitudes (Jovanović-Dunjić, 1983). Tall oatgrass is a perennial forage grass that belongs to the sub Central-European floristic element and has an area of distribution covering almost all of Serbia, including low and hilly mountainous regions. This species persists in mixtures with other grasses due its broad ecological amplitude and its resistance to cold and drought. It grows best on fertile and well-drained soils, but also on other soil types (Swedrzynski and Kozlowski, 1998). Tall oatgrass has high and stable forage yield and therefore is one of the significant forage grasses for mixtures, especially in the conditions of drought and poor quality soils in Serbia. Tall oatgrass shows somewhat lower forage quality compared to other forage grass species. Because of that, it has been considerably neglected in many countries. However, according to Čolić *et al*. (1986), this trait can be significantly improved by changing the cutting frequency and increasing the proportion of leaves in total dry matter. Tall oatgrass has maintained its role in fodder production in Serbia. The main breeding goal is quality improvement by increasing the crude protein content in dry matter and maintaining the high forage yield.

Materials and methods

The field experiment was carried out at the Centre for Forage Crops, Kruševac, 142 m asl Twenty nine populations of tall oatgrass were investigated in order to characterize populations and select genotypes that were outstanding in quality and forage yield. These populations were collected on farms in Central Serbia and probably originate from earlier commercial cultivars. Populations were seeded in the autumn 2000, as spaced plants at a distance of 60×60 cm. Each population was represented by 30 plants. Over a two year period morphological traits affecting the quality and production of forage were investigated (plant height in the first and second cut; number, length and width of the second leaf; number of tillers). Dry matter yield (DMY) was determined in three cuts in both investigation years. In this paper, average data for investigated traits over the period of two years are presented; analysis of variance was also carried out. Cluster analysis was carried out by the Ward method using Euclid's distances. Grouping is presented graphically.

Results and discussion

Average yields of populations were in range 105 to 241 g per plant (Table1). In the second year, population P15 had the highest average DMY of 290.4 g per plant. The highest mean number of tillers per plant (173) was in populations P8 and P10.

Table 1. Mean values and variability of traits in the collection of tall oatgrass populations.

Traits Populations	Plant height in first cut (cm)	Regrowth height (cm)	Number of leaves	Leaf lenght (cm)	Leaf width (mm)	Tiller number	Total DMY (g plant^{-1})
P1	132.2	95.5	3.74	21.1	10.5	160.0	188.4
P2	134.1	93.9	3.72	22.0	7.9	155.0	170.1
P3	139.9	92.1	3.63	22.9	9.5	127.1	171.8
P4	136.3	99.1	3.67	22.0	9.2	170.3	212.3
P5	135.1	96.2	3.78	22.3	11.3	156.0	194.5
P6	141.1	99.4	3.81	23.8	10.1	145.1	205.7
P7	138.9	96.9	3.57	22.5	10.3	159.2	222.7
P8	137.9	103.0	3.68	21.7	9.7	173.0	221.4
P9	139.9	99.6	3.67	21.6	9.3	162.8	216.1
A	138.9	97.1	3.63	20.6	9.2	143.5	174.7
P10	134.5	99.8	3.66	20.8	9.2	172.9	241.6
B1	138.9	96.1	3.57	20.7	10.0	114.9	153.0
K1	138.0	94.1	3.53	22.9	10.1	157.8	219.9
L1	135.1	93.9	3.59	22.5	10.2	123.7	169.8
P11	130.7	94.9	3.58	22.7	9.3	142.9	166.3
P12	143.2	94.8	3.69	21.0	10.2	145.3	190.1
P13	145.9	92.2	3.55	20.2	9.3	143.5	185.0
P14	144.7	89.5	3.73	21.7	10.4	120.0	166.8
P15	145.9	87.9	3.63	21.3	10.0	164.3	222.5
G1	142.7	80.5	3.50	20.0	8.7	92.9	105.7
Vš	146.6	91.4	3.56	20.3	9.8	152.0	199.3
K2	145.7	87.7	3.59	21.0	8.8	118.5	162.6
B2	148.5	93.3	3.58	22.4	9.9	138.1	176.2
K3	138.6	82.3	3.37	20.0	8.8	91.2	125.6
S1	147.1	86.6	3.36	22.5	9.2	116.8	159.9
L2	152.8	89.6	3.33	21.3	9.1	110.5	147.4
G2	150.0	86.7	3.57	21.8	9.4	139.8	189.0
L3	145.8	92.6	3.48	21.2	8.8	131.0	182.8
S2	143.1	75.9	3.37	21.3	9.1	117.6	171.8
CV(%)	3.95	6.63	3.45	4.46	7.27	16.32	16.64
LSD 0.01	4.75	2.11	0.072	0.38	0.24	1.98	3.23

There was significant variability within populations for DMY per plant and number of tillers per plant. For these traits coefficients of variation were over 16 % (Table 1). For other morphological traits, variation of mean values between populations was lower (CV between 3 and 7 %). In the first cut the average height of plants was approximately 140 cm, and in the re-growth it was between 90 and 100 cm. Populations P5 and P6 had the highest mean number of leaves per plant as well as size of leaf sheath. These morphological traits affect forage quality by increasing the proportion of leaves in total dry matter and improving crude protein content. Ševčikova and Šramek (2002) reported somewhat lower mean values of morphological traits in their investigations of European collections of tall oatgrass. There were highly significant differences between mean values of all investigated traits between the two investigation years. Populations were also cluster analysed in order to determine the similarities or differences among them. Three clusters were identified (Figure 1). Cluster 1 consisted of the highest number of populations (12) with yield values around the average and Cluster 2 included populations with the highest DMY of over 220 g per plant and more than 150 shoots. Eight populations of cluster 3 were characterized by the lowest values for all traits.

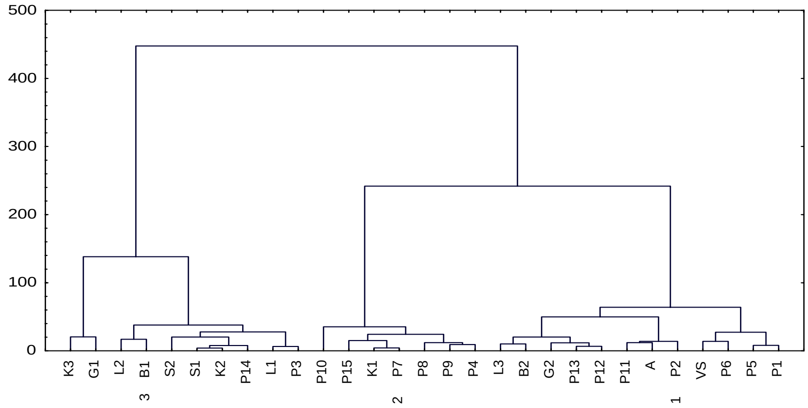

Figure 1. Cluster diagram of 29 populations based on 7 investigated traits.

The number of tillers and DMY per plant were the most important traits for such grouping of populations and they divided the populations (Figure 2).

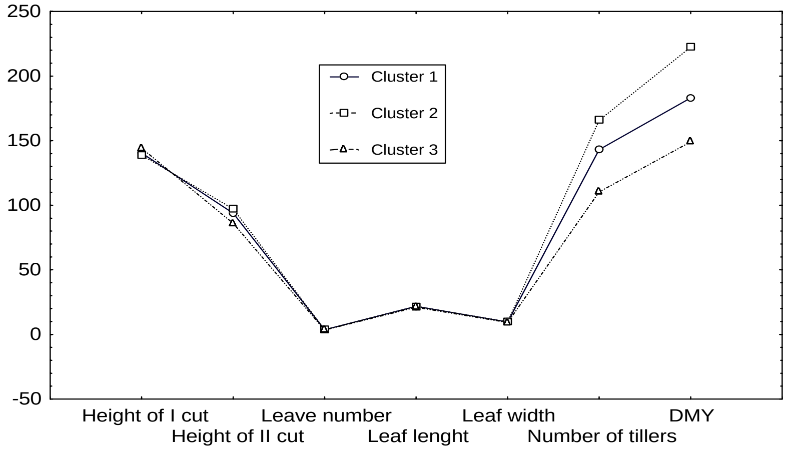

Figure 2. Cluster means for 7 investigated traits.

Based on previously presented traits and quality of dry matter it is possible to select the best genotypes for further improvement.

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Red clover yields and nitrogen content as related to sulphur supply

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Abstract

A one-year S-fertiliser experiment and a survey in established organic clover leys were undertaken to investigate if and where the supply of S was critical for the input of fixed N into organic fodder production in Norway. The red clover from many organically farmed leys appeared to be very low in S. Additional S-fertilisation did not result in increased clover production nor N-yield at the three experimental sites, and no causal relationship between a scarce S-supply and reductions in N-fixation was established. Analysis of the data from the survey revealed, however, a positive correlation between the S- and N-content of clover tissues that was independent of plant phenological stage. In some leys, high yields were harvested of grass and clover containing less than 0.10 % S. It is thus suggested that the critical tissue concentrations referred to in the literature are not valid for the plant production systems investigated here.

Keywords: biological nitrogen fixation, Norway, organic farming, *Trifolium pratense*

Introduction

Nitrogen fixation (NF) in the *Rhizobium*-red clover symbiosis is an important source of N in organic livestock production in Norway. The growing season in most of the country is cool, wet and short, and on a yearly basis, the potential for NF and plant production is lower than in continental Europe and the British Isles. The rate of mineralisation of organic matter is rather low, and the supply of P and S may limit the NF in the symbiosis. In the present investigation we wanted to see if and where the supply of S was critical for the input of fixed N into organic fodder production. We chose S because the deposits of S from rain and the atmosphere are very low in most of Norway, and because other authors have suggested that the NF is directly and severely inhibited when the S-supply to the symbiosis is low (DeBoer and Duke, 1982; Zhao *et al*., 1999).

Materials and methods

The study consisted of a farm survey conducted in 2001 and a field experiment performed the year after at sites with a low plant content of S and low S-deposits (2.3-3.0 kg S ha^{-1} y^{-1}). In the survey, red clover (*Trifolium pratense*) from 26 organic farms located in central, eastern and western Norway was collected and analysed for N and S at the time of the farmers' first cut. Samples from three different leys within each farm were taken, and the stage of phenological development of the predominant grass species and red clover at harvest was determined. The proportion of the plant stand constituted by the clover was determined by sorting and later drying of subsamples of the gross yield.

The field experiment was conducted in established grass-clover leys on three farms from the survey. Sulphur was applied in spring as $MgSO_4$ x $7H_2O$ at rates of 0, 30 and 60 kg S ha^{-1}. The plots were 6.0 m x 1.5 m, and there were four replicates laid out in a fully randomized design. Harvests were later taken in mid June and mid August, and the proportion of clover in the yield was estimated by sorting of subsamples. The content of N in red clover and timothy was analysed by mass spectroscopy, and the content of S, P, K, Mg, Ca in red clover by

ICP/AES. The NF in the different treatments was estimated according to an empirical model developed by Høgh-Jensen *et al.* (1998).

NF = Clover dry matter * % N in clover * Pfix * (1 + Proot + Psoil + Pimmob) (Equation 1)

Pfix refers to the proportion of clover N that is derived from NF (0.90). Proot (0.25) and Psoil (0.25) refer to the proportion of Pfix that is transferred to root and stubble and to soil, whereas Pimmob (0.25) refers to the proportion that is immobilised.

Results and discussion

The content of S in the red clover (SC) from the farm survey varied between 0.08 and 0.30 %, and most samples were in the range 0.10-0.20 % (Figure 1). According to authors cited by Whitehead (2000) and Marschner (1995), this is near or at a critically low level for plant growth. The content of N (NC) and S in the clover tissue was positively correlated ($P < 0.001$) irrespective of clover phenological stage (Figure 1). The NF in the surveyed fields as estimated according to (Equation 1), was not related to the S-status of the clover.

In the experiment, the supply of S caused a higher SC except for the first cut at site A (Table 1). Without any S application, the SC was below 0.10 % at all sites. Still, the increase in SC caused by the fertilisation was not followed by any significant responses in clover production nor NF (Table 1). At farms A and B, the production might have been severely limited by a shortage of water, P or K during the growing season. The yields of both clover and grasses obtained at a SC below 0.10 % at farm C, however, are considerably higher than the average for both conventional and organic farming in Norway (*http://www.ssb.no/english/subjects/10/04/10/jordbruksavling_en/*). It is thus obvious that the critical tissue concentrations referred to in the literature (Whitehead, 2000) may not be valid for the plant production systems investigated here.

Table 1. Yields, estimated nitrogen fixation (NF) and S-content in harvested clover tissues according to S-fertilisation in established leys in spring. Means within harvests that were significantly different after a one-way ANOVA and a Student-Newman-Keul test are marked with different letters.

	1st harvest			2nd harvest		
S (kg ha^{-1}) applied in spring	0	30	60	0	30	60
Farm A						
Total yield (kg DM ha^{-1})	3820	3790	3980	1660a	2070b	2080b
Clover yield (kg DM ha^{-1})	1640	1830	1700	990	1310	1250
NF (kg N ha^{-1})	47	57	54	22	33	33
S in clover (g kg^{-1} DM)	0.96	0.92	1.27	0.63a	0.97b	0.97b
Farm B						
Total yield (kg DM ha^{-1})	4540	4560	4460	2230	2700	2790
Clover yield (kg DM ha^{-1})	610	740	990	910	1400	1100
NF (kg N ha^{-1})	18	25	33	31	54	38
S in clover (g kg^{-1} DM)	0.62a	1.09b	1.29b	0.61a	0.93b	0.89b
Farm C						
Total yield (kg DM ha^{-1})	5390	4930	5110	4340	4250	4480
Clover yield (kg DM ha^{-1})	2760	2520	2490	2890	2360	2830
NF (kg N ha^{-1})	107	105	98	95	98	106
S in clover (g kg^{-1} DM)	0.95a	1.74b	1.74b	0.96a	1.33b	1.36b

At two of the experimental sites, the NC in the second cut was significantly higher in fertilised than in non-fertilised treatments (data not shown). This fact together with the positive correlation between NC and SC revealed in the farm survey, indicate that clover uptake and/or fixation of N may be related to S-supply in some instances.

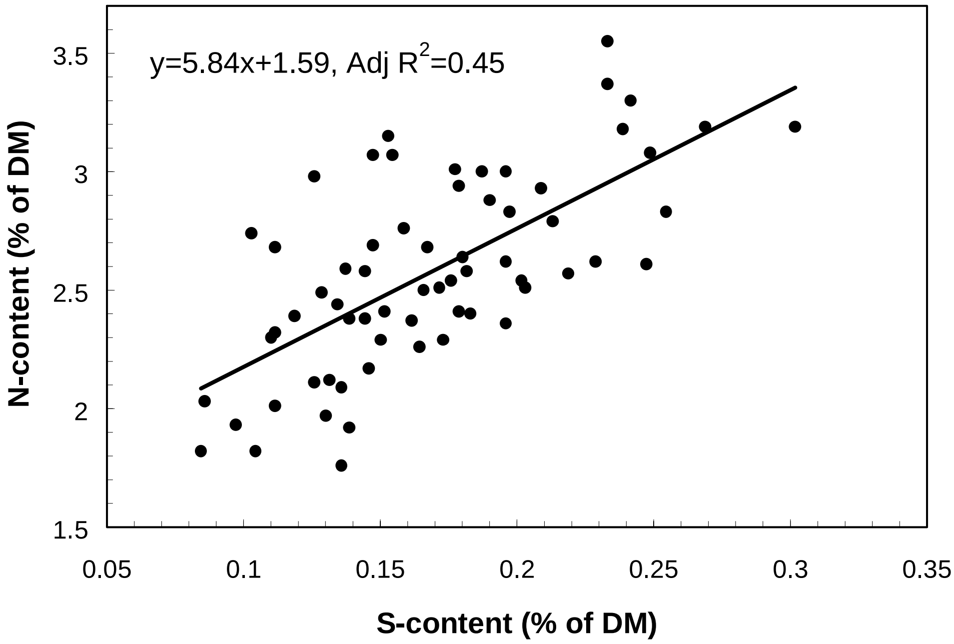

Figure 1. The relationship between the content of S and N in red clover sampled from 65 leys at 26 Norwegian organic farms at the time of the first cut in 2001.

Conclusions

Although the red clover from many organically farmed leys was very low in S, no causal relationship was identified between a scarce S-supply and reductions in N-fixation. In some leys, high yields were harvested of grass and clover containing less than 0.10 % S. It thus seems that the critical tissue concentrations referred to in the literature are not valid for the plant production systems investigated here.

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Use of lucerne for forage and seed production

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Abstract

Six field experiments were conducted with lucerne (*Medicago sativa* L.). A first crop of lucerne was cut for forage at weekly intervals from April 30 to June 11. Seed was harvested from first and second crops. Highest dry matter and digestible protein yields were obtained when the first crop of lucerne was cut at the latest date. Seed yields of the second crop were the lowest. It was found that, after cutting the first crop, there was a reduction in weed incidence, stem length, stem thickness and lodging in the second crop. During the first year of use, if the first crop was cut before bud initiation, seed yields of the second crop were identical with those of uncut lucerne. In the second and third years of use, seed yields increased significantly when cut at the same stage. If cut at the budding stage, the seed yields declined significantly. If 5 cm tops of the lucerne were cut in the third ten-day period of May before the start of budding, the seed yield increased significantly. But topping later, after the crop had lodged or after the first flowers had emerged reduced seed yields.

Keywords: lucerne, cutting time, forage and seed yield.

Introduction

In Lithuania the main perennial legumes for leys are red clover and lucerne. Lucerne seeds are unreliable and very much dependent on weather conditions during flowering and ripening. Lucerne plants generally produce an abundant vegetative growth leading to crop lodging. The crop and soil management practices used do not always result in a stand resistant to lodging. Mechanical treatments such as root undercutting and deep harrowing are often used to reduce the luxuriant growth of lucerne (Rincker *et al*., 1988). Chemical treatments are also used (Simko, 1993; Askarian *et al*., 1994). However, such treatments are costly and not always effective. One of the best means to reduce crop lodging is to take seeds from the second crop. In northern areas and mountainous regions lucerne seed is more often harvested from the first crop, while in the south, the first crop is cut for forage, and seed is taken from the second crop (Rincker *et al*., 1988). In the northern areas it is risky to cut the first crop for forage, as seed may not completely mature in the aftermath growth.
The aim of this study was to investigate the dual use of lucerne for forage and seed production, cutting the first crop at different dates for forage, followed by harvesting seed from the second crop.

Materials and methods

Six field experiments were carried out during 1998-2001 on a sod gleyic loam soil (Epicalcari -Endohypogleic Cambisols) in the central part of Lithuania (55º 23' N, 23º 51' E, average annual rainfall 555 mm, average temperature 6 ºC, vegetative growth period 194 days). The soil characteristics were as follows: pH $_{KCl}$ = 7.0, soluble P = 93 mg kg^{-1}, K = 116 mg kg^{-1}. Lucerne (cv. 'Birutė') was sown annually in 1998, 1999 and 2000 with a cover crop of spring barley. Pure lucerne was sown at a seed rate of 9 kg ha^{-1} and a row spacing of 23 cm. Experiments were conducted on the crops in their first, second and third years of use. Seed was taken from both first and second crops using a combine harvester. The first crop was cut at weekly intervals from April 30 to June 11. On May 21, and at weekly intervals afterwards, 5 cm tops were cut from the crop. The experiment was designed as a randomised complete block with 4 replications and a plot size of 2.5 m × 12.0 m. For an assessment of forage quality, chemical analyses of dry matter were performed for: crude protein, by determining the amount of nitrogen using the Kjeldhal method and multiplying by 6.25, crude fibre by the Henneberg-Stohmann method, crude fat by the Rushkovski method, crude ash, by combustion and digestibility of the dry matter *in vitro* using the pepsin-cellulase method. The lucerne stand received no organic or mineral manuring. During the experimental period only one year (1999) was favourable for lucerne flowering and seed ripening.

Results and discussion

Averaged data from 6 experiments indicate that the highest weekly dry matter yield increment of 0.82 t ha^{-1}, occurred at the beginning of May, when, due to rapid growth, the herbage yield increased by a factor of 2.3 (Table 1). Yield increases declined with later cuts, but significantly more herbage was harvested each week. The highest herbage yields were obtained from the lucerne during the second year of use. The largest amounts of dry matter, feed units and metabolizable energy content were obtained from lucerne cut on June 11, at the beginning of flowering. A delay in cutting date consistently reduced the outputs of feed units and metabolizable energy per kilogram of herbage dry matter. Herbage digestibility *in vitro* at the first cutting date was high (over 80 %, falling to 62-66 % at the last cutting date). Digestible protein contents fell from 208 to 117 g at the later cutting dates, but the levels were still sufficient to meet feed requirements.

Table 1. Lucerne herbage dry matter, metabolizable energy, and digestible protein yields. Averaged data 1999-2001 for the first cutting dates from six trials: three trials in the first year of use, two trials in the second year of use and one in the third year of use.

Cutting date	Dry matter t ha^{-1}	Metabolizable energy		Digestible protein		Digestibility *in vitro* of dry matter (%)
		GJ ha^{-1}	MJ kg^{-1} DM	kg ha^{-1}	g kg^{-1} DM	
30 April	0.64	7.65	12.0	133	208	81.8
7 May	1.46	17.10	11.7	273	187	81.6
14 May	2.07	23.43	11.3	357	172	81.6
21 May	2.72	29.28	10.8	392	144	73.4
28 May	3.13	32.82	10.5	429	137	69.2
4 June	3.63	37.19	10.2	436	120	66.0
11 June	4.02	41.84	10.4	471	117	61.9
$LSD_{0.05}$	0.31	3.32		44		6.2

Our experimental evidence suggests that after cutting the first crop, there was a decline in weed incidence, re-growth, stem length, thickness and lodging. If the first crop was cut on 28 May or later, flowering of the second crop started much later (24-35 days), the seed ripened later and there was a significant reduction in numbers of seed pods. The highest seed yields were obtained from first year stands. Seed yields varied greatly from year to year. In 1999, a dry year, seed yields from the first crop were over 800 kg ha^{-1} (Table 2). In wetter years (2000 and 2001), which are frequent in Lithuania, the seed yield was 8-12 times lower (67-100 kg ha^{-1}). When the first crop of first year lucerne was cut before budding (up to May 21), subsequent seed yields were similar to those of uncut lucerne. If the first crop of lucerne was cut later (at the end of May or beginning of June, after the first flowers had appeared) seed yields in the second crop fell by 1.5-1.7 times. When the first crop was cut at the start of lucerne flowering (the beginning of the second ten-day period of June), this resulted in the highest dry matter yields of herbage. However, subsequent seed yields were low, the three year average being 132 kg ha^{-1} or 2.5 times lower than uncut.

Table 2. Lucerne seed yields in different years of use (kg ha^{-1}).

Cutting dates of first forage crop	1st year of use				2nd year of use			3rd year of use	3-year average
	1999	2000	2001	Average	2000	2001	Average	2001	
No cutting	811	100	67	326	62	55	59	45	143
30 April	811	93	76	326	71	57	64	52	147
7 May	784	90	69	314	73	57	65	47	142
14 May	833	96	85	338	79	63	71	56	155
21 May	773	105	65	314	66	62	64	46	141
21 May ^{T}	896	109	79	362	77	70	73	52	162
28 May	502	69	50	207	37	38	38	32	92
28 May ^{T}	893	96	83	357	76	68	72	55	161
4 June	455	34	49	179	34	35	34	29	81
4 June ^{T}	851	75	68	331	39	53	46	34	137
11 June	332	26	38	132	24	30	27	28	62
11 June ^{T}	811	69	69	316	34	43	39	29	128
$LSD_{0.05}$	81.5	11.4	12.4	27.7	8.3	6.8	5.3	8.3	9.8

Note: ^{T} = 5 cm stem tops of cut.

Lucerne in the second and third years of use produced lower seed yields compared with that in the first year of use. When second and third year crops were cut on May 14, the seed yields increased significantly, but when cut on 28 May or later seed yields declined. If 5 cm stem tops of lucerne were cut in the third ten-day period of May, before the start of budding, seed yields increased significantly. If the tops were cut later, after lodging had begun and the first flowers appeared, seed yields declined. When the first crop of lucerne was cut on 28 May or later, the contents of hard seed in the second crop increased significantly. Germination and purity of the seed from the first and second crops were similar.

Conclusions

In the first year of use it is best to take seed from the first crop. Seed yields from second or third year lucerne are lower than in the first year of use. If seed is required from second or third year stands, it should be taken from the second crop. The first crop should be cut before bud initiation, not later than the end of the second ten-day period of May. Vigorous lucerne in the second and third years of use can produce about 3 t dry matter in high-quality forage. The subsequent seed yields are then up to 20 % higher than from lucerne left for seed after the first crop.

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Effect of imposed water deficiency stress on the growth of lucerne (*Medicago sativa*, L.)

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Abstract

A pot experiment with leached chernozem soil was carried out. Lucerne (*Medicago sativa*, L.) was used as the test plant. Soil was treated with two nitrogen forms (urea and KNO_3). Rates of 70, 140 and 210 mg N kg^{-1} soil were applied. Soil water content was maintained at 80 % of field capacity (FC), but, in the plant budding stage water deficiency stress was imposed, with the water supply reduced to reach the wilting point at 40 % FC. The results showed that both nitrogen forms increased shoot mass at optimal water conditions. The highest rate of nitrate N decreased both shoot and root mass. Under water deficiency stress the shoot mass decreased by 18-49 %. The root mass under imposed water deficiency stress was also decreased by 18-39 %. The root / shoot mass ratio was higher in the treatments with imposed water deficiency stress, mainly due to the higher rate of reduction of the shoot mass. Both ammonium and nitrate nitrogen significantly increased lucerne sensitivity to drought.

Keywords: lucerne, yield, water deficiency stress, nitrogen fertiliser, root / shoot mass ratio

Introduction

Water deficit is one of the most important factors limiting agricultural crop yield in the semi-arid Mediterranean region, as well as in warm temperate regions (Athar and Johnson, 1996; Dimitrova and Mehandjieva, 1990; Vasileva and Kostov, 2001). Nitrogen sources including biological nitrogen fixation have significant importance to legume plants. Lucerne is sensitive to high doses of mineral nitrogen because nitrogen has a negative effect on the nodulation processes (Vasileva and Kostov, 2001). There is limited knowledge about the effect of nitrate and ammonium nitrogen on lucerne plants under conditions of water deficit. The aim was to study the effect of different nitrogen sources on lucerne growth under optimal and water deficient conditions.

Materials and methods

A pot experiment was carried out with leached chernozem soil from the region of Pleven. Pots (Wagner type) with a 10 l capacity were used for sowing of the plants. Four plants were grown in each pot. The following design was used: 1) $Control_1$ + PK and $Control_2$ + PK, 2) NH_4^+-N_{70}PK, 3) NO_3^--N_{70}PK, 4) NH_4^+-N_{140}PK, 5) NO_3^--N_{140}PK, 6) NH_4^+-N_{210}PK, 7) NO_3^--N_{210}PK. All treatments were kept at optimal (80 % FC) conditions. At the budding phase the water deficiency stress was imposed by stopping the watering till the moisture dropped to 40 % FC. The lucerne cultivar Victoria was used. The following three levels of nitrogen were applied: 1) 70 mg N kg^{-1} soil, 2) 140 mg N kg^{-1} soil and 3) 210 mg N kg^{-1} soil. Two forms of nitrogen were used: 1) ammonium nitrogen as urea and 2) nitrate nitrogen as KNO_3. To all treatments P and K were applied in doses of 110 mg kg^{-1} soil. Shoot mass was harvested twice and the root system was washed with distilled water. Crop Sensitivity Index (CSI) was calculated using the following formula: CSI = (g shoot mass under optimal moisture content - g shoot mass under water deficiency stress) / (g shoot mass under optimal moisture content). Data were analysed using software SPSS for Windows 95, 98 and 2000.

Results and discussion

The results showed that both N forms increased the yield (36-60 %) at optimum moisture content when compared to control (Table 1). Under imposed water deficit both nitrogen forms slightly decreased the yield (1-6 %). At 70 and 140 mg N the nitrate N slightly increased the shoot mass. The opposite was observed with the dose of 210 mg N. In this case nitrate N slightly decreased the shoot mass. Imposed water deficiency stress significantly reduced the shoot mass (18-49 %). The same tendency was observed with root mass. The reduction of the root mass under imposed water deficiency stress was also significant (18-33 %) but less when compared with the reduction of the shoot mass.

Table 1. Effect of imposed water deficiency stress on quantity of the shoot and root mass.

Treatments	Shoot mass			Root mass		
	g pot^{-1} dry matter	% to $Control_1$ and $Control_2$	% to treatments with optimal moisture	g pot^{-1} dry matter	% to $Control_1$ and $Control_2$	% to treatments with optimal moisture
	Under optimal moisture content (80 % FC)					
1. $Control_1$PK	22.3	-	-	19.3	-	-
2. NH_4^+-N_{70}PK	30.4	36	-	20.9	+ 8	-
3. NO_3^--N_{70}PK	30.9	38	-	22.9	+ 19	-
4. NH_4^+-N_{140}PK	32.2	44	-	21.3	+ 10	-
5. NO_3^--N_{140}PK	33.7	51	-	25.3	+ 31	-
6. NH_4^+-N_{210}PK	35.7	60	-	24.1	+ 25	-
7. NO_3^--N_{210}PK	33.9	52	-	22.1	+ 14	-
	Under imposed water deficiency stress (40 % FC)					
8. $Control_2$PK	18.3	-	- 18	15.9	+ 5	- 18
9. NH_4^+-N_{70}PK	17.2	- 6	- 44	16.7	+ 6	- 26
10. NO_3^--N_{70}PK	18.0	- 2	- 42	16.9	+ 6	- 26
11. NH_4^+-N_{140}PK	17.3	- 6	- 46	16.8	+ 6	- 21
12. NO_3^--N_{140}PK	18.2	- 1	- 46	16.9	+ 6	- 33
13. NH_4^+-N_{210}PK	18.1	- 1	- 49	16.4	+ 3	- 32
14. NO_3^--N_{210}PK	17.9	- 2	- 47	16.2	+ 2	- 27
SE (P = 0.05)	2.0			0.9		

The root / shoot mass ratio (Table 2) was increased under the imposed water deficit, mainly due to the reduction of the shoot mass. The Crop Sensitivity Index data showed that both nitrogen forms increased sensitivity of the lucerne to drought. There were no significant differences between the two nitrogen forms. However, the results obtained can only be considered for the soil type used and under these experimental conditions.

Table 2. Root / shoot mass ratio and crop sensitivity index

Treatments	Root / shoot mass ratio	Crop Sensitivity Index	% increase or decrease
		Under optimal moisture content (80 % FC)	
1. $Control_1PK$	0.87	-	-
2. NH_4^+-$N_{70}PK$	0.69	-	-
3. NO_3^--$N_{70}PK$	0.74	-	-
4. NH_4^+-$N_{140}PK$	0.66	-	-
5. NO_3^--$N_{140}PK$	0.75	-	-
6. NH_4^+-$N_{210}PK$	0.68	-	-
7. NO_3^--$N_{210}PK$	0.65	-	-
		Under imposed water deficiency stress (40 % FC)	
8. $Control_2PK$	0.87	0.18	-
9. NH_4^+-$N_{70}PK$	0.97	0.43	+ 139
10. NO_3^--$N_{70}PK$	0.94	0.42	+ 133
11. NH_4^+-$N_{140}PK$	0.97	0.46	+ 156
12. NO_3^--$N_{140}PK$	0.93	0.46	+ 156
13. NH_4^+-$N_{210}PK$	0.91	0.49	+ 172
14. NO_3^--$N_{210}PK$	0.91	0.47	+ 161
SE (*P* = 0.05)	0.03		

Conclusions

Application of urea and KNO_3 increased the shoot and root mass of lucerne. Water deficit significantly reduced both shoot and root mass of lucerne. Ammonium and nitrate nitrogen did not show significant differences between them on the shoot and root mass. Both ammonium and nitrate nitrogen significantly increased lucerne sensitivity to drought.

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Influence of alfalfa flower colour on pollinator visitation and seed yield components

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Abstract

Alfalfa flowers were divided into three groups based on their colour intensity. Honeybees and other pollinator visitations to flowers depending on colour intensity were investigated. The highest number of pollinators were recorded on light-violet flowers. Honeybees visited more alfalfa flowers than other pollinators (2:1 ratio) and at the same time visited more light-violet flowers. Highest cluster forming was observed with violet flowers (61.51 %) in the first year with light-violet flowers (61.51 %) in the second year. Highest pod forming in clusters was obtained with light-violet flowers. In both years, there were significant differences in the number of seeds per pod and these were associated with flower colour.

Keywords: alfalfa, flower colour, pollinator, seed yield components

Introduction

Pollination of alfalfa, more specifically activity of pollinators, represents the most important moment in the production of seed. The melliferous bee, because of its great presence in pasture areas and mobility, though not the most efficient pollinator in our agro-ecological conditions, is a significant factor in the production of alfalfa seed. Differences in visits to alfalfa flowers of different colours have been observed (Clement, 1965). It has also been proven that individual bees tend to collect on plants with flowers of similar colour. Steiner *et al*. (1992) observed that the affinity of the melliferous bee towards alfalfa plants is based on the colour of the flower. Flowers of light colour are more frequently visited than dark flowers, but location also affects the number of visits. Seed yield and yield components are often more influenced by agro-meteorological factors, such as year and production technology, than by genetic potential (Eric, 1995; Mihajlovic *et al*., 1999). The objective of this paper was to determine how pollinators behave in our agro-ecological conditions towards alfalfa flowers of different colours, and if the colour of alfalfa flower has any effect on the parameters of seed yield.

Materials and methods

The experiment was carried out on the trial field in Mackovac, during 2001 and 2002. Experimental alfalfa lines were used in their third and fourth year. Individual plants seeded in holes with 60 × 60 cm spacing were monitored. Based on the colour of the flower three groups were determined: I) dark violet flowers, II) violet flowers and III) light violet flowers. In each group 30 plants were selected on which yield components were determined (number of clusters, flowers, pods and seeds).
Counting of pollinators was carried out for each group of flowers for 10 minutes. Pollinators were melliferous bees and spontaneous alfalfa pollinators (alfalfa leaf cutter and alkali bees). Counting was carried out three times per day (morning, noon and afternoon). The data was processed statistically and variance analysis was done for seed yield components. Differences among treatments were tested using LSD test.

Results and discussion

More pollinators were recorded during 2001 than in 2002. In both investigation years, the highest number of pollinators were recorded on alfalfa flowers of light violet colour (Table 1). The melliferous bee was more frequently recorded on flowers than any other alfalfa pollinator. It mainly visited alfalfa flowers of light violet colour. In the first year, other pollinators showed an affinity towards dark violet flowers, and in the second year towards violet flowers. Domination of the melliferous bee on alfalfa fields was also confirmed in investigations of Ciurdaresku (1974) and Jevtic (2001).

Table 1. Mean number of pollinators on different colored alfalfa flowers.

	Pollinators total		Honeybee		Other pollinators	
Year	2001	2002	2001	2002	2001	2002
Dark violet	5.0	4.0	2.6	2.6	2.4	1.4
Violet	5.0	4.2	3.3	2.7	1.7	1.5
Light violet	5.9	5.5	4.1	4.3	1.8	1.2
$\overline{X}$	5.30	4.57	3.33	3.20	1.97	1.37

Better cluster forming was achieved in 2001 than in 2002 (Table 2). In the first year, differences in cluster forming between alfalfa flowers of different colours were not significant. Considerably greater differences between treatments were achieved in the second year. Forming of clusters and pods is influenced by the growing technology, seeding density and cut intended for maximum seed production (Eric, 1995). Pod formation was better in the second year, but the difference between both years was small. In both years, the best pod formation was recorded in alfalfa flowers of light violet colour with significant differences in 2002 but not in 2001. Number of pods per cluster is also under the influence of their position on the stem (Djukic *et al.*, 1993) and cultivar (Kostic, 1996).

Table 2. Yield components of alfalfa with different colored flowers.

Year	Flower colour	Cluster forming (%)	Pods forming (%)	Number of seeds
2001	Dark violet	65.56 [a]	29.75 [a]	2.12 [b]
	Violet	79.53 [a]	30.77 [a]	2.48 [b]
	Light violet	72.52 [a]	37.01 [a]	3.09 [a]
	$\overline{X}$	72.54	32.51	2.56
2002	Dark violet	50.15 [ab]	32.84 [b]	3.63 [a]
	Violet	33.11 [b]	26.51 [b]	2.28 [b]
	Light violet	61.51 [a]	42.64 [a]	3.52 [a]
	$\overline{X}$	48.27	33.97	3.14

Values within the same year with the same letters are not significantly different ($P < 0.01$).

Significant differences between treatments as well as between years of investigation were also observed for the number of seeds per pod. In 2001 more seeds per plant were achieved with light coloured flowers, with dark-violet and light-violet flowers in 2002. As for seed forming the second year was much better.

Conclusions

Pollinators showed a higher affinity for light-violet flowers. In both years of investigation alfalfa flowers were more often visited by the melliferous bee than by other pollinators. The melliferous bee more frequently visited light-violet flowers. Yield components differed depending on colour of alfalfa flower. Alfalfa plants with light-violet flowers showed better results for almost all seed yield components. Differences were also registered between both examined years.

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Liming of acid soils as a measure of improving lucerne and red clover production

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Abstract

Acid soils, with an expressed calcium deficiency, account for 60 % of arable soils in the Republic of Serbia and is a regular cause of low crop yields. Two cultivars of lucerne (NS- Medijana ZMS V, NS – Slavija) and one of red clover (Kolubara) were studied, using soil liming and pre-sowing seed inoculation. Liming resulted in significantly higher yields of lucerne in the sowing year and pre-sowing seed inoculation also resulted in significantly higher yields, particularly in the variants with liming. No significant differences in the yield of red clover were observed when comparing liming and inoculation and inoculation itself. These treatments were found significantly to increase the yields of these plants on less suitable, i.e., acid soils.

Keywords: lucerne, red clover, liming, inoculation, yield, quality

Introduction

Acid soils occupy considerable areas in the Republic of Serbia, which explains a lower possibility of cropping with lucerne. In addition to calcium deficiency, acid soils are also characterised by a high content of readily mobile forms of Al, Fe, Mn, resulting in a reduced content of readily available phosphorus (Taylor and Quesenberry, 1996). Satisfactory yields of cultivated plants can be achieved if the acid soil amendment is performed by introducing limestone fertilisers. In addition to decreasing soil acidity and readily mobile forms of Al and others, the introduction of calcium can also increase the availability of some essential elements, thus providing suitable conditions for the developing of symbiotic nitrogen fixers. The number and microbiological activity of symbiotic nitrogen fixers in perennial legumes are limited by low pH value (Jarak *et al*., 2002). In acid soils, the viability of nodular bacteria is made difficult and their growth slowed down, resulting in lower yield of legumes.
The objective of the paper was to investigate the effect of soil liming and seed inoculation on the yield and quality of lucerne and red clover in less suitable soil conditions of the regions of Cacak and Kraljevo.

Materials and methods

The experiment was set up at the Faculty of Agronomy on the Smonitza type of soil, with pH of 5.1, a good potassium supply (26 mg 100 g^{-1} soil) and a low content of readily available phosphorus (1.78 mg 100 g^{-1} soil). The trial was set up in a randomized block design with four replications. The primary plot size was 6 m^2, with seeding performed on the 27th March 2001. Two cultivars of lucerne (NS Medijana ZMS V, NS Slavija) and one of red clover (Kolubara) were investigated. CaO in the amount of 3,000 kg ha^{-1} was used for liming. Prior to sowing, the seed of lucerne had been inoculated with two strains of symbiotic nitrogen fixers (R_1 and R_2) and that of red clover with one strain (R) (the strains originate from the collection of the microorganisms of the Institute of Field and Vegetable Crops, Novi Sad). The experiment was conducted under average weather conditions without irrigation. During the experiment, the following data were recorded: dry matter yield (t ha^{-1}), dry matter content (DM), crude protein content (CP), crude cellulose (CC) and total ash (TA).

The results obtained were treated by the three- and two-factorial analyses of variance for lucerne (liming × cultivar × inoculation) and red clover (liming × inoculation), respectively, with the coefficient of variation established for the content and quality of dry matter.

Results and discussion

The investigated cultivars of lucerne and red clover are characterised by a high production potential for fodder yield. The results of the yield and quality of fodder obtained for lucerne and for red clover are shown in the tables 1 and 2.
Over the sowing year of 2001, with two lucerne cuttings, the yield of dry matter of fodder in both cultivars averaged 10,157 kg ha^{-1}.

Table 1. The yield of dry matter (kg ha^{-1}) of lucerne and red clover.

Year	*2001*						
	With CaO			Without CaO			$\overline{X}$
Lucerne	Ø	R_1	R_2	Ø	R_1	R_2	
Medijana	10,191	11,145	12,550	8,952	9,881	10,586	10,551
Slavija	9,848	9,909	11,050	8,617	9,750	9,405	9,763
Red clover	Ø		R	Ø		R	
Kolubara	7,042		7,761	6,407		7,443	7,164
LSD			0.05	0.01			
	Lucerne		0.788	1.070			
	Red clover		0.303	0.458			
Year	*2002*						
	With CaO			Without CaO			$\overline{X}$
Lucerne	Ø	R_1	R_2	Ø	R_1	R_2	
Medijana	15,545	16,912	17,003	15,170	15,745	16,389	16,127
Slavija	15,966	17,343	17,690	16,118	17,768	18,006	17,148
Red clover	Ø		R	Ø		R	
Kolubara	7,945		8,755	8,127		8,459	8,322
LSD				0.05		0.01	
	Lucerne			0.708		0.891	
	Red clover			0.301		0.455	

In 2002, the year with four cuts, the total yield of dry matter averaged 16,637 kg ha^{-1} for both cultivars. The total yield of dry matter of NS-Medijana ZMS V averaged 16,127 kg ha^{-1} and that of NS-Slavija 17,148 kg ha^{-1}.
Comparing with the control, the pre-sowing inoculation of lucerne seed was also observed to give rise to considerably higher yields of dry matter, particularly in the variants with liming. The use of inoculation increases plant yield, as a result of enhanced nodulation and/or higher activity of the microorganisms, which is in agreement with results of Milosevic *et al*. (1997).
As regards the domestic cultivar of red clover, the total yield of 7,164 kg ha^{-1} was accomplished in the first and that of 8,322 kg ha^{-1} in the second year. According to Vasiljevic *et al*. (2001), the average three-year yield of the cultivar Kolubara achieved in the conditions of Zajecar, amounted to 8,550 kg ha^{-1}. The use of liming and inoculation and that of inoculation itself resulted in no significant differences in terms of yield, as the result of a higher tolerance of red clover to lower soil pH values. According to Mc Kenny *et al*. (1993), when compared with birdsfoot trefoil, red clover showed a higher tolerance to aluminum. The use of rhizobium inoculation resulted in a considerably higher yield, compared with the

control variant, particularly with liming. Staley (1993), reported that seed inoculation could on average increase fodder yield by 34 %.

In terms of dry matter content and quality parameters, no significant differences were evidenced. At the time of cutting, the content of dry matter was found to range from 22.65 g kg^{-1} to 24.80 g kg^{-1} in lucerne and from 20.50 g kg^{-1} to 22.79 g kg^{-1} in red clover. Crude protein contained in the dry matter of lucerne and red clover amounted to 19.47 g kg^{-1} DM and 18.07 g kg^{-1} DM, respectively. Katic *et al.* (2001) reported that the average crude protein content in ten cultivars of lucerne amounted to 18.62 g kg^{-1}, while Vasiljevic *et al.* (2001) reported that its content in the red clover of Kolubara amounted to 18.82 g kg^{-1} DM.

Table 2. The mean values of the content and quality (g kg^{-1}) of dry matter in lucerne and red clover .

	Dry Matter (DM)	Crude Proteins (CP)	Crude Cellulose (CC)	Crude Ash (CA)
Lucerne				
Medijana	24.05	20.13	30.33	8.89
Slavija	24.47	18.82	30.50	8.94
Average	24.26	19.47	30.42	8.92
Cv	2.25	5.03	6.79	5.52
Red clover				
Kolubara	22.44	18.07	28.75	9.49
Cv	2.80	1.34	3.33	7.56

The average content of crude cellulose was 30.42 g kg^{-1} DM in lucerne and 28.75 g kg^{-1} DM in red clover. As regards the total ash, its average content amounted to 8.92 g kg^{-1} DM in lucerne and 9.49 g kg^{-1} DM in red clover.

Conclusions

Over the sowing year, under less favourable soil conditions, high yields of dry matter of 10,157 kg ha^{-1} in lucerne and of 7,164 kg ha^{-1} in red clover, were achieved. In the second year, 16,637 kg ha^{-1} of dry matter in lucerne and 8,322 kg ha^{-1} in red clover, were reported.

Liming alone had a positive effect on the yield of lucerne only in the year of sowing. Concerning red clover, liming did not substantially increase yield, which resulted from its better tolerance to lower pH values.

The use of liming and pre-sowing seed inoculation significantly increased the yield of fodder in lucerne and in red clover.

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Growing peas and vetches for forage in Serbia and Montenegro

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Abstract

Both forage peas and vetches are well adapted to the environmental conditions of Serbia and Montenegro, especially to those prevailing in the country's northern part. Their growing has a long and successful tradition and is aimed mainly at the production of forage, hay and silage. A long-termed breeding program at the Institute of Field and Vegetable Crops in Novi Sad has produced both winter (2) and spring forage peas (2) as well as winter vetch (3) and spring vetch (2) cultivars. A field trial conducted between 2000 and 2002 included two winter peas (NS Pionir and NS Dunav), one spring forage pea (NS-Lim) and one spring common vetch (Beograd), grown either as single-stand or with wheat, barley and oats. The forage yield (fresh weight) of all legume cultivars grown as single-stand was generally lower than in their combinations with cereals. The combination of NS Pionir and winter barley had the highest yield of forage (45.6 t ha^{-1}), while the highest average content of crude protein (dry weight basis) was in the pea cultivar NS-Lim (23.4 %). The lowest yield of forage was in the vetch cultivar Beograd (26,8 t ha^{-1}). The combination of vetch and barley had the lowest crude protein content (13.3 %).

Keywords: pea, vetch, forage, crude protein, cereals

Introduction

The pea (*Pisum sativum* L.) varieties *arvense* and *sativum* are the two most widely grown peas for both forage and grain (Maxted and Ambrose, 2000). The pea represents a quality answer to increased global demands for protein feed and can play a significant role in diverse farming systems (Ambrose *et al.*, 1997). It is one of the most important pulse, vegetable and fodder crops. As a rich genus, vetch (*Vicia* L.) contains several economically important annual food and forage species such as field bean, *V. faba* L., narbon vetch, *V. narbonensis* L., and common vetch, *V. sativa* L. (Maxted, 1995). Two more species, the Hungarian *V. pannonica* Crantz and the hairy vetch *V. villosa* Roth, play an important role in the Balkans and the Eastern Mediterranean (Mišković, 1986; Orak, 2000).

Forage peas and vetches are rather well adapted to the prevailing environmental conditions in Serbia and Montenegro, where both species are grown on about 30,000 ha, mostly in the northern and central parts of the country (Mihailović *et al.*, 2003a). The winter forms are regularly sown during September and early October, while the spring cultivars are sown as soon in the early spring as the field conditions will allow (Mejakić and Nedović, 1996). If cut in full bloom or when the first pods begin to appear, which is usually in May, a forage of good quality is provided (Đukić, 2002). The average protein content of peas is about 23 % and more than 26 % in vetch (Vučković, 1999), with yields of about 40 t ha^{-1} for peas (Mihailović, 1991). Both fodder peas and vetches can also be grown alone or mixed with cereals (usually, the ratio is 3:1) and are used in the form of either hay, haylage or silage (Mihailović *et al.*, 1993). So far, all Serbian forage pea (2 winter and 2 spring) and common vetch (2 winter and 3 spring) cultivars have been developed at the Institute of Field and Vegetable Crops in Novi Sad (Mihailović *et al.*, 2003b).

Materials and methods

A trial, conducted between 2000 and 2002 at the Institute of Field and Vegetable Crops' Experiment Field, included the following Novi Sad forage cultivars: two winter peas, NS Pionir and NS Dunav, one spring pea, NS-Lim, and one spring common vetch, Beograd. They were grown either as single-stands (i.e., monocultures) or together with the appropriate Novi Sad winter or spring wheat, barley and oat cultivars. The experiment was sown as a split-plot randomized complete block design with four legumes as main plots and three cereal species as subplots. There were four replicates of 5 m^2 plots. The yield of both biomass and hay (based on field dry weight) was measured and the average crude protein content was determined. The results were processed by analysis of variance, with the LSD test applied.

Results and discussion

The single stand of legumes had the lowest yield of forage (31.6 t ha^{-1}) and hay (6.9 t ha^{-1}), while the combination of legume and barley in both cases gave the highest yields, namely 40.7 t ha^{-1} of forage and 8.9 t ha^{-1} of hay (Table 1). Of all four legumes and their different stands, NS Dunav had the highest yield of fresh weight (38.7 t ha^{-1}), and there was no significant difference between it and the other two pea cultivars. The highest yield of hay was found in NS-Lim (8.5 t ha^{-1}). Yields of hay of the two winter pea cultivars (7.2 t ha^{-1}) and the spring vetch (7.3 t ha^{-1}) were statistically very similar to each other.

Table 1. Mean values of yield (t ha^{-1}) of fresh weight (FW) and hay (H) of forage pea and vetch and their mixtures with small grains.

Legume (cultivar)	Year	Single		With wheat		With barley		With oats		Stand mean	
		FW	H	FW	H	FW	H	FW	H	FW	H
Winter pea (NS Pionir)	2000	20.9	4.4	25.2	4.3	48.2	8.7	33.5	6.0	38.2	7.2
	2001	47.3	10.2	43.9	7.5	53.4	9.6	47.7	8.6		
	2002	29.1	6.3	38.1	6.5	35.1	6.3	36.7	6.6		
	mean	32.4	7.0	35.7	6.4	45.6	8.2	39.3	7.1		
Winter pea (NS Dunav)	2000	23.9	5.1	30.0	5.1	46.1	8.3	33.3	6.0	38.7	7.2
	2001	48.1	10.6	46.7	7.9	52.8	9.5	46.8	8.4		
	2002	28.7	6.3	35.1	6.0	36.3	6.5	37.2	6.7		
	mean	33.5	7.4	37.3	6.3	45.0	8.1	39.1	7.0		
Spring pea (NS-Lim)	2000	27.2	5.8	29.9	6.4	28.3	7.5	30.2	7.4	38.5	8.5
	2001	40.2	8.0	44.2	8.7	54.3	11.4	57.1	11.2		
	2002	35.3	7.5	38.9	8.3	36.8	9.8	39.3	9.6		
	mean	34.2	7.1	37.7	7.8	39.8	9.5	42.2	9.4		
Spring vetch (Beograd)	2000	21.4	5.5	23.5	6.1	26.9	7.2	23.2	5.2	31.7	7.3
	2001	31.3	5.6	34.4	6.2	50.7	11.1	50.4	9.5		
	2002	27.8	7.2	30.6	7.9	30.1	9.3	30.1	6.7		
	mean	26.8	6.1	29.5	6.7	35.9	9.2	34.6	7.1		
Legume mean		31.6	6.9	34.9	7.0	40.7	8.9	38.7	7.8	36.8	7.5
LSD (5 %)		biomass	A 1.8	B 2.1	AB 3.0		hay	A 0.4	B 0.5	AB 1.4	
LSD (1 %)		biomass	A 2.6	B 5.7	AB 6.8		hay	A 0.5	B 0.7	AB 3.2	

NS Pionir had the highest yield in combination with barley with 45.6 t ha^{-1} of biomass and 8.2 t ha^{-1} of hay. As a single-stand, it had the lowest yield of biomass (32.4 t ha^{-1}), and combined with wheat it had the lowest yield of hay (6.4 t ha^{-1}). NS Dunav showed the same behaviour: the highest yields of both biomass and hay with barley (45.0 and 8.1 t ha^{-1}) and the lowest yield of biomass as single-stand (33.5 t ha^{-1}) and of hay with wheat (6.3 t ha^{-1}). NS-Lim yielded the most in mixture with oats (32.4 t ha^{-1} of biomass and 9.5 t ha^{-1} of hay) and barley (9.4 t ha^{-1} of hay), while grown as singe stand it had the lowest yields of biomass

(34.2 t ha^{-1}) and hay (7.1 t ha^{-1}). Beograd had the highest yields of biomass (35.9 t ha^{-1}) and hay (9.2 t ha^{-1}) when combined with barley. It had the lowest yields of both parameters as single stand (26.8 and 6.1 t ha^{-1}, respectively).

Table 2. Average level of crude proteins (g kg^{-1} DM) in forage pea and vetch and their mixtures with small grains.

Cultivar	Single	With wheat	With barley	With oats	Stand mean	LSD 5 %	LSD 1 %
NS Pionir	1.97	1.67	1.36	1.41	1.60		
NS Dunav	2.01	1.51	1.37	1.38	1.57		
NS-Lim	2.37	1.99	1.54	1.69	1.90		
Beograd	2.14	1.83	1.33	1.63	1.73	0.14	0.20
Cultivar mean	2.12	1.75	1.40	1.53	1.70		

The highest average level of crude protein in dry matter (Table 2) was in the pure stands (21.2 %), while the lowest (14.0 %) was in mixture with barley: NS Pionir (13.6 %), NS Dunav (13.7 %), NS-Lim (15.4 %) and Beograd (13.3 %). For the single cultivars, the highest proportion of protein was found in the spring pea NS-Lim (19.0 %), followed by the spring vetch Beograd (17.3 %) and the two winter peas, NS Pionir (16.0 %) and NS Dunav (15.7 %).

Conclusions

Forage production of peas and vetches is one of the easiest and least expensive ways to meet the constant demand for protein feed for animal production of Serbia and Montenegro. Growing them as a single-stand crop ensures the best quality and the highest crude protein content (almost 24 % in advanced cultivars such as spring pea NS-Lim). On the other hand, the mixtures with small grains, especially barley, offer the highest yields of both biomass (about 40 t ha^{-1}) and hay (about 9.0 t ha^{-1}), which are of poorer, but still satisfactory, quality.

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Influence of the height of cutting on the re-growing capacity of winter pea (*Pisum arvense* L.)

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Abstract

The study was carried out during the period 2000-2003 with winter forage pea variety Mir. The objective of the experiment was to determine the influence of the height of cutting on the re-growing capacity of winter pea (*Pisum arvense* L.). The primary growth was harvested at the height of 5 cm, 10 cm, 15 cm and 20 cm at the stages of budding-early flowering, 25 % flowering and 50 % flowering. The re-growth was harvested at the stages of full pod formation, filled lower pods and milky ripeness. The results showed that the height of cutting of primary growth and the phenological stage of development of winter forage pea exerted a determinative influence on the capacities for its second re-growth. The highest total yield of dry mass, (a 24.3 % increase over the control), was obtained when harvesting the primary growth at the budding-flowering stage at a cutting height of 20 cm and the filled lower pod stage of re-growth.

Keywords: winter forage pea, cutting, height and yield

Introduction

Research in recent years showed that under the meteorological conditions of the Republic of Bulgaria there were possibilities for two-cut harvesting of winter forage pea (Kertikov, 2002a). The phenological stage of harvesting of primary growth (Kertikov, 2002b), the grain and forage productivity (Kertikov, 2003a) as well as the quality of the products obtained (Kertikov, 2003b) have been determined. At this stage the height of cutting of the primary growth is of topical interest with the purpose of using more completely the capabilities of pea as a forage crop and prolonging the period of feeding with green forage.
The objective of this study was to determine the influence of the height of cutting of primary growth on the yield of the primary growth and the subsequent re-growth of winter forage pea (*Pisum arvense* L.).

Materials and methods

The field experiment covered the period 2000-2003. A layout design by the chessboard method was used with a plot size of 12 m^2, under non-irrigated conditions. Winter forage pea (*Pisum arvense* L.) variety Mir was studied. Nine treatments were laid out in 36 combinations. The primary growth was cut at four heights; 5, 10, 15 and 20 cm. The harvesting of the primary growth by treatments was performed at the following phenological stages: treatments 1, 2 and 3 at budding-first flower appearance, treatments 4, 5 and 6 after an interval of 7-8 days at 25 % flowering of pea and treatments 7, 8 and 9 after an interval of 4-5 days at 50 % flowering. The harvesting of the re-growth was performed at a cutting height of 12 cm at the following phenological stages: treatments 1 and 4 at full pod formation, treatments 2 and 5 at filled lower pods and treatments 3 and 6 at milky ripeness. No secondary growing-up was obtained for treatments 7, 8 and 9. The control treatment was harvested only once at the phenological stage of filled lower pods and a cutting height of 12 cm.
The climatic conditions during the period of study as well as dry matter content (green mass), forage yields from primary growth and re-growth, and total productivity depending on the height of pea cutting for the primary growth, were observed.

Results and discussion

Meteorological conditions were diverse with regard to rainfall and air temperature. Their manifestation was more unfavourable during the late autumn and early spring months. During the rest of the season, development the crop occurred under favourable meteorological conditions for the expression of its potential biological capabilities.

The dry mass productivity for growth stages (Table 1) showed a definite relationship. It depended on the height of cutting of primary growth on the one hand and on the phenological stage of harvesting of winter pea on the other hand. There was a general trend for a decrease of dry mass yield of the primary growth with an increase in the cutting height of plants. At the phenological stage of budding to early flowering the yield decrease was 14.4 % as the height of cutting increased from 5 cm towards 20 cm. At the phenological stage of harvesting (25 % and 50 % flowering), the yield decrease was 10.9 % and 24.6 %, respectively. The phenological stage of harvesting the primary growth also exerted an influence on the yield. There was a general and regular trend for the yield to be the lowest at the first stage (budding-early flowering) and highest when harvesting at the phonological stage of 50 % pea flowering. However, in this case when harvesting at the stage of 50 % flowering, a re-growth could not be harvested.

Table 1. Productivity of dry mass by growth periods (kg ha^{-1}), average for 2000-2003.

Primary growth					Re-growth				
Treatments and phenological stages at harvest	Height of cutting (cm)				Treatments and phenological stages at harvest	Height of cutting of the primary growth (cm)			
	5	10	15	20		5	10	15	20
Treatments (1-3) Budding-flowering	3211	3017	2777	2653	(1) Full pod formation	2396	3248	4674	5331
					(2) Filled lower pods	2341	3550	4527	5368
Treatments (4-6) 25 % flowering	3943	3767	3684	3513	(3) Milky ripeness	1919	3438	4562	4997
					(4) Full pod formation	998	2409	3138	3792
Treatments (7-9) 50 % flowering	5842	5271	5045	4407	(5) Filled lower pods	721	1420	2612	3564
					(6) Milky ripeness	529	1106	2341	3421
Control	6456								

The trend concerning the dry mass yields obtained from the re-growth was exactly opposite to that for the primary growth. Here, maximum yields from pea were obtained in the treatments harvested at the stages of full pod formation, filled lower pods and milky ripeness. In the primary growth the same treatments that were cut at the earliest phenological stage of pea development (budding-early flowering) had the lowest yield. At the same time a biological and physiological possibility for a faster start of development and re-growth were created in these treatments. In the re-growth the trend of the dry mass yield relative to the cutting height of the crop was also the opposite to that in the primary growth. In the re-growth the yield was higher for those treatments cut at a greater height when harvesting the primary growth. Probably the greater height of cutting of pea from primary growth ensured greater volume and concentration of plastic substances in over ground residues and the possibility for a faster rate of development and growing-up pea during the re-growth.

The total yield of dry mass (Table 2) obtained from the combined primary growth and re-growth of winter forage pea depended mainly on the phenological stage of harvesting and the heights of cutting the primary growth. With an increase in the height of cutting of pea the total yield of dry mass also increased. At the maximum height of 20 cm the dry mass yield obtained was 7.4 % to 24.3 % higher than the control. This result showed an efficient method for prolonged crop harvesting over time and the possibility for increasing forage productivity per unit area.

Table 2. Total yield of dry mass from the primary growth and re-growth depending on the height of cutting of the primary growth (kg ha^{-1}), on average for the period 2000-2003

Treatments	5 cm (kg ha^{-1})	% of control	10 cm (kg ha^{-1})	% of control	15 cm (kg ha^{-1})	% of control	20 cm (kg ha^{-1})	% of control
1	5607	86.8	6081	94.2	7450	115.4	7985	123.7
2	5552	86.0	6567	101.7	7305	113.2	8022	124.3
3	5130	79.5	6455	100.0	7338	113.7	7650	118.5
4	4941	76.5	6173	95.6	6822	105.7	7305	113.2
5	4664	72.2	5187	80.3	6296	97.5	7077	109.6
6	4472	69.3	4873	75.5	6025	93.3	6934	107.4
control		100.0		100.0		100.0		100.0
LSD $_{0.05}$	1.965		1.309		819		849	
LSD $_{0.01}$	1.422		948		623		615	
LSD $_{0.001}$	1.028		685		429		440	

Conclusions

The height of cutting of primary growth and the phenological stage of development of winter forage pea exerted a determinative influence on the capacities for its secondary growing-up. The highest total yield of dry mass, by 24.3 % over the control, was obtained when harvesting the primary growth at the phenological stage of budding-flowering at height of cutting of 20 cm and the re-growth at the phenological stage of filled lower pods.

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Soybean (*Glycine max* [L.] Merr.) crop establishment for forage in the United Kingdom

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Abstract

Field trials at The Royal Agricultural College have indicated the potential of Soybeans (*Glycine max*) for forage in the UK. However as yet no single cultivar has proven itself entirely suited to UK climatic conditions.

In order to identify suitable cultivars for use in future field trials; germination, seed vigour, planting depth and a cold test were conducted using 16 potential varieties, of both grain and forage types.

Germination results were acceptable for all varieties with Northern Star having the lowest at 88 %, significantly (P < 0.05) lower than all others, excluding Northern Conquest and K98. Seed vigour scores varied between 10 % and 100 % for Gentleman and K98 respectively. The cold test indicated the likely effect of cold, damp sowing conditions upon germination; the day length neutral varieties emerged more rapidly and produced a greater dry matter mass than adapted forage types. Planting depth investigation results were in agreement with those of Willmott *et al.* (1999) and agronomic advice from the United States.

Whilst the above results highlight issues relating to the establishment of a soybean crop, other field trials have demonstrated the potential of soybeans as a UK forage crop. Further investigation is required before firm conclusions may be drawn.

Keywords: soybeans, vigour, germination, planting depth

Introduction

Soybeans have increased in popularity in the United Kingdom over the past 10 years. Interest in the crop has largely risen due to the high cost of imported soybean meal from South America and the European Union, the ban on the use of meat and bone meal and fishmeal in livestock diets and interest in using GM free soya. The current area of soybeans produced in the UK is estimated at 1,200 ha and grain yields of 4.78 t ha^{-1} can be achieved (Willmott *et al*., 1999). In order to increase the area of soybeans grown in the UK the continual selection of the most promising varieties is necessary. Forage type soybeans developed by Dr T.E. Devine of the USDA ARS have been tested at the Royal Agricultural College, Cirencester since 2000 with some promising results. In addition, grain types bred in Canada, Belarus and the Ukraine have had success commercially in the UK. In order to select the most promising varieties for field trials in the 2003 season greenhouse tests were carried out over the winter months with the aim of determining the most vigorous varieties. One of the greatest factors in the establishment of a soybean crop is planting depth. Recommendations of planting depth vary widely though the generally accepted depth is 2.5-4 cm (Ritchie *et al*., 1997). The depth of planting will have an effect upon the seedling vigour, as exposure to low temperatures will be increased at greater depths. In addition there maybe also a decrease in emergence as the hypocotyls can break when faced with a soil crust. Shallow planting may however lead to seedling losses as the seed coats may not be discarded and there is a risk of herbicide damage, although the exposure of seeds to soil borne diseases is reduced (Upfold and Olechowski, 1994). In addition the maturity group (MG) of a variety must also be considered, ranging from MG0000 suited to the most northerly latitudes to MGX for very southerly latitudes. The grain types are less sensitive to day length and low temperatures being on average MG000, whereby the forage types range from MGIV to MGVI. Due to the cool damp UK climate it is necessary to select varieties that are capable of germinating and establishing a good even stand in a cool seedbed (10 ºC) as late drilling can lead to problems at harvest.

Materials and methods

Greenhouse tests were carried out at The Royal Agricultural College over the winter of 2002-2003. Initially a germination test was conducted for all 16 varieties. The germination test was carried out at 25 ºC in 3 cm deep trays of silver sand. Seeds were planted at 1 cm depth, 50 seeds per tray, 2 trays per variety and placed in the greenhouse. The seeds were unearthed after 7 days and were judged to have germinated when the radicle had broken through the seed coat. The results were expressed as a percentage (Table 1).
The seed vigour tests followed a similar protocol as for the germination test using moist potting compost in place of silver sand to more accurately replicate cold wet field conditions. Trays were placed in the greenhouse at 10 ºC for 7 days and then moved to the greenhouse for an additional 7 days at 25 ºC. As for the germination test a count was taken of those seeds, which had germinated, and the results expressed as a percentage. The results of the germination and seed vigour tests were analysed and used as an aid in the selection of varieties for further testing.
Eight varieties were selected and their ability assessed to emerge successfully at various planting depths. They were monitored on a daily basis and the number of plants emerged noted. Once emerged, plant height was also noted. Planting depths used were, 1, 3, 5 and 8 cm depth with 2 pots per variety and per depth. Pots were placed in the growth chamber at 25 ºC.
The same eight varieties were also used for a cold test to determine their resistance to extended periods of cold weather at planting. Pots were filled with compost and seeds planted at 4 cm. The plants were watered daily during the test and a temperature of 10 ºC maintained. The test continued for 31 days and plant height and development were noted.

Table 1. Results of germination and vigour tests.

Variety	Maturity Group	Type	Germination		Vigour	
			%	Mean	%	Mean
Northern Conquest	000	Grain	93	46.5	71	35.5
Northern Star	000	Grain	88	44	68	34
K98	0000	Grain	94	47	100	50
Elena Ukraine	0000	Grain	97	48.5	92	46
Elena UK	0000	Grain	100	50	97	48.5
Gentleman	000	Grain	100	50	10	5
Gaillard	000	Grain	100	50	99	49.5
Altesse	0000	Grain	99	49.5	93	46.5
7P116	IV	Forage	98	49	94	47
BL15	V	Forage	100	50	52	26
97NYCZ-29	IV	Forage	99	49.5	27	13.5
BL38	V	Forage	99	49.5	57	28.5
SG13#169	VI	Forage	99	49.5	85	42.5
8GH66	VI	Forage	99	49.5	98	49
Derry	VI	Forage	98	49	68	34
Donegal	V	Forage	95	47.5	67	33.5
LSD				3.27		5.84

Results and discussion

In the germination tests, all varieties gained a reasonable score with Northern Star and Northern Conquest having significantly (P < 0.05) lower scores than all other varieties excluding K98. In contrast the vigour tests revealed significant differences between the varieties. Gentleman and NYCZ-29 were the least vigorous being significantly (P < 0.05) less vigorous than all other varieties. K98 achieved a perfect vigour score with Gaillard, 8GH-66 and Elena UK all performing well.

The planting depth test indicated that a planting depth of 3 cm could lead to an increase in plant height over all other depths tested (Table 2). There was however no statistical significance to these results; this is thought to be the result of inconstant temperatures between replicates within the greenhouse.

Table 2. Planting depth effects upon plant height and dry matter.

Planting Depth (cm)	Plant Height (cm)			Dry Matter (g)		
	Replicate 1	Replicate 2	Mean	Replicate 1	Replicate 2	Mean
1	14.725	13.112	13.918	1.109	1.072	1.090
3	17.662	13.000	15.331	1.246	1.066	1.156
5	14.950	12.925	13.937	1.048	1.021	1.034
8	14.737	11.937	13.337	1.055	0.941	0.998
LSD			3.038			0.160

It was noted that deeply planted soya did not produce strong healthy seedlings. Plants sown at 8 cm did not reach the same height as shallower sown plants and also accumulated less dry matter. This is likely to be a result of too much energy being required for emergence from greater depths.

On the conclusion of the planting depth and cold tests the plants were dried to determine dry matter. The mean dry matter per variety of all planting depths was compared with the dry matter accumulated in the cold test. In the planting depth test 14 days after planting four of the grain types: Elena, Altesse, K98 and Gaillard all produced significantly (P < 0.05) more dry matter than the forage types. These results indicated that grain type soybeans emerge faster than forage types. In contrast after 31 days at low temperatures the forage types had closed the gap with the grain types. The grain types again produced a greater amount of dry matter though they only significantly (P < 0.05) out performed one forage variety namely Donegal. The closing of the gap indicated a varying growth habit for the grain and forage types, with the forage types being slower to establish than the grain types.

Conclusions

The grain type soybeans appear to be better adapted to cold wet planting conditions than the forage types. This is likely due to their maturity groups (MG) and also their sensitivity to photoperiod. This study has highlighted the importance of planting into a warmer seedbed and the effect varietal selection may have upon field establishment in a cooler spring.

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Some factors affecting efficient nitrogen accumulation in herbage yield and soil in Lithuania

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Abstract

Efficient nitrogen accumulation in forages and in soil plays a significant role in Lithuanian farms, both in economic and ecological aspects. Many factors affect nitrogen accumulation: introduction of high potential perennial legume into the sward, the legume species and cultivar, intensity of sward use – grazing or cutting frequency and others. The data obtained in different trials on loamy Cambisols showed that lucerne based swards (*Medicago varia* Mart.) accumulated 265-294 kg N ha^{-1} y^{-1} in the dry-matter yield and 203 kg ha^{-1}of nitrogen in its roots and stubble. The values for red clover (*Trifolium pratense* L.) based swards were 206 and 104 kg ha^{-1}, respectively. White clover (*Trifolium repens* L.) / grass pasture swards fixed the amount of nitrogen equivalent to 100-160 kg N ha^{-1} of mineral fertilisers. The most efficient nitrogen accumulation for lucerne or red clover based swards occurred in a 3 cut system whilst that for white clover / grass swards involved 4-5 grazings season^{-1}.

Keywords: legumes, herbage yield, nitrogen accumulation, soil.

Introduction

The economic and ecological benefits of forage legumes are well known. Suitable legume or legume/grass swards enable savings of 180-240 kg N ha^{-1} in mineral fertilisers in leys (Kadziulis and Masauskiene, 1980; Kadziulis and Kadziuliene, 2002) and 120-180 kg N ha^{-1} on pastures (Vasiliauskiene *et al*., 1996) in moderately productive systems (herbage yield of 5000-7000 kg DM ha^{-1}) and form the basis of organic farming. The present political and economic climate favours such farming because of food surplus on the EU market and increased demand for safe, ecologically clean products. The main source of N input to the organic system is N_2 fixed by legumes (Younie, 2000). Biological N accumulated by legumes can be useful in various aspects: it produces protein rich forage and completes the nutrient cycle at the farm level through farmyard manure and herbage yield residues (stubble and roots). The efficiency of N accumulation depends on many factors, such as temperature, light, soil pH, mineral macro- and micro- nutrient availability (Hartwig and Soussana, 2001), *Rhizobium sp*. activity (Lapinskas, 1993) and others. The task of our investigations was to determine the amounts of N accumulated in herbage yield and residues depending on forage legume species, cultivar, sward composition and intensity of sward use and to ascertain their impact on subsequent crops on loamy Cambisols.

Materials and methods

The growth of forage legumes in different swards was investigated at Dotnuva over the period of the last decade on a loamy Endocalcari-Epihypogleyic Cambisol soil. Soil pH varied between 6.5 to 7.0, humus content was 2.5-4.0 %, available P = 50-80 mg and K = 100-150 mg kg^{-1}. Red clover (*Trifolium pretense* L.) cvs. Liepsna, Vyliai, Kamaniai and Arimaiciai, alsike clover (*T. hybridum* L.) cv. Daubiai, white clover (*T. repens* L.) cv. Atoliai, hybrid lucerne (*Medicago varia* Martyn) cvs. Jõgeva 118, Augune II were grown in various field trials. The grass components were timothy (*Phleum pretense* L.) cv. Gintaras II, perennial ryegrass (*Lolium perenne* L.) cvs. Veja or Sodre, meadow fescue (*Festuca pratensis* L.) cv. Dotnuva 1, cocksfoot (*Dactylis glomerata* L.) cv. Asta and smooth stalked meadow grass (*Poa pratensis* L.) cv. Danga. For ley swards 1-2 grass species were used, for pasture swards 2-3 species were introduced as mixtures. Field trials had a randomised block design with four replicates. Legumes and legume/grass mixtures were sown with a cover crop for grain or green forage. All crops were fertilised with 26 kg P and 50 kg K ha^{-1} y^{-1}. Dry matter (DM) yield of the legumes was calculated on the basis of total DM yield excluding forbs and grasses. Nitrogen content was measured by the Kjeldahl method in the herbage of each cut or grazing and in herbage residues (roots at 0-20 cm depth and stubble, both on a DM basis) before ploughing-in for the following crop. All variables were analysed using analysis of variance.

Results and discussion

Red clover cv. Liepsna both in a pure sward and in clover/timothy mixtures accumulated a considerable amount of N in the yield of the first year after sowing only. The N accumulation capacity of lucerne / red clover/timothy was high in all three years (Table 1). The amount of N in the yield residues of lucerne- based swards was also much higher than that of clover-based swards. The grain yield of wheat grown after clover swards was 570-810 kg ha^{-1} higher than that produced following timothy. The grain yield produced following lucerne-based swards was 900-1350 kg ha^{-1} higher than that achieved after timothy or cocksfoot swards fertilised with 120 kg N ha^{-1} y^{-1}. Nitrogen accumulation capacity depended not only on legume species but also on the cultivars used (Table 2). The differences between species and cultivars related primarily to their persistence during the three years of use.

Table 1. Nitrogen accumulation in legume and legume / grass yield and in residues and their impact on subsequent crop yield (average data of 3 trials).

Swards	N kg ha^{-1}						Grain yield, (kg ha^{-1})
	in herbage yield			in roots	in stubble	total up to ploughing-in	
	1st year	2nd year	3rd year				
Clover/timothy swards for 2 years use							wheat
Trifolium pratense	206	62	-	73	31	372	3,950
T. pratense / *Phleum prat.*	200	76	-	72	37	385	3,710
P. pratense	22	28	-	37	16	103	3,140
LSD$_{.05}$	7.8	7.7	-	8.0	3.2	13.9	256.0
Lucerne – clover – timothy – cocksfoot swards for 3 years use							barley
Medicago varia / *T. prat.* / *P. prat.*	265	268	294	171	32	1,030	4,420
P. prat. /120 kg N ha^{-1}	98	84	76	64	17	339	3,520
D. glomerata / 120 kg N ha^{-1}	114	117	120	62	22	535	3,070
LSD$_{.05}$	10.9	11.2	11.5	11.1	4.9	22.4	240.0

Table 2. Nitrogen accumulation in the yield of different legume species and their cultivars and its impact on subsequent oats yield.

Legume species and cultivars	N kg ha^{-1} per year of use				Oats grain yield (kg ha^{-1})
	1st	2nd	3rd	total	
Trifolium pratense cv. Liepsna	92	19	4	115	1,540
T. pratense cv. Vyliai	100	55	18	173	1,840
T. pratense cv. Arimaiciai	108	76	57	241	1,960
T. hybridum cv. Daubiai	74	41	6	121	1,560
T. repens cv. Atoliai	39	35	56	130	2,350
Medicago varia cv. Augune II	82	139	227	448	2,970
LSD$_{.05}$	20.1	11.0	17.8	29.1	198.0

The impact of sward use intensity was considerable on pastures and leys. The data of table 3 suggest that, despite higher N concentrations in younger herbage at more intensive management, the total N accumulation was 22-29 % higher in legume/grass herbage at less frequent grazing intensity, and this was due to a higher DM yield (Kadziuliene, 2003).

Table 3. Nitrogen accumulation in the pasture yield of various swards (A factor) at different grazing frequency (B factor).

Swards	N kg ha^{-1} from 1st to 4th year of use									
	1999		2000		2001		2002		mean	
	F[1]	LF[2]	F	LF	F	LF	F	LF	F	LF
Trifolium repens / L. perenne / Poa pratensis	156	159	102	134	117	168	32	68	102	132
Medicago varia / L. perenne /P.pratensis	203	208	244	302	170	245	72	83	172	210
L. perenne	49	54	75	103	110	145	22	72	64	94
L. perenne 240 kg N ha^{-1}	137	187	142	179	129	156	54	95	116	154
$LSD_{.05}$ A / B factor	7.1 / 2.9		9.2 / 3.7		8.2 / 3.4		8.9 / 3.6		8.4 / 3.4	

[1] frequent grazing 5-6 grazings, [2] less frequent grazing 4-5 grazings season^{-1}.

Lucerne/grass swards yielded on average 56 kg N ha^{-1} more than grass swards fertilised with 240 kg N ha^{-1}, and white clover/grass sward yielded 38 kg N ha^{-1} more than grass swards without N fertilisers. The increased N yield of the grass swards without N fertilisation in the 2nd-4th years of use was probably caused by the excretal returns of grazing cows. In the other trials utilising leys (Kadziulis, 1972) we found that red clover yielded 204 kg and lucerne 283 kg N ha^{-1} y^{-1} when cut 3 times a year (at flowering stage), and 182 and 232 kg N ha^{-1} respectively, when cut 4 times a year (at budding stage).

Conclusions

The nitrogen accumulation capacity of forage legumes on loamy Endocalcari-Epihypogleyic Cambisols differed depending on legume species and cultivars, their persistence during the years of use, management regime and other factors. Hybrid lucerne accumulated the highest yield of nitrogen and markedly improved grain yield of subsequent crops. The best management regime for the most efficient N accumulation was 3 cuts a year for lucerne and red clover based swards and 4-5 grazings season^{-1} for white clover / grass pastures.

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Nitrogen fixation by red clover (*Trifolium pratense*) and lucerne (*Medicago sativa*) in Belgian leys

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Abstract

The interest in lucerne and red clover is increasing again because of their potential role in sustainable and organic systems. Nitrogen fixation reduces the use of inorganic nitrogen fertiliser in conventional farming and is the main source of this nutrient in organic farming.
Two methods were used for evaluating fixation: yield difference and fertiliser equivalence. Nitrogen yields of legume-grass mixtures were compared with pure grass plots fertilised with increasing rates of nitrogen (0 to 400 kg N ha^{-1} y^{-1}) during several years and on several sites in Belgium. In our experiment on humus-poor soils, very high values were recorded for N fixation: about 350 to 400 kg N ha^{-1}. The results of the two methods are compared and discussed.

Keywords: yield, nitrogen, fixation, method, legume

Introduction

Soil nitrogen is a major limiting factor for plant production in most ecosystems of the world. Even with modern intensive agriculture, where N is largely supplied from synthetic fertilisers, the amount of N removed from the soil as harvested crop, runoff, erosion, leaching and denitrification has been sometimes calculated to surpass the input on a regional scale (Doyle and Cowell, 1993). With current concerns about environmental degradation and loss of natural resources, there is a growing interest in assessing the potential for biological fixation of atmospheric N.
Among N_2-fixing plants, forage legumes have the advantage that a large proportion of the N accumulated is available for return to the soil through senescence of leaves and roots including nodules turnover, and becomes available for the companion grass.
The purpose of our study is to assess, by two methods, the amount of N_2 fixed by two legumes used in Belgian's cutting grassland, red clover (*Trifolium pratense*) and lucerne (*Medicago sativa*).

Materials and methods

Three loamy soils with low humus contents were selected. Each site was sown for three years (one year of establishment and two years of production). Characteristics of soils are shown in table 1. Sites 1 and 2 were established in 1999 and site 3 in 2000, according to the same protocol. Each site was sown with perennial ryegrass (*Lolium perenne)* (Lp) fertilised with increasing rates of nitrogen (0, 100, 200, 300 and 400 kg N ha^{-1} y^{-1}), and with a red clover-perennial ryegrass mixture (Tp+Lp). On sites 2 and 3, a lucerne-cocksfoot (*Dactylis glomerata*) mixture (Ms+Dg) was also sown. Mixture plots were not fertilised. Four cuts were taken annually on each plot. All experiments included four replicates in complete randomised blocks. Dry matter and total N yields were recorded.
Two methods were used for the quantitative assessment of N_2 fixation by legumes in the mixtures: yield difference (YD) and fertiliser equivalence (FE). In the first method (YD), based on total N yield, the amount of fixed N_2 is estimated by subtracting from the total amount of N yield of the grass-legume mixture, the amount of N yield of a pure grass with no

nitrogen fertilisation. In the second method (FE), the total N exported by the mixture is compared with those of pure ryegrass fertilised with increasing rates of N. The fertiliser equivalent value is the amount of inorganic N that would be required to produce an equivalent yield under otherwise comparable test conditions (Higgs *et al.*, 1976). The reference grass is a perennial ryegrass for both grass-legume mixtures.

Table 1. Soil characteristics of the three sites.

Site	pH	C (%)	Humus (%)	K (mg 100 g^{-1})	P	Na	Mg	Ca	C/N
1	6.0	0.9	1.6	9	9	3.0	10	89	10
2	7.2	1.0	1.7	21	12	3.0	20	213	10
3	7.0	1.2	2.0	24	17	2.6	15	205	10

Results and discussion

Results shown in table 2 highlight the interest of legumes in mixtures with grasses. Dry matter and N yields of grass-legume mixtures are close to those of pure ryegrass fertilised with 400 kg N ha^{-1} (Lp 400) in the first year of production. The nitrogen yields in the second year even exceed those of a N400 ryegrass.

Table 2. Total yields in dry matter (DM) and in nitrogen (N) and total N fixed by legumes assessed by yield difference (YD) and fertiliser equivalence (FE) methods. Standard errors of the mean are in exponents.

Site	Species	Total yields				Total nitrogen fixed (kg ha^{-1})			
		1st year ley		2nd year ley		1st year ley		2nd year ley	
		t DM ha^{-1}	kg N ha^{-1}	t DM ha^{-1}	kg N ha^{-1}	YD	FE	YD	FE
1	Lp+Tp	13.0 $^{1.0}$	328 ^{34}	13.3 $^{1.4}$	380 ^{45}	256 ^{23}	344 ^{30}	338 ^{19}	436 ^{24}
	Lp 400	16.5 $^{1.3}$	366 ^{29}	12.6 $^{1.6}$	342 ^{49}	-	-	-	-
2	Lp+Tp	13.9 $^{2.0}$	369 ^{62}	14.9 $^{1.2}$	411 ^{32}	287 ^{32}	458 ^{52}	377 ^{22}	545 ^{31}
	Dg+Ms	13.1 $^{1.5}$	375 ^{62}	13.1 $^{1.3}$	380 ^{37}	292 ^{36}	467 ^{61}	346 ^{27}	501 ^{38}
	Lp 400	15.2 $^{2.0}$	309 ^{60}	11.5 $^{1.1}$	305 ^{60}	-	-	-	-
3	Lp+Tp	15.1 $^{2.0}$	370 ^{72}	12.3 $^{0.9}$	469 ^{32}	312 ^{57}	401 ^{73}	303 ^{33}	406 ^{43}
	Dg+Ms	14.0 $^{1.3}$	390 ^{51}	11.6 $^{1.2}$	332 ^{47}	332 ^{37}	427 ^{47}	299 ^{36}	400 ^{48}
	Lp 400	16.4 $^{1.1}$	369 ^{40}	12.8 $^{1.1}$	333 ^{34}	-	-	-	-

The amounts of N fixation ranged from 256 to more than 400 kg N ha^{-1} y^{-1}. A part of this fixed nitrogen is transferred to the companion grass.
Estimates of N fixation vary according to the methods, but the two methods showed higher N-fixed amounts for the second year of production. No significant differences appeared between lucerne and red clover. N fixed by legumes according to the fertiliser equivalence (FE) method is highly superior ($P < 0.05$) to that of the yield difference (YD) method. The FE method may overestimate the amount of N_2 fixed by legumes: a high fertilisation rate of 400 kg N ha^{-1} may reduce significantly the amount of N taken up from the soil by the non-fixing control ryegrass. The amount of N derived from soil in the legume-based plots may then be much higher than in pure ryegrass plots. On the other hand, the yield difference method (YD) is based on the assumption that both fixing and non-fixing plants take up the same amount of N from the soil, an assumption that may not be wholly correct, especially if the plants differ in their seasonal pattern of growth and in root morphology (Ledgard and Peoples, 1988).

Conclusions

Legume-based forages are of great interest in terms of reducing inputs of nitrogen fertilisers and protein production and thus reducing costs at farm scale, thanks to symbiotic nitrogen fixation. They can provide high yields of up to 15.1 t DM ha^{-1} for red clover mixtures and 14.0 t DM ha^{-1} for lucerne mixtures. Data have been presented for the estimated amounts of N_2 fixed by red clover and lucerne in Belgian temporary grasslands. The amount of nitrogen fixed by legumes assessed by the two methods varied from 256 up to 545 kg N ha^{-1} y^{-1} for red clover and from 292 up to 501 kg N ha^{-1} y^{-1} for lucerne. However, it should be understood that the two methods are indirect estimations and do not provide absolute values of fixation.

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Influence of some insecticides for presowing treatment of seeds on nodulation and forage quality of vetch

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Abstract

A field trial with insecticides for presowing treatment of seeds of vetch (*Vicia sativa,* L.) Obrazets 666 variety was carried out. Promet 400 SC (furathiocarb) – 3 l, Mezurol 500 FS (mercaptodimetur) – 2 l, and Cruiser 350 FS (thiometaxan) – 0.9 l were used per 100 kg seeds. It was found that the insecticides tested had a positive influence on root mass growth and development and no toxic influence on nodulation. Root length increased by 9 to 17 %, dry root mass by 9 to 18 %, and the number of nodules formed by 23 to 41 %. Crude protein content in leaves increased by 1 to 8 %, water soluble carbohydrates by 12 to 29 %. When treated with Cruiser, the content of Ca and P were increased by 23 % and 9 %, respectively.

Keywords: insecticides, nodulation, seed treatment, crude protein, WSC, Ca, P, vetch

Introduction

Presowing treatment of seeds with insecticides is considered an efficient, economical and ecological means of controlling insect pests in many forage legume crops (Dochkova *et al*., 2000). Vetch is a valuable proteinaceous nitrogen-fixing crop. Under favourable conditions it fixed 50-125 kg N ha^{-1} y^{-1} (Brady, 2000). The efficiency of the symbiosis among plants and nodule bacteria depended on many ecological factors, as well as on the use of pesticides for controlling insect pests (Hartwig and Soussana, 2001).
The objective of this study was to investigate the influence of some insecticides for presowing treatment of seeds on root growth, nodulation and forage quality of vetch.

Materials and methods

The study was carried out in 2002-2003 in the experimental field of the Institute of Forage Crops. Vetch variety Obrasets 666 was used. A trial was carried out with four replications, plot size of 4 m^2 and sowing rate of 150 kg ha^{-1}. Promet 400 SC (furathiocarb) – 3 l (standard), Mezurol 500 FS (mercaptodimetur) – 2 l , and Cruiser 350 FS (thiometaxan) – 0.9 l were used per 100 kg seeds. Seed treatment was made on the day of sowing. Absorbent TZ 21 (2.54 % Mg) was used as a drying agent. A trial was carried out at the natural population density of the species of *Sitona* genus and insect pest complex. Nodulation was recorded at flowering and immediately before harvesting after taking soil cores of 40 × 20 × 30 cm including 30 plants per treatment. After washing of the root system, length and weight of root mass, number of nodules and number of nodules destroyed by the larvae of *Sitona* genus were recorded. The root mass was fixed for 15 min at 105 °C and dried to a constant weight at 60 °C. Content of crude protein, Water Soluble Carbohydrates (WSC) and mineral constituents, Ca and P, were determined by standard methods. Data were statistically processed using software SPSS for Windows 2000.

Results and discussion

The data in table 1 show that the insecticide preparations tested had a positive influence on the root growth and development of vetch. Compared with the control, the root system was longer by 9 to 17 % and the weight of dry root mass was higher by 9 to 18 %. One of the possible reasons for the higher values of these characteristics was Mg content in the absorbent which had a stimulating action on the plant development. Nodule number increased by 23 % and 41 % when treated with Mezurol and Cruiser. The nodule number was the smallest for the control (16) and the greatest for Cruiser (23). The effective insecticide action of Cruiser against the adult insect of nodule-feeding weevils resulted in a decrease in the percentage of the nodules destroyed by the larvae - 46 % for the control and 8 % for Cruiser.

Table 1. Root mass and nodulation in vetch after presowing treatment of seeds, average for 2002-2003.

Treatments	Root mass			Nodulation		
	cm	g plant^{-1}	+, % increase over control	nodules plant^{-1}	% increase over control	% destroyed nodules plant^{-1}
Control	11.5	0.11		16.4		45.9
Promet 400 SK	12.5	0.12	+ 9	22.3	36.0	11.9
Mezurol 500 FS	13.0	0.12	+ 9	20.1	23.0	13.4
Cruiser 350 FS	13.4	0.13	+ 18	23.2	41.0	8.0
SE (P = 0.05)	2.3	0.2		4.8		

Forage quality of vetch was positively affected by presowing treatment with insecticide preparations. Crude protein content in the leaves of vetch increased by 1 to 8 %, and WSC by 12 to 29 %, relative to the control (Table 2). After applying Cruiser, crude protein and WSC showed the highest values. The treatment with Promet and Cruiser increased the content of Ca by 15 to 23 % relative to the control, but the content of P increased when treated with Cruiser only. Content of Ca and P was the same as in the control when treated with Mezurol.

Table 2. Crude protein content in vetch treated with insecticide preparations, average for 2002-2003.

Treatments	Crude protein		WSC		Ca		P	
	g kg^{-1}	+ increase – decrease %	g kg^{-1}	+ increase – decrease %	g kg^{-1}	+ increase – decrease %	g kg^{-1}	+ increase – decrease %
Control	14.0		48.0		13.6		2.13	
Promet 400 SK	15.1	+ 7	55.0	+ 14	15.0	+ 15	1.99	– 6
Mezurol 500 FS	14.2	+ 1	54.0	+ 12	13.6	-	2.15	-
Cruiser 350 FS	15.2	+ 8	62.0	+ 29	16.4	+ 23	2.33	+ 9
SE (P = 0.05)	0.3		2.9		0.7		0.01	

Conclusions

The insecticide preparations Promet, Mezurol and Cruiser used for presowing treatment of seeds positively influenced root growth, nodulation and forage quality of vetch. Cruiser combines effective insecticide action and good forage quality.

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The interactions between *Glomus intraradices* fungus and *Rhizobium* genus bacteria in forage legumes

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Abstract

The paper presents a study of the relationships and interactions between *Glomus intraradices* symbionts and *Rhizobium spp.* bacteria isolated from some species of forage legumes (*Lotus corniculatus* L. (Lc), *Trifolium repens* L. (Tr) and *Medicago sativa* L. (Ms)) grown in an argillic brown earth soil within the Grassland Research Station, Timisoara, Romania. The aim of the study was to detect the best variants of combinations of synergism between symbionts regarding the increase of atmospheric nitrogen use and obtaining possible bio-preparates with these symbionts in the future. Starting from an *in vitro* model, the symbionts were aseptically isolated from plants and inoculated in the modified Gamborg culture medium (B_5), without any source of inorganic nitrogen. The experimental data showed the existence of some relationships of synergism and antagonism between symbionts**.** Thus, we found a close specificity regarding the synergic correlation between *Glomus intraradices* fungi and *Rhizobium* bacteria taken from the same host plant, the correlation coefficients being positive (*Glomus* GL-Lc 10 + *R. loti*, r = 0.94; *Glomus* GL-Ms 2 + *R. meliloti*, r = 0.98 and *Glomus* GL-Tr 4 + *R. trifolii*, r = 0.98). In combinations between symbionts obtained from different plants, we noticed an antagonistic relationship, with slow growth and negative correlation coefficients (*Glomus* GL-Lc 10 + *R. loti*, r = - 0.94; *Glomus* GL-Lc 10 + *R. trifolii*, r = - 0.75; *Glomus* GL-Ms 2 + *R. loti*, r = - 0.92; *Glomus* GL-Ms 2 + *R. trifolii*, r = - 0.94; *Glomus* GL-Tr 4 + *R. loti*, r = -0.83; *Glomus* GL-Tr 4 + *R. meliloti*, r = -0.94).

Keywords: *Glomus intraradices*, nitrogen fixation, *Rhizobium*

Introduction

The soil at the Grassland Research Station Timisoara, Romania is characterized as a poorly acid, moderately vertic-gleyed, argillic brown earth soil, of moderate fertility, with fine fluvial deposits and a clay texture. The inoculation of cultures with bacteria is important for the observation of the efficiency of production and the quality of the fodder plant biomass for animal feeding. The existence of *Glomus sp.* fungi and of *Rhizobium* bacteria has already been observed at the level of the root system of forage legumes (Parniske, 2000).
In this paper we present a preliminary study, based on an *in vitro* model, of the type of interaction between the *Glomus intraradices* fungus and the *Rhizobium sp.* bacteria isolated from three species of forage legume (*Lotus corniculatus* L., *Trifolium repens* L. and *Medicago sativa* L.).

Materials and methods

The biological material was represented by the hyphae of the *G. intraradices* fungus (GL-Lc 10 from *L. corniculatus* L., GL-Ms 2 from *M. sativa* L. and GL-Tr 4 from *T. repens* L.) and the *R. loti*, *R. meliloti* and *R. trifolii* bacteria, which are part of the collection of the Grassland Research Station in Timisoara. The nitrogen-fixing bacteria, *Rhizobium sp.*, were isolated in aseptic conditions from the pink nodules and from the hyphae of the *G. intraradices* fungus of the birdsfoot trefoil (*L. corniculatus*), alfalfa (*M. sativa*) and white clover (*T. repens*). All residues of soil were removed from the root fragments of these plants through multiple water washes so that any trace of contamination of the nodules with other bacteria or fungal sources would be eliminated. The pre-sterilization was performed in 70° ethyl alcohol for 3 seconds and the sterilization in calcium hypochlorite (2 %) + Tween 80, for 40 minutes. The oxidant agent was removed through successive washes with sterilized, distilled water. In order to study the inter-relationships between symbionts, we constructed an *in vitro* model typical of mycological study, namely double culture. In 100 mm diameter Petri dishes we introduced 20 ml Gamborg (B_5) culture medium, with 8 % Difco agar and the hormones BAP and NAA, (0.2 and 0.01 mg l^{-1}, respectively). The medium was maintained at pH = 6.8 (Handberg and Stougaard, 1992). In the centre of the Petri dish we placed a paper disk of 20 mm diameter, with a central hole of 5 mm diameter. To serve our purpose, the paper disk ring was imbibed in the bacterial suspension and placed aseptically in the colony dish. In the centre of the dish, a cellular fungi cluster of the *Glomus sp.* of approximately 5 mm diameter had been placed. After inoculation, the Petri dishes were moved into a constant temperature at 25 °C. In order to count the species of *Rhizobia* bacteria, a recent and instant technique was used, namely Rapid Hygiene Monitoring System, through the use of a HY-LiTE (Merck) spectrophotometer which functions according to the following principle:

ATP + *luciferine / luciferase* → ADP + PP + light

The experimental data were analysed statistically by calculating the correlation value *r* in order to establish the relationship between the variables of the *in vitro* system.

Results and discussion

The experimental data show that between the *G. intraradices* and the *Rhizobium sp.* bacteria there are interspecific relations of the synergistic and antagonistic type, aspects resulting from the correlation coefficients values. Thus, there is a synergistic relationship (*Glomus* GL-Lc 10 + *R. loti*, $r = 0.94$; *Glomus* GL-Ms 2 + *R. meliloti*, $r = 0.98$ and *Glomus* GL-Tr 4 + *R. trifolii*, $r = 0.98$) between the *G. intraradices* fungus and the *Rhyzobium sp.* bacteria drawn from the same species of host plant (Table 1). In the case of combinations between these fungi and bacteria drawn from different hosts, the relationship between the symbionts are antagonistic (*Glomus* GL-Lc 10 + *R. loti*, $r = -0.94$; *Glomus* GL-Lc 10 + *R. trifolii*, $r = -0.75$; *Glomus* GL-Ms 2 + *R. loti*, $r = -0.92$; *Glomus* GL-Ms 2 + *R. trifolii*, $r = -0.94$; *Glomus* GL-Tr 4 + *R. loti*, $r = -0.83$; *Glomus* GL-Tr 4 + *R. meliloti*, $r = -0.94$).
The strongest positive mutual influences between symbionts of our experiment are between the *Glomus* GL-Ms 2 fungus and the *R. meliloti* bacterium with $r = 0.98$ and between *Glomus* GL-Tr 4 + *R. trifolii*, where $r = 0.98$.
On the contrary, the most significant antagonistic relation was within the experimental combination of *Glomus* GL-Lc 10 + *R. trifolii* interspecific relationship, also emphasized by the correlation coefficient $r = -0.75$, as well as by the regression equation, where $r = -0.165\ x^2 + 1.755\ x + 3.39$, $R^2 = 0.99$. This high aspect of the antagonism between the *Glomus* GL-Lc 10 and *R. trifolii* symbionts is a result of the highly inhibiting action of bacteria on the growth of *Glomus* GL-Lc 10 fungus hyphae.
Our study shows the possibility of using another culture medium than the classical one (Kijne *et al*., 1988). We have successfully used the Gamborg (B_5) culture medium, with a very precise composition to induce the growth and development of symbionts, *G. intraradices* fungus and *Rhizobium* bacteria. We found the existence of clear specificity between the compatibility of *Rhizobium* bacteria and different possible forms of *G. intraradices*, even

though the specialized literature does not mention the existence of any varieties or subspecies of *G. intraradices* (Wegel *et al*., 1998). In the future, we will try to identify these special forms of *G. intraradices* fungi, compatible with the plant and the partner bacteria.

Table 1. The correlation coefficients between the growth rate of *Glomus intraradices* fungus and the growth of number of *Rhizobium sp.* bacteria on forage legumes.

Combinations between Glomus sp. fungus and the Rhyzobium sp.		Correlation coefficients (r)	Regression equations	R^2
Glomus GL-Lc 10	*R. loti*	0.94	$y = 0.0779x^2 + 0.2439x + 3.634$	0.95
	R. meliloti	-0.94	$y = -0.1386x^2 + 0.,4894x + 4.614$	0.87
	R. trifolii	-0.75	y = -0.165x2 + 1.755x + 3.39=	0.99
Glomus GL-Ms 2	*R. loti*	-0.92	$y = -0.0957x^2 + 0.2623x + 4.192$	0.86
	R. meliloti	0.98	$y = 0.1064x^2 + 0.3204x + 3.776$	0.95
	R. trifolii	-0.94	$y = -0.025x^2 + 0.055x + 0.51$	0.86
Glomus GL-Tr 4	*R. loti*	-0.83	$y = -0.1043x^2 + 0.4797x + 3,566$	0.91
	R. meliloti	-0.94	$y = -0.0407x^2 - 0.0107x + 4.812$	0.88
	R. trifolii	0.98	$y = -0.1114x^2 + 1.4806x + 3.722$	0.98

y = growth rate of *Glomus intraradices* (mm d^{-1}), x = number of bacteria cm^{-2} (log N_o).

Conclusions

Our experimental results have shown that, at the level of plant rhizosphere a rigorous selection takes place, regarding the future partners which will colonize the root system of host plants, namely forage legumes within the symbiotic complex.

We have also emphasized the existence of a desired specificity of compatibility, of a synergism between the symbionts *G. intraradices* and *Rhizobium*, aspects which result from the positive correlation coefficients.

Thus, our results show the existence of a synergistic relationship between *G. intraradices* fungi and the *Rhizobium sp.* bacteria isolated from the same forage legume species and of an antagonistic relationship between these symbionts when the host plant is different.

The practical importance of this preliminary study leads us to the idea of preparing, in the future, some possible biopreparates with these selective symbionts, taking into account, especially, the high degree of compatibility between these symbionts.

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The development of heterogeneity in mixtures of grass species

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Abstract

The development of patches of a single plant species from intimate mixtures of two species was studied in a greenhouse experiment under two defoliation intensities (cutting to 3 cm and 6 cm), with and without synthetic urine application. *Agrostis capillaris* was present in all mixtures. The companion species were *Deschampsia cespitosa, Festuca rubra, Lolium perenne*, *Nardus stricta* and *Phleum pratense*. The species mixtures showed different patch forming characteristics. *F. rubra* and *L. perenne* were able to retain their distribution pattern in the sward with *A. capillaris* whereas the cover of *P. pratense*, *N. stricta* and *D. cespitosa* declined and they disappeared or became aggregated in small patches within a year. The dynamics of change were modified by defoliation intensity and urine addition but the initial composition of the mixture had the greatest effect on species cover and aggregation.

Keywords: *Agrostis capillaris*, defoliation, species aggregation, urine

Introduction

Heterogeneous species distributions are common in grassland communities. Such differences in spatial distribution pattern are likely to affect interactions between component species at both the plant scale and ultimately at the community scale. Grazing by herbivores is thought to be a key determinant of the spatial dynamics of plant species, but there is little information on the extent to which the development of heterogeneity at the bite to feeding station scale (i.e., 0.05-1 m) relates to defoliation and nutrient inputs in extensively managed grasslands. We used intimate mixtures of two grass species grown under glasshouse conditions to test the hypotheses that the rate of development of patches of species depends on the species present in the mixture, the intensity of defoliation and the addition of urine. *Agrostis capillaris*, which has a widespread distribution in extensively managed grasslands, was present in all mixtures. It is classed by Grime *et al.* (1988) as a patch forming species whereas the companion species had different patch forming characteristics. In this paper we describe the changes in sward height of the component species in the mixtures and the changes in plant cover over a growing season.

Materials and methods

Intimate mixtures of two grass species arranged in a checkerboard design were created in October / November 2000 by planting alternate 2 cm × 2 cm soil plugs containing a seedling of *Agrostis capillaris* or a companion species (either *Deschampsia cespitosa*, *Festuca rubra*, *Lolium perenne*, *Nardus stricta* or *Phleum pratense*). Each mixture (34 cm × 24 cm) contained 204 plants, 102 plants each of *Agrostis capillaris* and the companion species. In addition, *Agrostis capillaris* was grown on its own in monoculture. Two cutting height treatments (cut to 3 cm or 6 cm at two week intervals from March to April 2001 and weekly from May until November 2001) and two synthetic urine treatments (with and without synthetic urine applied in May and September 2001 following a weekly cut) were applied to the mixtures. The composition of the synthetic urine was adapted from Clough *et al*. (1996) and Williams *et al*. (2000), and the rate of application (400 ml) was equivalent to 236 kg N ha^{-1} and 246 kg K ha^{-1}. This rate was chosen to simulate a single urination in the field, taking into account the restricted volume of soil compared with field conditions. The synthetic urine was applied evenly across the surface of the grass mixture using a small watering can, then a spray of 100 ml deionised water was used to wash the synthetic urine from the herbage. The control boxes received only deionised water (500 ml) applied in the same way. There were two replicates for each species mix × cutting height × urine treatment combination.

The spatial distribution of species was measured in March, May, June, August and October before cutting. A perspex box placed over the sward allowed measurements to be made without disturbing the foliage. The surface of the box was etched into 2 cm × 2 cm cells, identical to the planting pattern, and the presence of foliage of the two species within every cell was recorded. Percentage cover of the two species and/or bare ground was recorded in a centrally located 10 cm × 10 cm area. The height of each species in the mixture was measured (5 measurements per species) before cutting. Data were analysed by repeated measures analysis of variance.

Results and discussion

Sward height prior to the weekly cut was significantly (P < 0.001) taller for 2 to 11 weeks following synthetic urine addition in May and for 3 to 6 weeks after the September treatment. The maximum height difference occurred 3 weeks after the May application (+ urine 12.2 cm and control 7.7 cm, s.e.d. = 0.44). In both cutting height and both synthetic urine treatments *Agrostis capillaris* was generally taller than *Deschampsia cespitosa* and *Nardus stricta* but shorter than *Festuca rubra*, *Lolium perenne* and *Phleum pratense*. A species ability to successfully compete with *Agrostis capillaris* and retain its presence in the mixture could be affected by differences in height. Potentially more leaf material is removed by cutting from a taller companion species, while a shorter species may compete less effectively for light.

The presence of cells containing a single species was rare in mixtures containing *Festuca rubra* and *Lolium perenne* (two species that were taller than *Agrostis capillaris*) but they were present in the other mixtures from May (Table 1). By October, mixtures with *Nardus stricta* and *Phleum pratense* had the greatest number of cells containing *Agrostis capillaris* only and no cells containing only the companion species. Although *Phleum pratense* was generally taller than *Agrostis capillaris*, it formed far fewer tillers and therefore lost a greater proportion of plant biomass under the weekly cutting regime. *Deschampsia cespitosa*, a species that is capable of forming near monocultures (Grime *et al*., 1998), was the most successful species in excluding *Agrostis capillaris*. *Agrostis capillaris* only cells were more frequent in the treatment cut to 3 cm without synthetic urine application (P < 0.05), but there was no effect of cutting height or urine treatment on the number of cells containing only the companion species.

Table 1. The percentage of cells containing a single species, *Agrostis capillaris* only and the companion species only, in mixtures of *Agrostis capillaris* with *Deschampsia cespitosa* (Ac/Dc), *Festuca rubra* (Ac/Fr), *Lolium perenne* (Ac/Lp), *Nardus stricta* (Ac/Ns) or *Phleum pretense* (Ac/Php). To compare species mixtures over time, s.e.d. = 7.2 for *Agrostis capillaris.*

Mixture	Percentage of cells with *Agrostis capillaris* only				Percentage of cells with companion species only			
	May	June	August	October	May	June	August	October
Ac/Dc	0.1	0.2	1.0	14.1	0	0	0	4.1
Ac/Fr	0.0	0.0	0.0	0.0	0	0	0	2.2
Ac/Lp	0	2.5	0.7	0.3	0	0	0	0.5
Ac/Ns	23.7	24.1	26.9	50.8	0	0	0	0
Ac/Php	0.2	9.1	24.7	57.5	0	0	0	0

In March, there was still bare ground in mixtures with *Nardus stricta*, *Festuca rubra*, and *Phleum pratense* but this had disappeared by May. In October the cover of dead material was highest in mixtures with *Phleum pratense* and least in mixtures with *Festuca rubra* (38 % and 7 %, s.e.d. = 12.5) The cover of the component species differed between the mixtures (Figure 1). From May, the cover of *Nardus stricta* was lower than that of any other companion species and it persisted at this low level throughout the experiment. *Lolium perenne* and *Festuca rubra* were the most successful species in retaining their presence in the mixture. Both urine addition and cutting height affected the cover of *Agrostis capillaris*, but not its companion species. The cover of *Agrostis capillaris* was greater when urine was applied in mixtures with *Deschampsia cespitosa* and *Nardus stricta* ($P < 0.05$) and greater at 6 cm cutting height in mixtures with *Lolium perenne*, but lower in mixtures with *Phleum pratense* ($P < 0.05$).

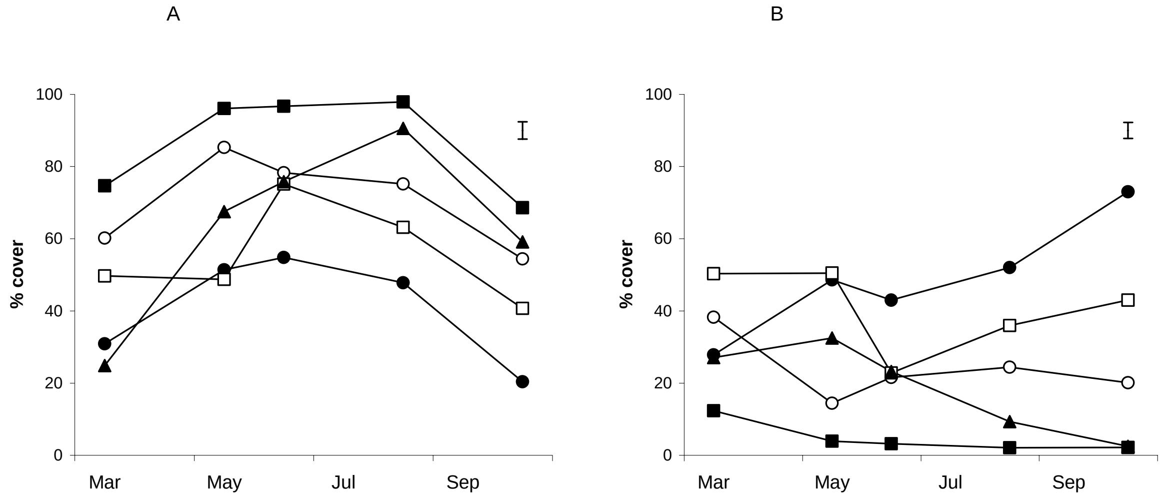

Figure 1. Percentage cover of A) *Agrostis capillaris* and B) the companion species in mixtures of *Agrostis capillaris* with *Deschampsia cespitosa* (○), *Festuca rubra* (●), *Lolium perenne* (□), *Nardus stricta* (■) and *Phleum pratense* (▲). Bars show standard errors of difference (s.e.d.).

Conclusions

The species composition of mixtures affected the rate of change in species cover and species aggregation during the growing season. Where there were effects of cutting height and urine addition on species cover and aggregation, these were small in comparison to the effect of initial composition of the mixture.

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Leaf nitrogen distribution and canopy assimilation in grass-clover mixtures

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Abstract

The effect of leaf nitrogen (N) distribution within the canopy on daily canopy CO_2 assimilation was studied in field grown monocultures and mixtures of perennial ryegrass (*Lolium perenne*) and white clover (*Trifolium repens*) with (+N) and without N fertiliser (-N) during a re-growth period in summer. Daily canopy assimilation was simulated based on the previously established relationships between light saturated rate of leaf assimilation and leaf N concentration for grass and clover. The results were compared for observed (actual) and uniform leaf N distributions. The overall benefit of a heterogeneous leaf N profile was low (< 10 %). However, this benefit increased with increasing total canopy LAI during re-growth. Maximum daily canopy photosynthetic gain due to a non-uniform leaf N profile was 8.8 and 8.4 % for clover in +N and -N mixtures, respectively. In addition, in the -N mixtures clover took more advantage from a non-uniform leaf N profile than grass.

Keywords: perennial ryegrass, white cover, leaf N concentration, canopy CO_2 assimilation, simulation

Introduction

Generally, the light saturated CO_2 assimilation rate (A_m) of single leaves is highly correlated with the N concentration in leaf tissues. Since leaf A_m responds strongly to N, it is evident that canopies with a low average N concentration will maximise CO_2 assimilation when upper leaves, which are more frequently exposed to high light, have a greater leaf N concentration than leaves lower in the canopy. Numerous studies have revealed that leaf N concentration declines with depth in closed canopies in many plant species. This phenomenon is generally believed to be related to the changing light profile within the canopy. It has been suggested that given a fixed amount of N available to the leaves, plants re-allocate N in order to optimise total canopy CO_2 assimilation, and maximum canopy CO_2 assimilation rate is reached when the N distribution over the leaf canopy follows the light profile. Therefore, canopy CO_2 assimilation will depend not only on the amount, but also on the vertical distribution of N within the canopy.

Studies of N distribution in canopies are mainly limited to single species. Experimental results (Lantinga *et al.*, 1999) have shown that in grass and clover the pattern of leaf area and light distribution over canopy height was different in mixtures and monocultures. This can affect the leaf N distribution as well. However, very little is known about the importance of the N distribution profile for daily CO_2 assimilation in multi-species canopies, such as grass-clover mixtures.

This papers deals with the vertical distribution of leaf N within canopies of grass and clover in pure stands and in mixtures to compare the effects of different patterns of leaf N distribution on canopy CO_2 assimilation in monoculture and mixture.

Materials and methods

Mixtures and monocultures of perennial ryegrass cv. Barlet and white clover cv. Alice without (-N) and with 150 kg N ha^{-1} (+N) were used (for experimental layout see Nassiri and Elgersma, (2002)). N was applied only to the grass monoculture. Results of this paper are taken from one re-growth period (22 July-2 September) out of 5 re-growth periods in 1996. The vertical distribution of photosynthetically active radiation (PAR), leaf area of both species and leaf N concentration on a leaf area basis (g N m^{-2} leaf) was measured weekly in 5-cm canopy layers. Leaf N concentration of each layer within the canopy (N_h, g N m^{-2} leaf) was fitted to equation 1:

$$\mathbf{N_h = N_0 \exp(-k_N L_h / LAI)}, \qquad \mathbf{(1)}$$

where N_0 is the leaf N at the top of the canopy, k_N the extinction coefficient of N, LAI total leaf area index and L_h the LAI at depth h within the canopy. A value of 0 for k_N indicates a uniform profile of leaf N per unit area, in which all leaves have the same N concentration equal to the mean. N_0 and k_N were estimated from the log-transformed form of equation 1. Absorbed PAR by species was calculated using a multi-layer canopy model for grass-clover canopies (Lantinga *et al.*, 1999). Gross CO_2 assimilation light response for leaves was approximated by equation 2:

$$\mathbf{A_h = A_m (1-\exp(-\varepsilon I_a / A_m))}, \qquad \mathbf{(2)}$$

where A_h is gross CO_2 assimilation rate (kg CO_2 ha^{-1} h^{-1}), A_m the maximum CO_2 assimilation rate (kg CO_2 ha^{-1} h^{-1}), ε the initial light use efficiency (kg CO_2 ha^{-1} h^{-1} (J m^{-2} $s^{-1})^{-1}$) and I_a the absorbed PAR (J m^{-2} s^{-1}). The daily total gross canopy CO_2 assimilation (P_{day}, kg CO_2 ha^{-1} d^{-1}) of grass and clover was calculated by integration of instantaneous rates over canopy height and day length. The effect of leaf N profile on canopy CO_2 assimilation was compared with a uniform N distribution. For a non-uniform N profile, the A_m of each canopy layer was calculated based on the leaf N concentration in that layer (N_h, equation 1) and the previously established relationship between A_m and leaf N (Nassiri and Elgersma, 1998).

Results and discussion

The overall benefit of the actual over the uniform leaf N profile for P_{day} was low (in all cases less than 10 %). The assimilatory gain of the actual profile increased during time. For all treatments it was highest after 42 days of re-growth when the canopy was closed and the leaf N profiles were fully developed. In both mixtures, clover absorbed more light with regard to its contribution to the total LAI (Table 1). In monocultures, grass got a higher benefit from the actual N profile (7.5 %) than clover (4.7 %). In mixtures, the increase in canopy CO_2 assimilation of clover, using actual compared to uniform profiles, was higher than in monoculture (8.4 and 8.8 % in -N and +N mixtures, respectively). However, for grass the benefit of a heterogeneous leaf N profile was lowest in the -N mixture, but it was the same in the +N mixture and in monoculture (Table 1). The effect of radiation level on assimilatory gain of the actual N profile was studied by simulation of P_{day} of closed canopies (42 days of re-growth) under a clear sky (I_0 = 13.2 MJ m^{-2} d^{-1}, Table 1). The canopy assimilation increased under a high radiation level, but the benefits of the actual N profile remained unchanged.

Considering the relation between A_m and leaf N concentration, the decreasing profile of N_h will lead to a gradient of A_m. In this study, ε (initial light use efficiency) was set constant and independent of leaf N for both species, so the leaf CO_2 assimilation response to the different N profiles depended only on the response of A_m to the leaf N concentration. In nearly-closed canopies (28 days of re-growth) no significant difference in canopy CO_2 assimilation was obtained between the two profiles (Table 1).

Table 1. Simulated values of P_{day} (kg ha^{-1} d^{-1}) of species in mixture and monoculture. For each date, total daily incoming PAR (I_0, MJ m^{-2} d^{-1}), LAI and simulated fraction of PAR (f_a) absorbed by each species are shown. P_{day} was simulated for the actual leaf N profile, based on data estimated from equation (1), and for a uniform leaf N profile (k_N = 0 and leaf N equal to mean).

Days of re-growth	Treatment	I_0	P_{day}							
			Grass				Clover			
			LAI	f_a	actual	uniform	LAI	f_a	actual	uniform
21 days	Mixture (-N)	4.2	1.19	0.33	102.4	101.6	1.10	0.49	137.4	135.2
	Mixture (+N)		2.06	0.59	184.2	180.6	0.45	0.20	43.1	42.6
	Monoculture		2.20	0.73	228.8	224.5	1.72	0.80	240.9	237.0
28 days	Mixture (-N)	10.4	1.83	0.34	264.0	262.2	1.63	0.56	405.9	401.6
	Mixture (+N)		3.10	0.68	497.8	486.2	0.59	0.21	143.4	139.3
	Monoculture		3.20	0.85	630.9	618.3	2.60	0.91	641.5	619.1
35 days	Mixture (-N)	5.4	2.37	0.31	118.9	117.4	2.12	0.66	238.2	231.2
	Mixture (+N)		3.98	0.71	271.1	268.0	0.72	0.24	80.1	78.2
	Monoculture		4.15	0.92	350.1	345.7	3.20	0.95	350.7	345.9
42 days	Mixture (-N)	8.3	2.49	0.29	145.6	139.1	2.34	0.68	417.5	385.1
	Mixture (+N)		4.30	0.69	398.8	372.2	0.80	0.26	150.1	137.9
	Monoculture		4.51	0.93	541.6	503.7	3.91	0.97	541.2	517.0
42 days	Mixture (-N)	13.2*	2.49	0.29	227.2	215.3	2.34	0.68	671.6	618.8
	Mixture (+N)		4.30	0.69	622.4	578.2	0.80	0.26	236.8	216.5
	Monoculture		4.51	0.93	828.9	766.4	3.91	0.97	825.6	792.3

* I_0 set equal to the observed maximum daily incoming radiation during the 42 days of re-growth.

Although the canopies in monoculture and mixtures were closed after 35 days of re-growth, the difference between both profiles in terms of P_{day} was only found in the last week (Table 1). This might be explained by the increase in k_N in the last week of re-growth and the higher radiation level at day 42 than day 35. However, simulation results showed that the effect of radiation level was less important than k_N (Table 1).

Our results showed that in mixed canopies in addition to LAI, the position of the leaves of the species within the canopy may also be important for the benefit from a non-uniform N distribution.

In both +N and -N mixtures the increase of the P_{day} due to the N profile was higher for clover (Table 1), which reflects the different patterns of leaf area distribution and therefore light absorption by species in a mixed canopy, as well as the different profiles of leaf N and the stronger assimilatory response of clover to leaf N compared to grass.

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Higher yield and fewer weeds in grass / legume mixtures than in monocultures – 12 sites of COST action 852

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Abstract

A common experiment was established in 39 sites in Europe, Australia and Canada within Working Group 2 of COST action 852 to 1) assess the benefits of grass / legume mixtures over monocultures, 2) test their stability and 3) evaluate the consistency of the observed patterns over broad environmental gradients. Results of the first harvest from 12 sites covering a North-South gradient from Iceland to Spain suggest that mixing grasses and legumes enhances productivity and increases the stability of the sward by reducing weed invasion. Mixing fast- and slow-growing grasses was found to provide yield benefits in a few sites, but mixing fast- and slow-growing legumes did not produce any effect. Effects of fast- and slow-growing species are expected to become more important over time, when succession of the species may increase the stability of the mixtures. The emerging patterns were quite consistent and, due to the large environmental gradient taken into account in this study, they are considered to be reliable.

Keywords: grass / legume mixtures, forage yield, sowing density, stability, establishment, environmental gradient

Introduction

Among the many challenges posed by rapid changes in the global environment caused by human activities, there is a demand for increased agricultural productivity, safe food production and ecologically sound agricultural practices. Utilisation of grass / legume mixtures instead of grass monocultures can offer a sensible, low-input alternative to reach those goals. However, instability of simple grass / legume mixtures with only one grass and one legume species is a major problem (Wachendorf *et al*., 2001). Within COST action 852, a common experiment was set up to: 1) assess the benefits of grass / legume mixtures over monocultures in terms of forage production, 2) test whether the combination of fast and slow-growing species improves the stability of the mixtures and 3) evaluate the consistency of the emerging patterns over a large environmental gradient. The slow-growing species are expected to establish slowly but be more persistent than the fast-growing species. We applied a novel experimental approach that differentiates responses resulting from varying the number of species from those obtained by modifying their proportion in multi-species mixtures.

Materials and methods

A common experiment with 30 plots containing mixtures of the functional groups legumes and grasses in different proportions was established in 39 sites in Europe, Australia and Canada. One species of each functional group was fast- and the other was slow-growing (always two species per functional group). The 30 plots included monocultures of each species plus various 4-species combinations ranging from dominance by one (sowing rates by seed weight of the four species 0.7; 0.1; 0.1; 0.1) or two (0.4; 0.4; 0.1; 0.1) species to total evenness (0.25; 0.25; 0.25; 0.25, the centroid), following a simplex design (Cornell, 1990) which was duplicated at two sowing densities (100 % and 60 %). Results from the first harvest (not considered a cleaning cut) were analysed from12 sites covering a North-South gradient from Iceland to Spain. Six mixtures were tested: one North European (*Phleum pratense, Poa pratensis, Trifolium pratense, T. repens*), two Mid European (*Lolium perenne, Dactylis glomerata, T. pratense, T. repens*; and *L. perenne, P. pratense, T. pratense, T. repens*), one Mediterranean moist (*L. perenne, D. glomerata, T. pratense, Medicago sativa*) and two Mediterranean dry (*L. rigidum, D. glomerata, M. polymorpha, M. sativa*; and *L. perenne, D. glomerata, T. subterraneum, M. sativa*). The swards were managed according to local farming practices. All plots of the same site were managed equally (cutting frequency and fertiliser). A mixed model was fitted to the log of total yield from 8 of the sites. The variates associated with each plot were: proportion of the two grasses (G_1 and G_2) and legumes (L_1 and L_2) sown in the mixture, overall density and, as random effects, site, site × G_1, site × G_2, site × L_1 and site × L_2, where the species with a '1' subscript were fast growing and the species with a '2' subscript were slow growing. Various quadratic terms were added to this model to check for synergistic or antagonistic interactions between sown species. There were 6 such interaction terms grouped into $L_1 \times L_2$ (not significant), $G_1 \times G_2$ and the four grass-legume terms ($L_1 \times G_1$, $L_1 \times G_2$, $L_2 \times G_1$, $L_2 \times G_2$; all positive) pooled to give a functional group mixing term.

Results and discussion

Grass / legume mixtures at the centroid (sowing rates by seed weight: 0.25, 0.25, 0.25, 0.25) produced more yield than predicted from averaging the four monocultures in all sites except one, and showed lower proportions of non sown species (Table 1). This suggests the existence of synergistic effects among the sown species and better establishment and higher resilience in front of weed invasion of the mixtures. The centroid grass / legume mixture was more productive than the most productive monoculture in 6 sites. At 4 sites the fast-growing legume monoculture and at 3 sites the fast growing grass were the most productive swards (Table 1). The modelling of yield at 8 sites showed that the strongest yield enhancement effect was found for the mixing of the functional groups grasses and legumes. This effect was significant in all but one site (Table 2). Mixing fast- and slow-growing species showed a small but significant effect at two sites for the grasses (Table 2) but no effect for the legumes. The aim of increasing the stability of the mixture over years by combining fast- and slow-growing species cannot be tested at this early phase of the experiment. As expected, the fast growing species produced high yields in this early phase of the experiment as demonstrated by the monocultures (Table 1). However, it remains to be seen whether the slow-growing species will become more productive and will succeed the fast-growing species in time, thus enabling the productivity of the mixture to be maintained.

Table 1. Yield of the four monocultures and the mixture at the centroid[1] for 12 sites in 2003 (g m^{-2}). The percentage change in yield and in weed biomass between the value measured in the mixture and expected from averaging the four monocultures is shown.

Region	Fast-growing grass	Slow-growing grass	Fast-growing legume	Slow-growing legume	Mixture at the centroid	% change in yield (centroid / averaged monocultures)	% change in weeds (centroid / averaged monocultures)
Northern Europe	75	106	311	106	242	+62	-75
Northern Europe	405	208	259	160	397	+54	-81
Northern Europe	664	308	673	365	743	+48	nd
Northern Europe	146	190	246	251	272	+31	nd
Mid Europe	308	272	524	271	447	+30	nd
Mid Europe	214	156	178	194	179	-4	-55
Mid Europe	458	275	427	338	585	+56	-58
Mid Europe	32	181	429	369	496	+96	nd
Mediterranean	142	83	88	54	167	+82	-67
Mediterranean	381	61	177	158	260	+34	nd
Mediterranean	24	16	280	89	113	+11	-16
Mediterranean	136	23	8	45	186	+251	nd

[1] at sowing rates of the four species of 0.25, 0.25, 0.25, 0.25; nd: not determined.

Table 2. Predicted percentage change in yield due to mixing effects for eight sites at the centroid[1]. Shown are the $G_1 \times G_2$[2] and functional group (grass × legume) mixing effects, and the predicted ratio of centroid yield to average monoculture yield.

Region	G_1 x G_2 mixing effect		Grass x Legume mixing effect		Predicted yield ratio centroid / monocultures
	% change	*P*-value	% change	*P*-value	
Northern Europe	+32	0.007	+41	0.013	1.86
Northern Europe	+14	0.180	+50	0.003	1.71
Northern Europe	+34	0.004	+124	<0.001	3.00
Mid Europe	+9	0.378	+30	0.058	1.41
Mid Europe	+4	0.664	+4	0.780	1.08
Mid Europe	-2	0.812	+90	<0.001	1.86
Mid Europe	-7	0.473	+51	0.003	1.42
Mediterranean	+8	0.404	+48	0.005	1.60
Average	**+11**		**+51**		**1.67**

[1] at sowing rates of the four species of 0.25, 0.25, 0.25, 0.25; [2] fast and slow-growing grass.

Conclusions

The first results from 12 of the 39 sites suggest that mixing forage species from different functional types, grasses and legumes, enhances productivity and decreases biomass of unsown species. The observed advantages of the mixtures were consistent for most sites, and the results are assumed to be reliable due to the broad gradient considered in this study.
In terms of yield the advantage from mixing fast- and slow-growing species was small in this early phase of the experiment. Long term observations are needed to test whether the succession from fast- to slow-growing species will increase the stability of the mixtures.

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Effects of legume genetic diversity on the productivity of legume / grass mixtures – COST Action 852

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Abstract

A modelling approach was used to analyse data obtained from the first growing season of the COST 852 experiment at Aberystwyth, UK. This experiment investigated temporal patterns in species contribution in a range of grass / legume mixtures. An extra treatment was added which investigated the effects of greatly increasing the genetic heterogeneity of the legume component of the various mixtures. The selected model predicted the occurrence of positive synergistic effects between legumes and grasses on cumulative mixture yield. In addition, the results showed that increasing the heterogeneity of the legume decreased the cumulative yield of grass / legume mixtures, although the effect on legume monoculture yield was not significant.

Key words: functional groups, genetic base, multi-species mixtures

Introduction

Multi-species mixtures of grasses and legumes are likely to become increasingly important components of grassland agriculture in Europe. Their advantages might include more efficient use of environmental resources, a positive impact on aspects of soil structure, improved forage quality, higher productivity and yield stability, and, perhaps, public approval for their greater biodiversity. The COST 852 experiment was set up to investigate issues of community structure, function and their interrelationships in multi-species grass / legume mixtures. The experimental design was based on a simplex structure (Cornell, 1990).

The four species used in the experiment represent four functional groups. Thus, the grass (G) and legume (L) functional groups are further subdivided into species with subscript '1' (fast growing and competitive), and subscript '2' (relatively slow growing and persistent). The Working Group 1 (WG 1) element of the COST experiment added an extra treatment, comprising 'wide genetic base' mechanical mixtures of the legume species used in the WG 2 experiment. The effect of genetic heterogeneity on population productivity is of interest from an ecological perspective and also in terms of plant breeding. In order to make valid comparisons between mixtures containing legumes with contrasting levels of genetic diversity, the WG 1 plots were sown at the same time as those in the WG 2 experiment and were randomly distributed within it. The WG 1 treatment has recently been sown at a number of sites throughout Europe but data were available for the 2003 growing season from only one site (Aberystwyth, UK).

Materials and methods

At the Aberystwyth site G_1 was *Lolium perenne* cv. Fennema; G_2 was *Dactylis glomerata* cv. Cambria; L_1 was *Trifolium pratense* cv. Merviot, and L_2 was *Trifolium repens* cv. Alice. In the WG 1 treatment the bulk mixture for L_1 contained seed of 11 commercial varieties, plus a small amount of a 'northern red clover composite' population from Norway / Denmark. The red clover varieties used in this mixture encompassed all the categories employed by red clover breeders (early / late flowering; diploid / tetraploid). For L_2 the bulk mixture contained seed of 14 commercial varieties, plus a small amount of 'gene pool' material from Central Asia. All white clover varieties used in this mixture were classified as either ‘medium’ or ‘large’ leaved.

The experiment was established in August 2002 using seed broadcasting. The required mixtures comprised a range of species proportions based on monocultures sown at two densities. In Aberystwyth the ‘high density’ monoculture plots were sown at rates of 40, 30, 15 and 5 kg ha^{-1} for G_1, G_2, L_1 and L_2, respectively; the ‘low density’ monocultures were sown at 60 % of these rates. The first harvest was taken on 19 May 2003, with subsequent harvests on 7 July, 19 August and 15 October. At each harvest the plots were cut to a height of 5 cm. Species proportions for each plot were obtained from botanical separation of a 100 g subsample of the cut herbage, followed by oven drying and weighing. After each harvest nitrogen was applied to all plots at a rate equivalent to 30 kg N ha^{-1}.

A modelling approach was used to analyse the data. The models used were derived from Scheffe polynomials for the analysis of mixture data (Cornell, 1990). A selection procedure led to the following model for the cumulative DM yield (y) of data from 4 harvests.

$$\begin{aligned} y = {} & \beta_1 G_1 + \beta_2 G_2 + \beta_3 L_1 + \beta_4 L_2 + \beta_5 Density + \beta_6 Gen\_base(L_1 + L_2) \\ & + \beta_7 Quad\_L_1 + \beta_8 Quad\_L_2 + \beta_9 Gen\_base(L_1 + L_2)(G_1 + G_2) + \varepsilon \end{aligned}$$

where, for each plot, G_1, G_2, L_1 and L_2 are the sown proportions of the two grasses and legumes, Quad L_1 is $(G_1 + G_2) \times L_1$ and Quad L_2 is $(G_1 + G_2) \times L_2$. The coefficient of density is the effect of high vs. low sowing density, and the coefficient of Gen-base is the effect of narrow vs. wide genetic base of the legume component. The latter enters the model as a term [Gen-base $\times (L_1 + L_2)$] since the genetic base effect must be zero for zero legume proportion, and may depend on the total legume amount in the mixture. The Gen-base $\times$ $(L_1 + L_2)(G_1 + G_2)$ interaction tests whether this genetic base effect depends on the level of the grass component in the mixture. The coefficients β_1, β_2, β_3 and β_4 estimate the total yield of a monoculture of G_1, G_2, L_1 or L_2 at low density and, for the legumes, narrow genetic base. This model does not contain an intercept and so the expected yield for a monoculture of G_1 is $\beta_1 + \beta_5$ *Density*, where density is taken as high. Various quadratic terms were added to this model to check for synergistic or antagonistic interactions between sown proportions of species. These reduced to two functional group mixing terms: the mixing effect of grass with L_1, and the mixing effect of grass with L_2. The coefficients β_7 and β_8 are the effects on yield of mixing grass with L_1 and L_2 respectively. Interactions between density, genetic base and grass and legume proportions and between density and genetic base were also tested for inclusion in this model but only the grass x genetic base interaction was significant. ε is a random error, assumed to be normally and independently distributed with a mean of zero and constant variance. The model was selected and fitted using the statistical package ‘Genstat’.

Results and discussion

It should be borne in mind that these results are preliminary. The anticipated addition of data from other sites and from more than one growing season will greatly increase the value of this experiment.

Values of the coefficients for the above model are given in table 1, together with their standard errors and level of significance.

Table 1. Estimates of coefficients for model of cumulative DM yield with standard error, t value and significance.

	Coefficient	s.e.	t (34 df)	*P* value
G_1	3.00	0.571	5.25	<0.001
G_2	5.80	0.571	10.16	<0.001
L_1	11.07	0.578	19.15	<0.001
L_2	7.39	0.578	12.79	<0.001
Density High	0.13	0.303	0.42	0.679
Genetic base	0.24	0.632	0.38	0.706
Quad L_1	21.71	2.83	7.66	<0.001
Quad L_2	12.61	2.83	4.45	<0.001
Grass × Genetic base	-7.67	2.6	-2.95	0.006

Predicted cumulative yields (t ha^{-1}) for monocultures at low density and narrow genetic base were significantly different between each pair of species (2.94 for *L. perenne,* 5.74 for *D. glomerata*, 11.00 for *T. pratense* and 7.32 for *T. repens*). The effects of sowing density in all mixtures, and of genetic base in the legume monocultures were not significant. However, there was a significant (P = 0.006) effect of legume genetic base for any grass combination with any legume combination. The model predicted that the cumulative yield of mixtures containing a broad based legume was negatively changed by a quantity: $0.24\ (L_1 + L_2) - 7.67\ (G_1 + G_2) \times (L_1 + L_2)$, relative to those containing a single variety. The negative effect of broad genetic base was least in mixtures containing large proportions of either legume species, and greatest in mixtures starting off with equal proportions of grass and legume. The presence of a large degree of diversity for morpho-physiological traits in natural plant populations might suggest that the use of blends of varieties, or composite populations with a high degree of heterogeneity, would be advantageous under agricultural conditions. However, a study carried out on white clover by Annicchiarico and Piano (1997) showed that greater heterogeneity in genotype morphology failed to produce a DM advantage. A similar result was obtained by Williams *et al*. (2003). However, in that study there was some evidence that the yield of blends of varieties was more consistent over the duration of the experiment.

The model predicted the occurrence of positive quadratic (i.e., synergistic) effects of legume / grass mixtures on cumulative yield. In mixtures with any grass combination the synergistic effect of the presence of L_1 on cumulative yield was large and statistically significant ($P < 0.001$); the effect of the inclusion of L_2 in mixtures was smaller but still statistically significant ($P < 0.001$). The synergy between legumes and grasses may be attributed to the positive effect on grass growth of nitrogen transfer from the legume.

The design used in the COST experiment has created a wide range of communities and allows questions concerning the effect of community composition on plant performance to be addressed. Analysis of the direction and rate of change occurring in plant communities over a number of years at many sites will allow issues of fundamental agronomic importance, such as productivity, adaptability (location-to-location variability) and stability (year-to-year variability) to be elucidated.

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Yield potential of cocksfoot and tall fescue in mixture with white clover at different levels of nitrogen fertilisation

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Abstract

To determine the impact of white clover, *Trifolium repens* (cv. Carpatin), on nitrogen supply, two grass species were grown in a simple mixture: tall fescue *Festuca arundinacea* (cv. Brio and Adela) a less competitive species, and cocksfoot *Dactylis glomerata* (cv. Poiana and Regent), a highly competitive species, at three levels of fertilisation, N_0, N_{50}, N_{100}. The grass / clover mixtures gave higher forage yield at all the fertilisation levels, compared with grass treatments in pure culture. At N_0, the forage yield of cocksfoot / white clover mixtures exceeded the yield of cocksfoot by 0.4 t DM ha^{-1} in pure culture at N_{50}, and the tall fescue / white clover mixtures exceeded the yield of tall fescue by 0.25 t DM ha^{-1} in pure culture at N_{50}. The yield of grass / clover mixtures at N_0 was exceeded only by the pure cultures of grass fertilised with N_{100}. In cocksfoot / white clover mixtures the percent of white clover decreased from 26.7 % at N_0 to 8 % at N_{100} and in tall fescue / white clover mixtures from 48.5 % at N_0 to 25.5 % at N_{100}.Competitiveness of varieties of the same species plays an important role in grass / clover mixtures.

Keywords: *Trifolium repens*, *Festuca arundinacea*, *Dactylis glomerata*, simple mixture, N fertilisation

Introduction

The inclusion of white clover in swards improves forage quality, and thus the feeding value, and reduces fertiliser nitrogen costs by relying on fixed N from clover. Each percent of white clover extracts, on average, 3.5 kg N ha^{-1} y^{-1}, which is incorporated in yield and used by the companion grass (Breazu e*t al*., 1987).
The use of mixtures of different grass species and white clover in an adequate proportion is essential for organic farming systems, reducing the risks of pollution (Breazu *et al*., 2002). The objective of this paper is to determine the contribution of white clover (*Trifolium repens)* on nitrogen supply in simple mixtures, with two grass species: tall fescue (*Festuca arundinacea)* and cocksfoot *(Dactylis glomerata).*

Materials and methods

Experimental studies were carried out between 2001-2003 at the Grassland Research and Development Institute, Brasov, on a levigated chernozem of sandy loam texture soil; pH = 5.8, P = 41 ppm and K = 164 ppm.
Two grass species were used: a less competitive, tall fescue (Brio and Adela varieties), and a highly competitive cocksfoot (Poiana and Regent varieties), each in pure culture and in mixture with white clover (Carpatin variety, nanum type). The seed rate was 25 kg ha^{-1} for each grass species and 3 kg ha^{-1} for white clover.
Three nitrogen fertiliser levels were used: N_0, N_{50} and N_{100}. For N_{50} treatments, the fertiliser was applied in spring, at the beginning of growing season, and for N_{100} treatments, 50 kg ha^{-1} was applied in spring and 50 kg ha^{-1} after the first cut. The plots were subdivided into 4 replications at each level of fertilisation, the harvestable area of each plot being 12 m^2.
The experiments took place during a severe drought for this geographical zone, the rainfall in the third year of experiments being 310 mm lower than the long-term average, with higher

temperatures and sunburn. Consequently, only 2 cuts could be obtained in the first year of the experiment, 3 cuts in the second year and only 2 cuts in the third. The botanical determinations were made at every cut. For statistical interpretation the analysis of variance was used.

Results and discussion

At levels N_0 and N_{50} of fertilisation the grass / white clover mixtures gave higher yields compared with the same grass species in pure culture (Figure 1, mean of three years).

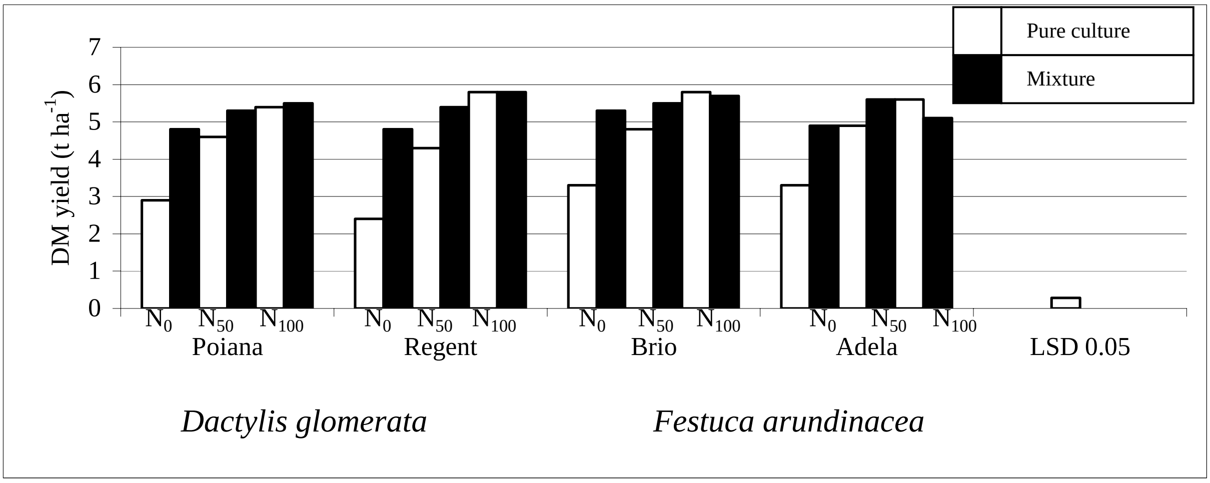

Figure 1. Dry matter (DM) yields of *Dactylis glomerata* and *Festuca arundinacea* varieties in pure culture and simple mixtures with *Trifolium repens*, at different levels of N fertilisation.

The positive effect of clover is more evident at the N_0, the forage yield of grass / white clover mixtures exceeding the yield obtained in pure culture of grass at N_{50}. At $N_{0,}$ the forage yield gain was 2.2 t DM ha^{-1} for cocksfoot / white clover mixtures and 1.8 t DM ha^{-1} for tall fescue / white clover mixtures. In unfertilised treatments, the forage yield of cocksfoot / white clover mixtures exceeded by 0.4 t DM ha^{-1} the yield of cocksfoot in pure culture at N_{50}, and the tall fescue / white clover mixtures exceeded by 0.25 t DM ha^{-1} the yield of tall fescue in pure culture at N_{50}.
At N_{50} the forage yield increase was 0.85 t DM ha^{-1} for cocksfoot / white clover mixtures and 0.7 t DM ha^{-1} for tall fescue / white clover mixtures over the grass in pure stands.
At N_{100} the cocksfoot / white clover mixtures produced the same yield of DM as the pure grass variants, while tall fescue / white clover mixtures produced a 0.2 t DM ha^{-1} lower yield than the tall fescue in pure culture.
The greatest differences between the forage yield of grass / clover mixtures and the pure culture of the same grass species were registered in the second crop year: +4.8 t DM ha^{-1} at $N_{0,}$ +1.85 t DM ha^{-1} at N_{50} and +0.5 DM ha^{-1} at $N_{100,}$ for cocksfoot / white clover mixtures and +4.5 t DM ha^{-1} at $N_{0,}$ +2.6 t DM ha^{-1} at N_{50} and +0.4 DM ha^{-1} at N_{100} for tall fescue / clover mixtures. At N_{100} for both grass species in mixture with white clover, yield gains were obtained only in the second crop year.
It was ascertained that there was a high inter-specific difference concerning the competitive ability. At the same seeding rate, the percent of white clover in the mixtures with cocksfoot was on average 15.3 %, decreasing from 26.7 % at N_0 to 8 % at N_{100}, and in the mixtures with tall fescue the percent of white clover was on average 38 %, decreasing from 48.5 % at N_0 to 25.5 % at N_{100}.

Depending on the crop year, the percent of white clover had the highest values in the first year and the lowest in the third year.
Inter-varietal differences were also found. For tall fescue, Brio variety is less competitive than Adela, and for cocksfoot Poiana variety is less competitive than Regent. Choosing the right varieties of grass compatible with white clover is very important for a high nutritive quality of the forage.

Conclusions

The DM yields were increased when grasses were grown in mixtures with white clover. Yields and average legume content were highest in the second year and declined in the third crop year. The yields of grass / clover mixtures at N_0, for both species of grass, were exceeded only by the pure cultures of grass fertilised with N_{100}.
White clover can contribute to efficient production systems by symbiotic N_2 fixation, reducing or eliminating the need for N fertilisation and by providing high quality herbage, and therefore plays an important role in organic farming systems.

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Lucerne, white clover and red clover in leys for efficient N use

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Abstract

The contribution of legumes due to their capability to fix nitrogen is an essential factor for maintaining soil fertility and productivity of subsequent crops in sustainable agriculture. The large variability within swards and between years in leys is one of the main shortcomings of legumes. The productivity of legumes, symbiotic N_2 fixation and transfer of fixed N from white clover, red clover, lucerne and their different mixtures to grass, and to a subsequent crop of wheat was estimated during three years of swards use. Lucerne / grass and lucerne / white clover / grass swards were most suitable for three years' use in leys. The N_2 fixation, its transfer to grass and effect on wheat yield was the highest in lucerne-based swards.

Keywords: legumes, ley, nitrogen, grass, subsequent crop

Introduction

The cheapest and high-value forages involving the lowest energy inputs can be produced from legume and legume / grass swards (Halling *et al*., 2002; Wilkins and Kirilov, 2003). It is aimed to exploit the benefits of legumes as soil improvers and as valuable preceding crops. The advantages of legumes as one of the main nitrogen sources and valuable winter forage are still underused. The current expansion of sustainable agriculture and organic farming systems highlights the positive effect of legumes on subsequent crops. The complex of factors and their interactions influence the potential of legumes, which is greatly dependent on legume species and successful management. Many results underline that sward establishment and persistence problems are clearly greater with forage legumes than with grasses (Porqueddu *et al*., 2003). The aim of the present study was to identify more suitable mixtures for leys and to estimate their influence on subsequent crops.

Materials and methods

Field studies were conducted on a loamy Endocalcari-Epihypogleyic Cambisol in Dotnuva (55^{o} 24' N). Soil pH varied between 6.5 to 7.0, humus content was 2.5-4.0 %, available P 50-80 mg kg^{-1} and K 100-150 mg kg^{-1}. Legumes and grasses were sown with a cover crop of barley for grain. Red clover (*Trifolium pratense* L.) cv. Arimaiciai and lucerne (*Medicago varia* Mart.) cv. Birute were sown in pure stands or in mixtures with white clover (*Trifolium repens* L.) cv. Atoliai and perennial ryegrass (*L. perenne* L.) cv. Sodre and timothy (*Phleum pratense* L.) cv. Gintaras II for 3 years' use for cutting. Legume / grass ratio in the sown mixtures was 60:40. The grasses were also sown in pure stands and either fertilised with 240 kg N ha^{-1} y^{-1} or not. The experiments had a randomised block design with four replicates. The net plot size was 2.5 × 12.5 m. P and K were applied according to the need based on soil analysis. The yield of swards was taken at flowering stage of legumes. The swards were cut 3 times per year in the first and second year and twice in third year ley. Apparent N_2 fixation was calculated using the difference method, by subtracting the N yield of the grass monocultures from the total yield of mixtures. The N content in stubble and roots (0-10 cm) from 20 × 20 cm blocks was determined after washing and drying, and calculated on a DM basis. The N concentration was determined by the Kjeldahl method. After 3 years of swards use in the crop rotation, winter wheat was grown without nitrogen fertilisation in order to estimate different effects of nitrogen. The yield data and its analysis were statistically processed using analysis of variance.

Results and discussion

There were substantial differences in DM yield for the various legume species (Table 1). Pure lucerne and lucerne / grass swards were the highest yielding in all three years of ley use. The lucerne-based swards showed the highest persistence and less variation between years.

Table 1. Effect of different legume and legume / grass swards on the productivity of ley.

Treatment	DM kg ha^{-1}					
	1st experiment			2nd experiment		
	1998	1999	2000	2000	2001	2002
Trifolium repens	4,198	3,138	2,525	3,580	4,122	1,645
Trifolium pratense	9,392	4,418	2,440	6,550	8,488	1,580
Medicago varia	9,458	7,132	8,698	8,998	10,562	4,782
T. repens / grasses	5,820	3,402	2,888	4,560	3,850	1,487
T. pratense / grasses	10,290	5,178	3,318	7,225	8,800	1,605
M. varia / grasses	10,065	8,118	9,525	9,492	11,112	5,655
Grasses, N_{240}	8,955	4,900	5,282	9,295	6,360	2,050
Grasses, N_0	2,488	2,842	2,618	3,012	1,922	770
$LSD_{.05}$	576	616	774	461	699	634

The DM yields of pure red clover or red clover with grass were similar to the yields of lucerne in the first year of sward use and considerably lower in the second and third years. Irrespective of the cultivars used for lucerne and red clover, the same ranking between the legumes was observed on suitable soils (pH 6.0-7.0) for both legumes (Kadziulis, 2001). Pure white clover and white clover / grass swards were the poorest yielding. All legume and legume / grass swards exceeded the yield of grasses without fertiliser N and lucerne-based swards surpassed the 240 kg N ha^{-1} fertilised pure grass. In most countries legume-grass mixtures gave generally higher yield than pure swards without N fertiliser (Halling *et al.*, 2002).

The results of our experiments show that the N yield and apparent N_2 fixation were the highest in lucerne-based swards (Table 2), i.e., it was higher than in grass herbage fertilised with 240 kg N ha^{-1}. The amount of nitrogen in red clover-based swards was less than in lucerne, but higher than in grass herbage without N fertilisation. White clover-based swards produced the lowest N yield and apparent N_2 fixation. The N content of ley is closely related to legume productivity and content in swards (Kristensen *et al.*, 1995; Granstedt, 2000).

The N yield and fixation were higher in the first year. Nitrogen fixation declined markedly in the third year both in white clover and red clover swards. Crop residues (roots and stubble) and content of N incorporated into the soil were dependent on sward composition. More nitrogen was incorporated in the soil with lucerne and left more than 128-242 kg N ha^{-1} (Table 2). Similar results were obtained by other researchers (Arlauskiene and Maiksteniene, 2001). The grain yield of 1,420-3,332 kg ha^{-1} in our experiment was quite low (Table 2). The highest winter wheat yield was obtained when it had been grown after ploughed-in lucerne-based swards. After three year ley-use ploughing in lucerne-based swards, winter wheat yield was twice as high as that obtained after ploughing-in pure grass swards without nitrogen. A first or second year ley with a high clover content can provide a better source of mineralisable N for the subsequent crop than a third year ley with lower clover content (Granstedt, 2000; Kristensen *et al.*,1995).

Table 2. N yield, apparent N_2 fixation by legumes in pure and legume / grass swards and their effect on winter wheat grain yield

Treatment	N yield (kg ha^{-1})			Apparent N_2 fixation (kg ha^{-1})			N (kg ha^{-1}) in residues	Grain (kg ha^{-1})
	1st experiment							
	1998	1999	2000	1998	1999	2000	2000	2001
Trifolium repens	145	103	60	113	50	27	104	2,438
Trifolium pratense	263	128	59	231	75	26	116	2,250
Medicago varia	318	224	267	286	171	234	128	2,850
T .repens / grasses	128	82	45	96	29	12	120	1,625
T. pratense / grasses	248	131	63	216	78	30		2,135
M. varia / grasses	322	223	286	290	170	253		2,662
Grasses, N_{240}	169	104	123				187	1,862
Grasses, N_0	32	53	33				96	1,420
$LSD_{.05}$	16.8	23.8	32.6					325.7
	2nd experiment							
	2000	2001	2002	2000	2001	2002	2002	2003
Trifolium repens	83	109	25	55	77	17	114	2,260
Trifolium pratense	177	214	29	149	182	21	204	2,387
Medicago varia	267	276	114	239	244	106	242	3,060
T .repens / grasses	77	85	24	49	53	16	177	2,260
T. pratense / grasses	185	214	30	157	182	22		2,380
M. varia / grasses	238	288	140	210	256	132		3,332
Grasses, N_{240}	146	133	43				178	2,382
Grasses, N_0	28	32	8				95	1,517
$LSD_{.05}$	11.4	17.6	15.3					376.0

Conclusions

Lucerne-based swards showed the highest potential DM yield, persistence, N yield and apparent N_2 fixation in three-year leys and less variation between years. All legume / grass swards were superior to grasses fertilised with up to 240 kg N ha^{-1}. The highest winter wheat yield was obtained after ploughed-in lucerne-based swards. The leys consisting of legumes can be productive without mineral N and can reduce external inputs.

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A comparative study of five sown 'grass-legume' mixtures and the indigenous vegetation when grown on a rain-fed mountain area of Greece

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Abstract

On a mountainous area of Greece, under rain-fed conditions, a study was carried out to compare the herbage production and quality of five different 'grass-legume' sown mixtures against the indigenous vegetation. The mixtures comprised perennial ryegrass (*Lolium perenne*) sown along with one of the following legumes: *Lotus corniculatus*, *Medicago sativa*, *Trifolium hybridum*, *Trifolium pratense* or *Trifolium repens* following a completely randomised design with four replicates. Herbage production, botanical composition and chemical composition of the hay produced were determined over the subsequent two years.
Total herbage production ranged between 7,400-16,000 and 5,600-15,400 kg DM ha^{-1} during the first and the second years, respectively. The '*T. repens* mixture' gave the highest production and the '*T. hybridum* mixture' the lowest. Indigenous vegetation production exceeded the mean of the five mixtures. Chemical analysis of the herbage harvested produced mean values of 14.5 % for CP content and 23 % for CF on a dry matter basis, but differences between treatments were small. It was concluded that fields that are abandoned from arable crops can be cultivated successfully with perennial sown mixtures under rain-fed conditions.

Keywords: sown pastures, grass, legumes, Greece

Introduction

Abandoned marginal fields are a feature of the socio-economic environment of the European Union (Baldock *et al*., 1996). The reintegration of abandoned marginal fields into a scheme of extensive utilisation can be achieved by establishing sown swards. This would benefit both the local livestock farming and the environment since erosion processes will be reversed, soil fertility will be improved and wild fauna can be sustained (Baldock *et al*., 1996). The establishment of sown swards in temperate climates can be effected with perennial species, while for xerothermic environments annual species should be selected (Wilkins and Kirilov, 2003).
The objective of the present study was to evaluate the production and herbage quality characteristics of five 'grass-legume' mixtures of perennial plants, grown under rain-fed conditions on a mountain area in central Greece.

Materials and methods

The experimental field was established in the Evritania Prefecture at an altitude of 1100 m asl. The clay soil has a pH of 6.2 and is of moderate fertility and organic matter content. Climate is 'Mediterranean Mountain' with cold winters and dry summers, while average precipitation is 1100 mm y^{-1}.
The field was divided in twenty-four (5 m × 2 m) sub-plots, where the five mixtures were sown after tillage in a randomised design, with four replicates. The four control plots were untilled. Sowing was carried out at the end of May using perennial ryegrass (*Lolium perenne* cv. Olympion) together with one of the following legumes: lotus (*Lotus corniculatus*), lucerne (*Medicago sativa* cv. Ipati-84), hybrid clover (*Trifolium hybridum* cv. Ab 217.00), red clover

(*Trifolium pratense* cv. Nesson) or white clover (*Trifolium repens* cv. Konitsa). A synthetic fertiliser was added at the rate of 10 units P_2O_5 and 13 units K_2O y^{-1}.
Herbage production was measured for two consecutive years, by harvesting the vegetation twice during each growing season. Each mixture was harvested at a specific height, determined by the legume physiology (4 cm above ground level for the indigenous vegetation and the 'white clover', 5 cm for the 'lucerne', 'hybrid clover' and 'red clover' and 6 cm for the '*Lotus*' mixture. Residual herbage was then evaluated through a second sampling. Herbage samples were dried for 48 h at 80 ^{o}C and ground through a 1 mm screen before proximate analysis assessment through the use of NIRS technology (Deaville and Flinn, 2000).

Results and discussion

During the first cropping year all mixtures yielded equal amounts of dry matter (Table 1). The residual dry matter differed between mixtures and represented 52 % of total dry matter for '*Lotus*', 45 % for 'Lucerne', 45 % for indigenous vegetation, 45 % for '*T. hybridum*', 40 % for '*T. pratense*' and 70 % for '*T. repens*'.

Table 1. Total dry matter harvested (g m^{-2}) from the 'grass-legume' mixtures and respective fractions of sown 'grass', 'legume' and 'other indigenous vegetation' for the first harvesting year.

Treatments	Total dry matter harvested (g m^{-2})	'Grass' dry matter (g m^{-2})	'Legume' dry matter (g m^{-2})	'Other vegetation' dry matter (g m^{-2})
'*Lotus* mixture'	526.0 ^{a}*	122.4 ^{a}	387.8 ^{a}	15.8 ^{a}
'Lucerne mixture'	500.6 ^{a}	116.1 ^{a}	369.9 ^{a}	14.5 ^{a}
Indigenous vegetation'	654.7 ^{a}	269.5 ^{b}	198.2 ^{a}	186.9 ^{b}
'*T. hybridum* mixture'	449.8 ^{a}	111.6 ^{a}	289.4 ^{a}	48.8 ^{a}
'*T. pratense* mixture'	715.3 ^{a}	88.2 ^{a}	593.7 ^{b}	33.3 ^{a}
'*T. repens* mixture'	460.9 ^{a}	181.6 ^{a}	258.9 ^{a}	20.4 ^{a}

*means within each column sharing different letter superscripts differ at the $P < 0.05$ level.

During the second cropping year the dry matter yields were different between mixtures, with '*T. hybridum*' yielding the lowest and 'Lucerne' the highest (Table 2). The residual dry matter was again different between mixtures and represented 40 % of total dry matter for '*Lotus*', 35 % for '*Medicago*', 38 % for 'indigenous vegetation', 50 % for '*T. hybridum*', 30 % for '*T. pratense*' and 75 % for '*T. repens*'.

Table 2. Total dry matter harvested (g m^{-2}) from the 'grass-legume' mixtures and separation into fractions of sown 'grass', 'legume' and 'other indigenous vegetation' during the second harvesting year.

Treatments	Total dry matter harvested (g m^{-2})	'grass' dry matter (g m^{-2})	'legume' dry matter (g m^{-2})	'Other vegetation' dry matter (g m^{-2})
'*Lotus* mixture'	509.2 ^{bc}*	136.4 ^{bc}	351.8 ^{d}	21.0 ^{a}
'Lucerne mixture'	577.1 ^{c}	51.0 ^{a}	511.1 ^{c}	15.1 ^{a}
Indigenous vegetation	479.3 ^{bc}	134.0 ^{bc}	225.1 ^{c}	120.2 ^{c}
'*T. hybridum* mixture'	289.6 ^{a}	239.4 ^{d}	2.7 ^{a}	47.5 ^{a}
'*T. pratense* mixture'	454.6 ^{bc}	78.6 ^{ab}	310.7 ^{cd}	65.4 ^{ab}
'*T. repens* mixture'	417.9 ^{ab}	191.4 ^{cd}	109.8 ^{b}	116.7 ^{bc}

* means within each column sharing different letter superscripts differ at the $P < 0.05$ level.

The perennial ryegrass used in this study appears less competitive to the legumes used in mixtures, since in all mixtures during the first year and in most of them during the second, perennial ryegrass did not contribute more than 25 % to the total dry matter yielded.

Forage chemical analysis demonstrated the higher crude protein (CP) and lower crude fibre (CF) content of the legume fraction of the sown mixtures as compared to grasses (Table 3), indicating the higher nutritive value of the harvested herbage from mixtures as compared to the indigenous vegetation.

Table 3. Chemical composition (mean values over first and second year harvests) of the sown 'grass' and 'legumes' grown in mixtures and of the indigenous vegetation.

	Ash (g kg^{-1} DM)	CP (g kg^{-1} DM)	CF (g kg^{-1} DM)
Lolium perenne	83.3	101.0	277.0
Lotus corniculatus	98.4	170.9	214.0
Medicago sativa	108.0	148.0	216.0
Trifolium hybridum	129.0	179.5	188.0
Trifolium pratense	113.0	155.0	196.0
Trifolium repens	121.4	168.6	215.0
Indigenous grasses	82.8	107.0	281.1
Indigenous legumes	113.7	149.5	235.3
Other forbs	102.3	122.0	245.0

Conclusions

Sown pastures can effectively reintegrate abandoned fields into a scheme of extensive agriculture. Furthermore, they produce forage of higher nutritive value than the indigenous vegetation, which can be used for 'sustainable' animal farming systems. However, further research is required to validate the present results and test alternative cultivars and management options.

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Production and quality of red clover (*Trifolium pratense*) and lucerne (*Medicago sativa*) in pure stand or in grass mixture in Belgium

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Abstract

The interest in red clover and lucerne is increasing again because of their potential role in sustainable and organic systems. Moreover, more persistent varieties of red clover are now available.
Dry matter, energy and protein yields were recorded on several loamy soils in Belgium, in cutting systems. Grass-legume mixtures were compared with fertilised pure grass stands. Several varieties were tested in pure stands or in grass-legume mixtures to provide data on yield and quality variability of the two species. This paper is a synthesis of six experiments carried out between 1996 and 2002. Varieties of lucerne and red clover, tested in this experiment, produced very good yields of quality forages compared to nitrogen fertilised ryegrass.

Keywords: yield, energy, protein, legume

Introduction

Legumes in association with *Rhizobium* bacteria have the ability to fix substantial amounts of N_2 from the atmosphere. This can benefit grass growth in grass-legume associations and enhance soil fertility for succeeding crops. Systems relying on biologically fixed N_2 are likely to be less damaging to the environment than those relying on high N-fertiliser applications, due to a lower rate of nitrate leaching (Ryden, 1984). Fertiliser N costs have risen progressively, and the use of legumes could reduce significantly the production costs. Moreover, nitrogen fertiliser processing requires a lot of fossil fuel energy that contributes to greenhouse gas production (Frame, 1990). Compared with grass, pure lucerne and red clover, as well as grass-legume mixtures, have a high feeding value because of high intake characteristics, high digestibility and high concentrations of protein, Ca and Mg (Campling, 1984). In this paper, dry matter (DM), crude protein (CP) and energy (VEM: forage unit milk) yields of grass-legume mixtures are compared with fertilised pure grass stands. The aim is to assess the forage potential of two common legumes in Belgian temporary cutting grasslands: lucerne and red clover. Varieties of legume were also compared.

Materials and methods

The trial sites were located in a loamy region with low soil humus content (1.6 %). Two sites in 1999 and two sites in 2000 (Experiment 1) were sown with pure perennial ryegrass (*Lolium perenne*, Merganda) (Lp) fertilised with increasing rates of nitrogen (100 to 400 kg N ha^{-1}), and with red clover (Merviot)-ryegrass (Merganda) (Tp + Lp) and lucerne (Europe)-cocksfoot (*Dactylis glomerata*, Barola) (Ms + Dg) mixtures with no nitrogen fertilisation. The plot size was 8 m × 3 m. They were managed for three years (one year of establishment and two years of production). Two other trials were established (Experiment 2): in 1996 eight red clover-ryegrass (Merganda) mixtures and in 2000 nine varieties of lucerne were sown in pure stands for two years of production. The names of legume varieties are indicated in tables 2 and 3.

Four cuts per year were taken at 7 cm height on each plot for each trial, during the production years. DM yields were recorded. Energy (VEM = Forage Unit Milk; 1000 VEM = 1650 kcal) and CP contents were determined by Near Infra-Red (NIR) spectroscopy. All experiments included four replicates in complete randomised blocks.

Results and discussion

As shown in table 1 (Experiment 1), grass receiving fertiliser applications above 300 kg N ha^{-1} out-yielded grass-legume swards for dry matter and energy production in the first year.

Table 1. Mean dry matter, protein and energy (VEM) production and standard error (exponent) of the four sites in experiment 1.

Species	First year of production			Second year of production			Total of the two years		
	DM (t ha^{-1})	CP (t ha^{-1})	10^6 VEM ha^{-1}	DM (t ha^{-1})	CP (t ha^{-1})	10^6 VEM ha^{-1}	DM (t ha^{-1})	CP (t ha^{-1})	10^6 VEM ha^{-1}
Lp 0	4.8 $^{1.3}$	0.4 $^{0.1}$	4.2 $^{1.2}$	2.7 $^{0.5}$	0.2 $^{0.0}$	2.3 $^{0.6}$	7.5 $^{1.4}$	0.6 $^{0.2}$	6.5 $^{1.2}$
Lp 100	9.0 $^{1.5}$	0.8 $^{0.1}$	8.0 $^{1.2}$	5.7 $^{0.7}$	0.6 $^{0.1}$	5.3 $^{0.7}$	14.7 $^{2.1}$	1.4 $^{0.2}$	13.2 $^{1.7}$
Lp 200	12.5 $^{0.9}$	1.3 $^{0.1}$	11.3 $^{0.7}$	9.2 $^{0.7}$	1.1 $^{0.1}$	8.5 $^{0.7}$	21.7 $^{1.1}$	2.4 $^{0.2}$	19.8 $^{0.9}$
Lp 300	15.2 $^{1.1}$	1.8 $^{0.1}$	13.6 $^{0.9}$	11.5 $^{1.1}$	1.7 $^{0.2}$	10.5 $^{1.0}$	26.7 $^{2.0}$	3.5 $^{0.2}$	24.1 $^{1.7}$
Lp 400	16.1 $^{1.0}$	2.2 $^{0.2}$	14.6 $^{1.1}$	12.3 $^{1.3}$	2.1 $^{0.2}$	11.4 $^{1.1}$	28.4 $^{2.3}$	4.3 $^{0.5}$	26.0 $^{2.2}$
Lp+Tp	14.0 $^{1.5}$	2.2 $^{0.3}$	12.6 $^{1.4}$	15.2 $^{1.5}$	2.3 $^{0.2}$	11.8 $^{1.2}$	29.2 $^{2.3}$	4.5 $^{0.4}$	27.4 $^{2.0}$
Dg+Ms	14.2 $^{3.1}$	2.5 $^{0.8}$	11.1 $^{2.7}$	12.4 $^{1.3}$	2.2 $^{0.3}$	10.5 $^{1.2}$	26.6 $^{9.1}$	4.7 $^{1.9}$	21.6 $^{7.8}$

The protein production of red clover mixtures was similar during this first year with the 400N ryegrass; while grass-lucerne mixtures out-yielded 400N fertilised grass by 0.3 t CP ha^{-1}. In the second year of production, the dry matter yields of grass-red clover swards were significantly ($P < 0.001$) higher than those of the 400N fertilised grass. CP and VEM productions of grass-red clover swards out-yielded those of 400N fertilised grass. During this second year, grass-lucerne swards showed similar dry matter yields and protein production to 400N ryegrass.

Table 2. Dry matter, CP and energy (VEM) yields and standard error (exponent) of varieties of lucerne of experiment 2.

Lucerne varieties	First year of production			Second year of production			Total of the two years		
	DM (t ha^{-1})	CP (t ha^{-1})	10^6 VEM ha^{-1}	DM (t ha^{-1})	CP (t ha^{-1})	10^6 VEM ha^{-1}	DM (t ha^{-1})	CP (t ha^{-1})	10^6 VEM ha^{-1}
Bella	17.0 $^{0.6}$	3.2 $^{0.2}$	14.3 $^{0.5}$	16.1 $^{1.1}$	2.9 $^{0.2}$	13.2 $^{1.1}$	33.2 $^{1.5}$	6.1 $^{0.3}$	27.5 $^{1.4}$
Recor	16.9 $^{0.8}$	3.0 $^{0.2}$	13.9 $^{0.7}$	16.1 $^{1.4}$	2.8 $^{0.3}$	13.1 $^{1.1}$	33.1 $^{1.7}$	5.9 $^{0.3}$	27.0 $^{1.2}$
Capri	16.0 $^{0.9}$	2.9 $^{0.3}$	13.2 $^{0.9}$	16.4 $^{1.6}$	2.9 $^{0.2}$	13.4 $^{1.0}$	32.4 $^{2.0}$	5.8 $^{0.3}$	26.6 $^{1.5}$
Defi	16.7 $^{0.8}$	2.9 $^{0.2}$	13.6 $^{0.9}$	15.3 $^{0.8}$	2.8 $^{0.2}$	12.8 $^{0.8}$	32.0 $^{1.4}$	5.7 $^{0.3}$	26.4 $^{1.4}$
Alégro	16.4 $^{0.8}$	3.0 $^{0.2}$	13.6 $^{0.7}$	15.4 $^{0.8}$	2.7 $^{0.0}$	12.6 $^{0.3}$	31.8 $^{1.3}$	5.7 $^{0.2}$	26.2 $^{0.8}$
Sanditi	16.3 $^{0.3}$	2.9 $^{0.1}$	13.5 $^{0.3}$	15.5 $^{0.4}$	2.8 $^{0.1}$	12.8 $^{0.4}$	31.8 $^{0.6}$	5.7 $^{0.2}$	26.3 $^{0.7}$
Derby	16.3 $^{1.0}$	3.0 $^{0.2}$	13.8 $^{0.9}$	15.0 $^{0.4}$	2.7 $^{0.1}$	12.4 $^{0.1}$	31.4 $^{1.0}$	5.7 $^{0.3}$	26.2 $^{0.8}$
Janu	15.6 $^{0.6}$	2.9 $^{0.2}$	13.1 $^{0.7}$	15.5 $^{0.7}$	2.8 $^{0.1}$	12.8 $^{0.4}$	31.1 $^{0.5}$	5.6 $^{0.1}$	25.9 $^{0.4}$
Sitel	15.2 $^{1.0}$	2.8 $^{0.2}$	12.6 $^{0.7}$	14.7 $^{0.7}$	2.7 $^{0.2}$	12.2 $^{0.6}$	29.9 $^{1.4}$	5.4 $^{0.3}$	24.8 $^{1.1}$

The lower dry matter yields of lucerne compared with red clover in the second year probably results from the fact that no inoculation of *Rhizobium* was used. In those conditions, red clover may have a better growth than lucerne. Nevertheless, both associations showed very high DM yields and a good forage quality when compared with fertilised grass. The high yields of the associations partly result from the high production of legumes during summer time (data not shown) when pure grass stands production decreased because of drought and high temperatures.

Table 3. Dry matter, CP and energy (VEM) yields and standard error (exponent) of perennial ryegrass- red clover mixtures of experiment 2.

Red clover varieties	First year of production			Second year of production			Total of the two years		
	DM ($t\ ha^{-1}$)	CP ($t\ ha^{-1}$)	10^6 VEM ha^{-1}	DM ($t\ ha^{-1}$)	CP ($t\ ha^{-1}$)	10^6 VEM ha^{-1}	DM ($t\ ha^{-1}$)	CP ($t\ ha^{-1}$)	10^6 VEM ha^{-1}
Ruttinova	$17.3^{0.4}$	$3.0^{0.2}$	$15.6^{0.4}$	$17.3^{0.8}$	$3.1^{0.2}$	$15.5^{0.9}$	$34.6^{1.0}$	$6.1^{0.3}$	$31.1^{1.0}$
Vanessa	$16.9^{0.8}$	$3.0^{0.1}$	$15.2^{0.7}$	$17.3^{0.6}$	$3.2^{0.2}$	$15.6^{0.6}$	$34.3^{1.2}$	$6.2^{0.2}$	$30.8^{1.0}$
Temara	$17.1^{0.8}$	$2.9^{0.1}$	$15.3^{0.8}$	$16.9^{0.8}$	$3.0^{0.2}$	$15.1^{0.6}$	$34.0^{0.9}$	$5.9^{0.1}$	$30.4^{0.7}$
Karim	$16.4^{1.6}$	$3.0^{0.3}$	$14.9^{1.4}$	$16.8^{1.2}$	$3.0^{0.3}$	$15.1^{1.1}$	$33.1^{2.4}$	$6.0^{0.5}$	$30.0^{2.1}$
Merviot	$15.6^{1.2}$	$2.8^{0.1}$	$14.0^{1.0}$	$16.3^{0.8}$	$3.0^{0.1}$	$14.8^{0.7}$	$31.9^{1.7}$	$5.7^{0.2}$	$28.9^{1.4}$
Kvarta	$16.0^{1.4}$	$2.9^{0.1}$	$14.5^{1.1}$	$15.9^{0.5}$	$2.8^{0.1}$	$14.2^{0.5}$	$31.9^{1.2}$	$5.6^{0.2}$	$28.7^{1.1}$
Violetta	$16.0^{1.1}$	$2.8^{0.2}$	$14.3^{1.0}$	$15.7^{0.7}$	$2.7^{0.3}$	$14.0^{0.8}$	$31.7^{1.4}$	$5.6^{0.4}$	$28.4^{1.3}$
Barfolia	$15.9^{1.3}$	$2.9^{0.2}$	$14.5^{1.1}$	$15.2^{0.6}$	$2.8^{0.1}$	$13.8^{0.5}$	$31.1^{1.6}$	$5.7^{0.3}$	$28.3^{1.3}$

Table 2 (Experiment 2) shows the production of 9 varieties of lucerne (in pure stands) while table 3 shows the production of 8 varieties of red clover in mixture with perennial ryegrass (Merganda). For lucerne, three varieties (Capri, Recor and Bella) outyielded the others in terms of dry matter, crude protein and energy yields. For red clover varieties, Ruttinova and Vanessa showed particularly high yields and forage quality over the two years of ley. Results were lower over the two years for Barfolia indicating a lack of persistence.

Conclusions

Substantial yields of 14 to 15 t DM ha^{-1} y^{-1} with no fertiliser inputs may be sustained in grass-legume mixtures, otherwise only achievable by heavy application of N on pure grass stands. N application could be eliminated in the grass-legume mixtures without any yield depression and thus create financial economy at farm scale.

New varieties of legumes produced high yields of up to 17.3 and 16.4 t DM ha^{-1} y^{-1} for ryegrass-red clover mixtures and pure stands of Lucerne, respectively during the second year of production.

Forage quality of grass-legume mixtures is also very high if compared with pure fertilised ryegrass stands. Annual energy production is up to 15,615 VEM ha^{-1} for the red clover-grass mixture and 14,276 VEM ha^{-1} for lucerne in pure stand, while the maximum energy production obtained for a 400N fertilised grass is 14,586 VEM ha^{-1}.

In conclusion, legume based mixtures allow high yield production with very good forage quality without any fertiliser applications.

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The productivity of cocksfoot and tall fescue in pure stand and simple mixtures with birdsfoot trefoil by varying nitrogen fertilisation

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Abstract

Birdsfoot trefoil (*Lotus corniculatus*) is a valuable partner for grass in ecological areas unfavorable for white clover: acid, unfertile, salt soils, or excessive drought.
The contribution of birdsfoot trefoil (cv. Doru) on forage yield was studied in mixtures with two grass species with different competitive abilities: less competitive tall fescue, *Festuca arundinacea* (cv. Brio and Adela), and highly competitive cooksfoot *Dactylis glomerata* (cv. Poiana and Regent), at three levels of fertilisation: N_0, N_{50}, N_{100}.
The yield of the binary mixtures of cocksfoot / birdsfoot trefoil in the unfertilised variant exceeded the DM yield of a pure stand of cocksfoot at N_{50} by 1.4 t ha^{-1} and the DM yield of a pure stand at N_{100} by 0.25 t ha^{-1}. For tall fescue / birdsfoot trefoil mixtures, the DM yields obtained at N_0 exceeded the DM yield of a tall fescue pure stand at N_{50} by 1.7 t ha^{-1} and the DM yield of a pure stand at N_{100} by 0.95 t ha^{-1}.
Cocksfoot was very competitive in mixtures with birdsfoot trefoil, the birdsfoot trefoil percent in mixtures decreasing from 45.5 % at N_0 to 7.5 % at N_{100}. In mixtures with tall fescue the legume component was 61.5 % at N_0 and 33.0 % at N_{100}.

Keywords*: Lotus corniculatus, Festuca arundinacea, Dactylis glomerata*, binary mixture, N fertilisation

Introduction

Birdsfoot trefoil, well adapted on various soil and climatic conditions, is the most suitable legume for podzol soils (Pop *et al*., 1998). In ecological areas unfavorable for white clover, birdsfoot trefoil contributes to the N balance. On average, each percent of birdsfoot trefoil can extract 2.7 kg N ha^{-1} y^{-1} which is included in biomass (Dragomir *et al.*, 1992).
With regard to environmental requirements, the role of legumes has increased considerably in recent times due to the reduction of fertiliser N inputs, the grass / legume mixtures playing an important role in sustainable farming systems (Razec *et al.*, 2001).
The aim of this research was to establish the impact of birdsfoot trefoil in simple mixtures with two grass species: tall fescue (*Festuca arundinacea)* and cocksfoot *(Dactylis glomerata),* in relation to N fertilisation.

Materials and methods

Experimental studies were carried out during 3 consecutive years (2001-2003) at the Grassland Research and Development Institute, Brasov, situated in the nemoral level, at an altitude of 560 m asl, on a sandy loam chernozem soil; pH = 5.8, P = 41 ppm and K = 164 ppm.
Two grass species were used: tall fescue (Brio and Adela varieties), and cocksfoot (Poiana and Regent varieties), each in pure stands and in mixture with birdsfoot trefoil (Doru variety). The seed rate was 25 kg ha^{-1} for each grass species and 5 kg ha^{-1} for birdsfoot trefoil.
Three nitrogen fertiliser levels were used: N_0, N_{50}, N_{100}. For N_{50} variants, the fertiliser was applied in spring, at the beginning of the growing season and for N_{100} variants, 50 kg ha^{-1} was applied in spring and 50 kg ha^{-1} after the first cut. The studies were conducted on 12 m^2 plots, with four replications at each level of fertilisation.

The period of the experiments coincided with severe drought conditions for this geographical region, the rainfall in the second and third year of experiments being about 300 mm lower than the 59 year average, with higher temperatures and sunburn, especially in June (-100 mm, +3.3 °C), May (-44,8 mm, +4.6 °C) and August (-66.5 mm, +2.8 °C), causing negative repercussions on plant growth and development. Consequently, only 2 cuts were obtained in the year of establishment, 3 cuts in the second year and only 2 cuts in the third year, with the production 40-50 % lower than in normal rainfall years. Botanical analyses were made at every cut.

Results and discussion

From the data presented in figure 1, it follows that the presence of birdsfoot trefoil in mixtures with grasses ensured higher production, averaged over three years, with an additional 1.48 t DM ha^{-1} in combination with cocksfoot and 2.18 t DM ha^{-1} in combination with tall fescue, compared with pure grass stands.

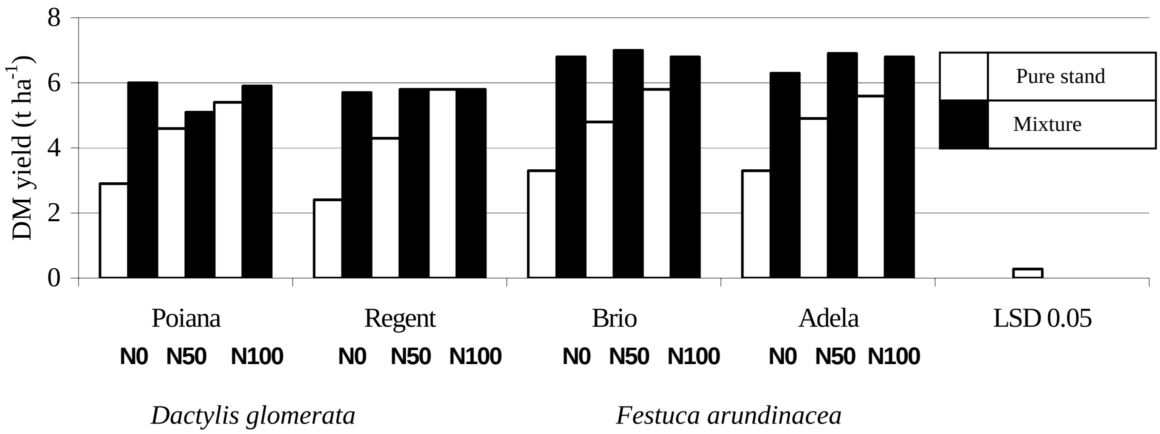

Figure 1. Dry matter (DM) yields of *Dactylis glomerata* and *Festuca arundinacea* varieties in pure stands and simple mixtures with *Lotus corniculatus*, on different level of N fertilisation (means of three years are shown).

The yield gains were found at all the levels of N fertilisation, being: 3.2 t DM ha^{-1} at N_0, 1.0 t DM ha^{-1} at N_{50} and 0.25 t DM ha^{-1} at N_{100} in mixture with cocksfoot, and 3.25 t DM ha^{-1} at N_0, 2.1 t DM ha^{-1} at N_{50} and 1.2 t DM ha^{-1} at N_{100} in mixture with tall fescue. The highest differences were obtained at N_0. The yield of the binary mixtures, cocksfoot / birdsfoot trefoil in the unfertilised variant exceeded the DM yield of a pure stand at N_{50} by 1.4 t ha^{-1} and the DM yield of a pure stand at N_{100} by 0.25 t ha^{-1}. For tall fescue / birdsfoot trefoil mixtures, the DM yields obtained at N_0 exceeded the DM yield of a pure stand at N_{50} by 1.7 t ha^{-1} and the DM yield of a pure stand at N_{100} by 0.95 t ha^{-1}.

At all the levels of fertilisation, in the year of establisment, the DM yield of grass / birdsfoot trefoil mixtures was a little lower than the grass in pure stand. In the second year the highest differences between the grass / birdsfoot mixtures and the pure stands were determined, being on average +5.6 t DM ha^{-1} at N_0, +2.6 t DM ha^{-1} at N_{50} and +5 t DM ha^{-1} at N_{100}. In the third year the DM yield gain of mixtures decreased to +3.97 t DM ha^{-1} at N_0, +2.05 t DM ha^{-1} at N_{50} and +0.89 t DM ha^{-1} at N_{100}.

Considering the percent of birdsfoot trefoil in mixtures, there were great differences between the two types of mixtures, caused by different competitive abilities. Cocksfoot is more competitive, with the percent of birdsfoot trefoil decreasing from 45.5 % at N_0 to 21.5 % at

N_{50} and to 7.5 % at N_{100}, while for tall fescue, a less competitive species, the percent of birdsfoot trefoil decreased from 61.5 % at N_0 to 46.5 % at N_{50} and to 33.0 % at N_{100}.

Conclusions

We concluded that the cultivation of grass / birdsfoot mixtures is more favorable than cultivating the grass in pure stands. The tall fescue / birdsfoot mixture is suitable in conditions of drought. The presence of birdsfoot trefoil increases the yields, so that the mixtures, even at $N_{0,}$ exceeded the yield of grass in pure stands fertilised with $N_{100,}$ thus, saving costs and reducing the risk of pollution. The cultivation of grass / birdsfoot trefoil mixtures ensures a good quality of forage, playing at the same time an important role in sustainable farming systems, especially on soils of low fertility.

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Forage production and persistency from *Lotus*-based swards under low-input management

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Abstract

Sowings of *Lotus* (*Lotus corniculatus* and *L. pedunculatus*) with companion grasses were made at several sites in the UK and recorded for up to 5 years. Experimental aims were to investigate effects of sowing methods on establishment, and of management on *Lotus* persistence and herbage production. Establishment of *Lotus* was poor after oversowing into an existing sward, compared with sowing after cultivation. On lowland sites, annual DM yield in year 1 was up to 12 t DM ha^{-1}, with > 50 % *Lotus* in the DM, declining to < 6 t DM ha^{-1} in 2002/03 and *Lotus* contributing up to 33 % of DM. Yields and *Lotus* persistency on acid upland compared favourably with other forage types. In general, *Lotus* persistence, and its contribution to DM yield, were greatest in treatments harvested two/three times per year compared with more frequent harvesting; nutrient additions benefited companion grasses more than *Lotus*, except on an upland site where PK additions increased both the *Lotus* and total DM yields.

Keywords: *Lotus*, Trefoil, legumes, production, persistency

Introduction

Among the *Lotus* (trefoil) species, birdsfoot trefoil (*Lotus corniculatus*) and greater bird's-foot trefoil (*L. pedunculatus*) have potential to contribute to European forage resources, particularly in sustainable, low-input situations. They currently occupy a minor role compared with the principal legumes (white clover, red clover, lucerne) and have received comparatively little agronomic investigation in Europe. Previous research had shown relatively high dry matter yield, with a good contribution of *Lotus* initially, but poor persistence (Hopkins *et al*., 1996). Increasing recognition of the nutritional properties of *Lotus* species associated with condensed tannin (Barry and McNabb, 1999) as well as their suitability as N-fixing legumes for low-fertility grassland, has highlighted the need to address agronomic questions relating to *Lotus* herbage yield potential and persistency under different situations. In 1998 we commenced a programme of small-plot experiments and associated mesocosm studies to (a) compare alternative methods of *Lotus* establishment and identify factors affecting establishment, and (b) investigate forage yield and persistence of *Lotus* in sown grass-*Lotus* swards in relation to site and management.

Materials and methods

Establishment experiments: On an old permanent pasture at IGER North Wyke, we compared two sowing methods: ploughing and full cultivation followed by sowing a *Lotus*-grass mixture (with *Phleum pratense* + *Festuca pratensis*), versus direct sowing (strip seeding) of *Lotus* into the existing sward after partial rotary cultivation, with either *L. corniculatus* (cv. Rocco, 13.5 kg ha^{-1}) or *L. pedunculatus* (cv. Maku, 11 kg ha^{-1}), giving 4 treatments with 4 replicated plots (each of 8.0 m × 6.0 m) of each treatment. Sowing was made in June 1998 and simulated hay cuts taken in June 1999 and June 2000. The plot area was grazed with sheep during autumn and winter. Assessments were made of herbage yield and its botanical components, and of the frequency of *Lotus* plants in ground-level quadrats. Additional mesocosm studies investigated the effect on seedling establishment of sowing depth and rhizobia application (these used replicated free-draining metal sward boxes (1.0 m × 1.0 m × 0.3 m deep) containing soils from the three persistence experimental sites (below) managed under uniform conditions in a well-ventilated polytunnel).

Persistence experiments: At three contrasting sites in the UK we established small-plot field experiments sown with a *L. corniculatus* (cv. Rocco) plus *L. pedunculatus* (cv. Maku) mixture (13.5 kg *Lotus* seed ha^{-1}), with companion grasses (*P. pratense* + *F. pratensis* / *Cynosurus cristatus)* by broadcast sowing after complete cultivation. The sites were at (1) Cirencester, southern England, a calcareous clay loam on an organic farm at 140 m elevation; (2) Devon, south-west England, a sandy clay loam on a conventional farm at 150 m elevation; and (3) west Wales, peat over clay, on a conventional farm at 400 m. At each site treatment plots were laid out to include the effects of harvesting frequency and fertiliser addition. These comprised three cuts versus four cuts per year at sites 1 and 2, and two cuts versus three cuts per year at the upland site 3; and fertiliser as nil inputs versus either mineral PK (20 kg ha^{-1} P plus 42 kg ha^{-1} of K) at sites 2 and 3, or as composted farmyard manure (FYM) at site 1. At each site there were 3 replicated plots (size 6.0 m x 1.5 m) of each treatment. Assessments of herbage yield were made at each harvest, and sub-sampled to determine the proportion of *Lotus*. Additional botanical assessments were made to determine the frequency of *Lotus* and other plant species in ground level quadrats each year. Sites 1 and 2 were recorded in 1999-2003; site 3 in 1999-2000 only, with additional botanical assessments in 2002.

Results and discussion

Establishment studies: In October of the establishment year there was a high density of *Lotus* plants recorded on the full cultivation treatments (*Lotus* present in > 70 % of 10 cm^2 quadrat cells) but a much lower density (*ca*. 20 % of 10 cm^2 cells) on the oversown treatments. In both years, DM yield ('hay crop' plus sampled exclusion areas during aftermath grazing) contained a greater proportion of *Lotus* from the full cultivation treatments than the oversown treatments (Table 1). Results were significant at $P < 0.01$ in 1999 and $P < 0.05$ in 2000. On the oversown treatments Rocco made a negligible contribution in both years, whereas the yield of Maku increased in the second year. On the ploughed and cultivated treatments there was a good establishment and yield of both Maku and Rocco in 1999, but Rocco decreased in 2000.

Table 1*. Harvested total yield (kg DM ha^{-1}) and % *Lotus* in the DM in relation to establishment method and *Lotus* species, 1998, sown on a silty clay loam, permanent pasture.

	1999		2000	
	Oversown	Full cultivation	Oversown	Full cultivation
L. corniculatus (cv. Rocco)	4940 (0.1%)	4750 (22%)	8600 (0.1%)	6190 (2%)
L. pedunculatus (cv. Maku)	5300 (2%)	5060 (24%)	9810 (5%)	7270 (18%)

*For more detailed information on *Lotus* herbage yield and statistical analyses please contact author.

In the associated mesocosm experiments, sowing depth was a significant factor affecting short-term establishment. At 20 days after sowing seedling numbers (as % of Rocco seed sown) were 30 % for 2 mm sowing depth, 42 % for 20 mm depth, and 57 % for 10 mm depth. These values remained constant for at least 12 days thereafter.

The effect of applying specific rhizobia in mesocosm sowings with Rocco and Maku was evaluated for three contrasting soils. There was no effect on establishment, although soil type had an independent effect (the peaty soil had a lower seedling establishment than two loamy soils, for both types of *Lotus*).

Persistence experiments: Good establishments of *Lotus* and companion grasses were obtained on all sites, notably at site 1 where the frequency of *Lotus* plants was *ca*.100 % in all plots (in terms of presence in 10 cm^2 cells of 3 × 50 cm^2 quadrats per plot) by October of the establishment year. Most plots on the other two sites had frequency values of > 90 % in the establishment year. Table 2 summarizes the total herbage and *Lotus* yields over time.

Table 2. Harvested total herbage yield and *Lotus* yield (as kg DM ha^{-1}) in successive years at contrasting sites, mean yields of all treatments. All sites sown in 1998.

	1999	2000	2001	2002	2003
Site 1: total DM	11392	7650	§	6439	4532
Site 1: *Lotus* DM	7255	5060	§	1475	823
Site 2: total DM	7252	6084	6717	7379	6101
Site 2: *Lotus* DM	2694	1261	519	572	480
Site 3: total DM	1809	2551	§	§	§
Site 3: *Lotus* DM	425	779	§	§	§

§ Site not recorded in these years (plots were sheep grazed only).

At the organic farm (site 1) mean total DM yield in 1999 was 11.4 t ha^{-1}, of which *Lotus* contributed 64 % and, although mean total DM was lower in subsequent years, an acceptable, albeit declining, proportion of *Lotus* remained (66 % in 2000, 23 % in 2002, 18 % in 2003). The treatments that received FYM gave a higher total DM yield, but had a lower proportion of *Lotus* in the herbage. Treatments cut three times per year gave a higher total yield and the *Lotus* yield was higher, compared with those cut four times; e.g., in both 2002 and 2003 the three cuts, nil-FYM treatment contained *ca*. 33 % *Lotus* in the harvested DM, compared with 10-15 % for the treatments cut four times. By 2003 almost all the *Lotus* that remained was *L. corniculatus.* At site 2, the mean DM yield remained relatively constant between 1999 and 2003, though the proportion of *Lotus* in the harvested yield declined from 37 % in 1999 to 21 % in 2000, and stabilized at about 8 % in the subsequent years. The treatments that received PK fertiliser gave similar total DM yields, with a similar percentage of *Lotus*, as the nil-fertiliser treatments. Treatments mown three times per year gave a higher total yield and the proportion of *Lotus* was higher, compared with those cut four times; e.g., in both 2002 and 2003, the three cut-treatments contained *ca*. 12 % *Lotus* in the harvested DM, compared with only 3 % for the four-cut treatments. By 2003, most of the *Lotus* that remained was *L. corniculatus*, though *L. pedunculatus* was present.

At the upland site (site 3) total DM yields were low reflecting the marginal conditions, but the contribution of *Lotus* at 24 % in 1999 and 30 % in 2000 was encouraging for a site where other legumes, such as white clover, would not be expected to survive. Treatments that received PK fertiliser had more than twice the total herbage DM yield as unfertilised treatments, and also a higher yield and a greater proportion of *Lotus*. Cutting frequency also affected total yield and *Lotus* content: e.g., in 2000, the yield of the three-cut unfertilised treatments was 1330 kg DM ha^{-1} of which 14 % was *Lotus*, whereas the two-cut, PK-fertilised treatments yielded 4130 kg DM ha^{-1} of which 44 % was *Lotus*. Botanical assessments made in 2002 showed *Lotus* had persisted on most plots, and it was predominantly *L. pedunculatus.*

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Comparison of grassland seed mixtures grazed by dairy cows under different levels of fertilisation

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Abstract

An experiment was performed to compare different legume and grass mixtures under grazing at different levels of fertilisation: farmyard manure, mineral fertilisers or unfertilised. Samples were collected before and after grazing to estimate dry matter content, botanical and chemical composition. The experiment demonstrated that forage legumes are important in Estonian grassland husbandry, because the majority of farmers cannot afford to apply sufficient mineral N fertiliser. White clover is especially valuable for dairy cows which require high-yielding, high-protein and nutritious forages. Hence, white clover is important in seed mixtures for grazing. Red clover and alfalfa are generally sown in mixture with other species and are major constituents in short-term leys. The experiment showed that cows grazed selectively and did not prefer pure grass swards grown without NPK fertilisers, thus emphasising the importance of legumes and of mineral fertilisers.

Keywords: botanical composition, grazing, legumes, pasture, sustainable agriculture

Introduction

Up to 15-30 years ago it was the practice in Estonia to grow pure grass swards, using high rates of nitrogen fertilisation. This has led to increased N losses through leaching into the groundwater or through gaseous forms into the atmosphere. It is now mostly recommended to establish pastures using species-rich seed mixtures (Raave, 2000). Yields and quality of mixed swards are more stable than in pure stands (Laidna, 2003). In low-input grassland farming forage legumes have an essential role in that legume-rich pastures provide low-cost forage during the growing season, benefiting the majority of Estonian farmers who cannot afford to apply sufficient mineral N fertiliser (Viiralt and Parol, 2001). Legumes are essential in organic farming systems as they can produce high yields and good quality herbage, and in association with *Rhizobium* bacteria, can fix atmospheric nitrogen (Newton, 1999).
The objective of our research was to study the productivity of different grass-legume mixtures, suitable for utilisation by grazing. The swards were either not fertilised or fertilised with mineral or organic fertilisers.

Materials and methods

The experiment, with 12 treatments and 4 replicates, was established in 2001 at the Experimental Station of EAU on Podzoluvisols. Soil pH_{KCl} was 5.9-6.1, the organic matter content 2.2-2.7 % and available P and K contents were 157 and 141 mg kg^{-1}, respectively. The plot area was 200 m^2 (12.5 m x 16 m) and the total grazed area was 0.5 ha. In 2002, a very dry year, the total rainfall for the growing season was 180 mm and the swards were grazed by cows 3 times each season at a stocking rate of 77 cows ha^{-1}. Fresh herbage yield, DM yields and the N content of the grass were measured. The botanical composition of each sward treatment was determined by hand separation of herbage samples before and after the grazing cycle. Ten 1 m^2 subplots were sampled and weighed before grazing the remaining area. After grazing the swards were topped and any grass rejected by the cows was weighed in sample areas of 20 m^2 to determine the level of utilisation of the grass by the cows. Sward

tiller density m^{-2} was recorded at the end of the growing season. The experimental data were subject to analyses of variance, ANOVA.
The following seed mixtures and seeding rates (kg ha^{-1}) were used:

1. Basic grass mixture in all mixtures included timothy cv. Tika (5); perennial ryegrass cv. Raidi (10); bluegrass cv. Esto (3).
2. Additional species sown with the grass species were: lucerne cv. Juurlu (10); meadow fescue cv. Arni (10); red clover cv. Ilte (8); white clover cv. Jõgeva 4 (4).

The new Estonian hybrid lucerne cultivar Juurlu was bred especially for grazing. This is a pasture type, which spreads vegetatively by creeping roots (Bender *et al*., 2000), and it is desirable to research its yield potential and persistence under grazing.
Fertilisers used were: farmyard manure (10 t ha^{-1}) or mineral fertiliser (P-30, K-90 and to the grasses N-200 kg ha^{-1}), applied at the end of April. N was applied after the first and second cuts.

Results and discussion

Tetraploid red clover cv. Ilte covered 58 to 71 % of the botanical composition. White clover and alfalfa were more sensitive to drought in 2002, and proportions in the swards varied between 37-51 % and 47-64 %, respectively (Figure 1). Perennial ryegrass was a valuable component in the grass seed mixtures, which responded strongly to N fertiliser application.

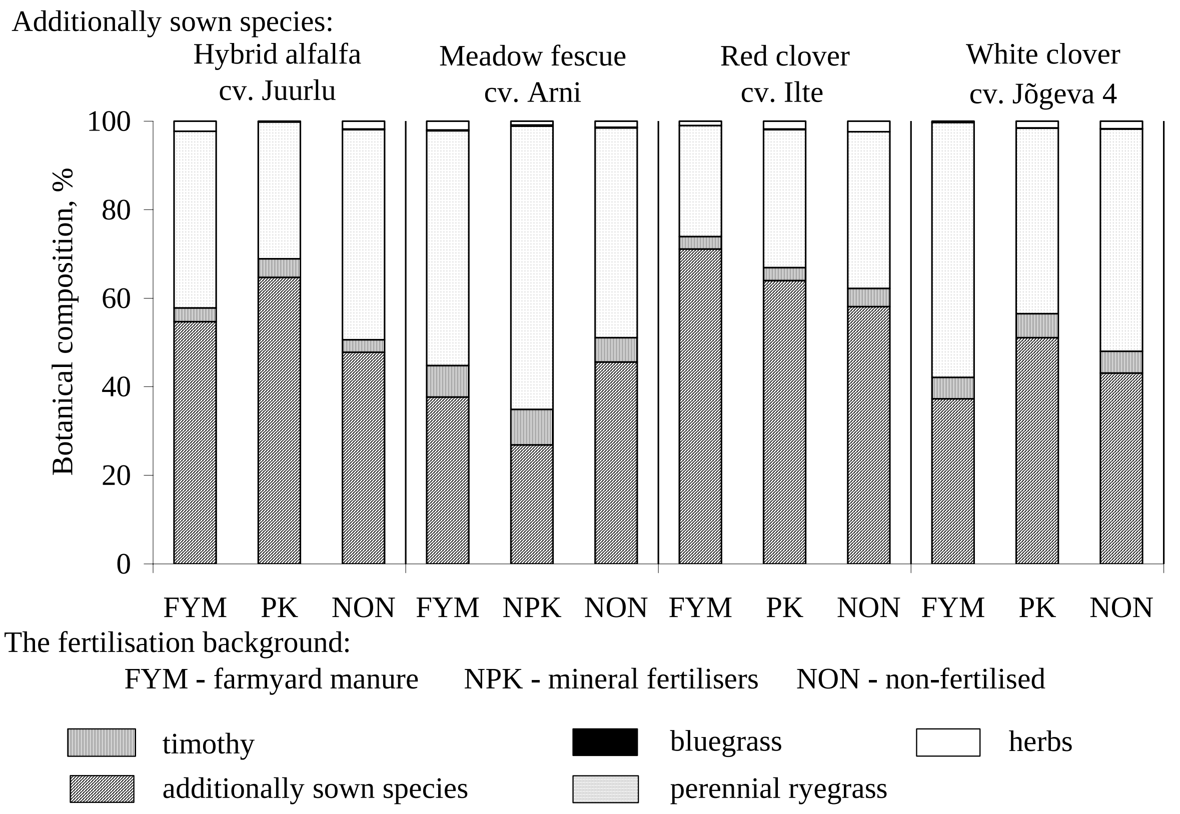

Figure 1. The botanical composition (% by weight) of the swards in 2002.

The highest annual DM yields were obtained in pure grass sward (7.7 t ha^{-1}) with $N_{200}P_{30}K_{90}$ fertilisation and in the red clover and grass mixtures (6.5-6.9 t ha^{-1}) during the first grazing year (Table 1). Red clover gave a high yield rich in protein, which resulted in better animal performance than from the grasses. Red clover late tetraploid cultivar Ilte had good persistence and productivity. The results of the experiment showed that the cows grazed selectively. The best level of herbage utilisation by the cows (% of maximum) was obtained in the red (64-68 %) and white clover (75 %) swards with mineral PK-fertilisers or unfertilised. The use of the grass by the cows was lowest in the alfalfa-grass (27 %) and pure-grass (17 %) swards with farmyard manure application. Mean intake (11.6 kg DM cow^{-1} d^{-1}) was greatest on the grass-legume mixtures and the least (0.7 kg DM cow^{-1} d^{-1}) on pure grass swards with farmyard manure. CP contents of the grass ranged from 7.7 to 15.7 % of the DM, being highest with mineral fertiliser treatment. Grass sward densities were 3140-6720 tillers m^{-2} year depending on the main species sown.

Table 1. DM yields and CP contents by grazing cycle, DM intake and sward density at grazing in 2002.

Treatment[a]	Main sown species	Dry matter yield (t ha^{-1})				CP content (%)			DM intake	Sward density
		1st	2nd	3rd	total	1st	2nd	3rd	(kg cow^{-1})	(tillers m^{-2})
FYM	Hybrid alfalfa	2.6	2.1	0.9	5.6	12.4	12.3	12.8	3.6	5090
PK		2.7	2.3	0.7	5.7	12.9	15.7	13.6	5.8	6170
NON		3.2	2.1	0.7	6.0	11.1	12.2	14.8	6.2	6430
FYM	Meadow fescue	2.4	1.0	0.5	4.0	7.9	7.7	8.7	0.7	5520
NPK		3.8	3.0	0.9	7.7	15.0	13.6	10.2	8.7	4350
NON		3.1	1.0	0.4	4.5	7.7	8.9	7.7	3.8	5100
FYM	Red clover	2.5	3.0	1.4	6.8	13.1	10.7	13.0	9.4	3140
PK		3.3	2.7	1.0	6.9	11.8	12.9	14.1	11.6	4240
NON		3.0	2.7	0.8	6.5	15.0	12.3	13.2	10.0	5150
FYM	White clover	2.4	2.1	0.7	5.1	10.9	12.1	13.0	4.1	5150
PK		3.0	2.5	0.5	6.1	12.1	14.0	12.7	10.3	6220
NON		3.4	2.3	0.4	6.1	11.1	11.9	13.5	11.2	6720
	LSD_{05}				0.9					

[a]Treatment: FYM – farmyard manure; (N)PK – mineral fertilisers; NON – unfertilised.

Conclusions

The experiment demonstrated that forage legumes are important as a source of N in organic pasture. White clover is especially valuable for grazing. Red clover and alfalfa are generally used more for cutting, but the trial indicated that the presence of red clover in pasture was beneficial for cows. The results emphasised the importance of the legumes and of the use of N in pure grass mixtures. It was observed that the cows grazed selectively, and that pasture utilisation ranged within wide limits (17-75 %) depending very much on the type of fertilisation.

Acknowledgements

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Optimum management intensity of legume- and grass-based grassland swards

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Abstract

The optimum management intensity of grassland swards is mainly judged by dry matter (DM)- and protein-yields. The efficiency of the applied nitrogen and of technical equipment has to be considered for the sustainable use of grassland systems.

In an experiment in Aulendorf, South Germany, 9 alternative grassland swards (late and early varieties of *Lolium perenne, Trifolium repens* and *Medicago sativa)* with different cutting frequencies (4 to 6 per year) and different date of first harvest of primary growth were compared. These swards were compared and judged on the basis of yields of dry matter, crude protein and net energy. Moreover, N-use efficiency and economic parameters like machinery costs and fertilisation were also determined.

After 2 experimental years, the initial results of the on-going experiment show that legume-based grassland swards have higher N-efficiency than grass-based swards. (On average 50 kg DM kg^{-1} N for grass-based swards compared with 130 for white clover and more than 200 kg DM kg^{-1} N for lucerne). Dry matter yields were the highest in lucerne variants with 4 cuts. Net-energy consumption was the highest in grass-based swards with a high cutting frequency of 6 cuts. The results suggested that the optimum intensity of grassland use in South-Germany depend on the reference factor. Highest quality in grassland growth will be obtained with high cutting frequency and highest N-efficiency will be achieved by 4 cuts. Sustainable farming systems should be based on legumes.

Keywords: management intensity, energy content, yield, white clover, lucerne, N-efficiency

Introduction

The intensity of grassland production depends on local circumstances and the use of the forage produced, although it might be flexible over time. Moreover ‘optimum intensity’ is depending on economic factors and agro-political structures. Doubtless, high yielding dairy cows need a high energy density in their forage. If such forage is produced from permanent grassland, it was necessary to investigate whether highest cutting intensity gave the highest yields with sufficient energy density. A further question is whether the use of the applied mineral nitrogen, as a main factor in energy consumption at farm level is efficient. Results of investigations (Whitehead, 1995; Elsaesser, 1999; Kelm *et al.*, 2003) show, that the N-recovery-rate is rather low for grassland, but could be increased substantially by using legumes. The objectives this experiment was to investigate the effects of high production intensity from grassland on different yield parameters.

Materials and methods

In the years 2001 and 2002, 9 seed-variants of grassland and forage mixtures were tested under different utilisation conditions at the experimental station of Aulendorf (South Germany, 590 m asl, average annual rainfall, 1000 mm). The plot size was 1.5 × 6.0 m with 4 replications. All variants were sown with a basic seed mixture and received additional species (Table 1). Details of seed mixtures and utilisation regime are given in table 2. The experimental year 2003 is not yet finished, with the experiment continuing until 2004.

Table 1. Basic seed mixture.

Species	Cultivars	Variant 1-5	Variant. 6,7	Variant 8,9
Lolium perenne	Toledo, Respect, Recolta: middle	6 kg ha^{-1}	8 kg ha^{-1}	3 kg ha^{-1}
Festuca pratensis	Cosmolit	5 kg ha^{-1}	7 kg ha^{-1}	8 kg ha^{-1}
Phleum pratense	Tiller, Lirocco	5 kg ha^{-1}	5 kg ha^{-1}	7 kg ha^{-1}
Poa pratensis	Lato, Oxford	4 kg ha$^{-1;}$	6 kg ha^{-1}	4 kg ha^{-1}
Festuca rubra	Gondolin	3 kg ha^{-1}	3 kg ha^{-1}	0 kg ha^{-1}
Trifolium repens	Lirepa	2 kg ha^{-1}	6 kg ha^{-1}	6 kg ha^{-1}

Table 2. Mixture variants and cutting frequency.

Variant	Basic seed mixture (see table 1) plus	Cultivars	Date of 1st utilisation	Cutting frequency	Fertilisation (kg N ha^{-1})
1	*Lolium perenne* - 10 kg ha^{-1}	Early / middle	9.5 / 8.5	6	340
2	*Lolium perenne* - 10 kg ha^{-1}	Early / middle	9.5 / 8.5	5	250
3	*Lolium perenne* - 10 kg ha^{-1}	Middle / late	9.5 / 8.5	5	250
4	*Lolium perenne* - 10 kg ha^{-1}	Middle / late	9.5 / 8.5	4	180
5	*Lolium perenne* - 10 kg ha^{-1}	Middle / late	16.5 / 16.5	5	250
6	*Trifolium repens* - 6 kg ha^{-1}		9.5 / 8.5	5	90
7	*Trifolium repens* - 6 kg ha^{-1}		16.5 / 16.5	4	90
8	*Medicago sativa* - 3 kg ha^{-1}		16.5 / 16.5	4	90
9	*Medicago sativa* - 3 kg ha^{-1}		25.5 / 16.5	3	60

Results and discussion

Seed variants differed widely in DM-yield per ha and year (Table 3 and Figure 1). Highest yields of 16.8 and 14.9 t DM ha^{-1} were obtained for both lucerne variants and, where the first cut at optimum stage, had significant higher dry matter and energy yields. Grass variants were lower and differed significantly. The increase in cutting frequency from 4 to 5 to 6 cuts per year gave DM yields of 11.2, 12.7 and 13.9 t ha^{-1}, respectively, and increased the energy yields to 66.9, 76.8 and 85.6 GJ NEL ha^{-1}, respectively. The comparison between early and late cultivars of *Lolium perenne* (var. 2 and 3) resulted in slightly higher DM-yields for late cultivars, but gave no significant differences in energy yield, N-recovery and N-efficiency. Also the effects of date of first cut were negligible because the parameters gave no significant difference between variants 3 and 5. Even the energy yields were nearly the same, however the net energy contents differed markedly. The efficiency of N-use was the opposite for these variants: Highest efficiency was obtained with 4 cuts with a 62.3 kg DM per kg used N. Compared with this the highest cutting frequency (6 cuts y^{-1}) gave only an N efficiency of 40.9 kg DM kg N^{-1}.

Table 3. DM- and energy yields, N-recovery and N efficiency (2001 and 2002).

Variant and cultivar	Date of 1st cut 2001 / 2002	Cuts y^{-1}	DM-yield (t ha^{-1})	Energy-yield (GJ NEL ha^{-1})	N-recovery (kg N ha^{-1})	N-efficiency (kg DM kg N^{-1})
1 *Lolium perenne* early	9.5 / 8.5	6	13.9 bc	85.6 b	373.7 b	40.9 f
2 *Lolium perenne* early	9.5 / 8.5	5	12.7 d	76.8 c	334.1 cd	50.9 ef
3 *Lolium perenne* late	9.5 / 8.5	5	13.1 cd	78.8 c	347.9 bcd	52.3 ef
4 *Lolium perenne* late	9.5 / 8.5	4	11.2 ef	66.9 d	288.0 e	62.3 e
5 *Lolium perenne* late	16.5 / 16.5	5	12.7 d	77.0 c	340.2 bcd	50.7 ef
6 *Trifolium repens*	9.5 / 8.5	5	12.3 de	74.9 c	365.7 bc	136.4 c
7 *Trifolium repens*	16.5 / 16.5	4	11.0 f	66.0 d	315.0 de	121.8 d
8 *Medicago sativa*	16.5 / 16.5	4	16.8 a	97.5 a	438.1 a	186.6 b
9 *Medicago sativa*	25.5 / 16.5	4	14.9 b	85.3 b	418.6 a	247.9 a

Different letters indicate significant differences at the 0.05 level of significance.

The use of legumes resulted in a great increase of productivity because of the much higher N efficiency, but there exists significant differences between white clover and lucerne. It seems to be absolutely crucial to use white clover based grassland swards with higher cutting frequency. Only 4 cuts and a late date of the first cut gave lowest DM and energy yields. Whereas lucerne used with 4 cuts per year and an early harvest of primarily growth had best results in this experiment. Even a late first cut had same DM and net energy yields like the most intensive grass variant.

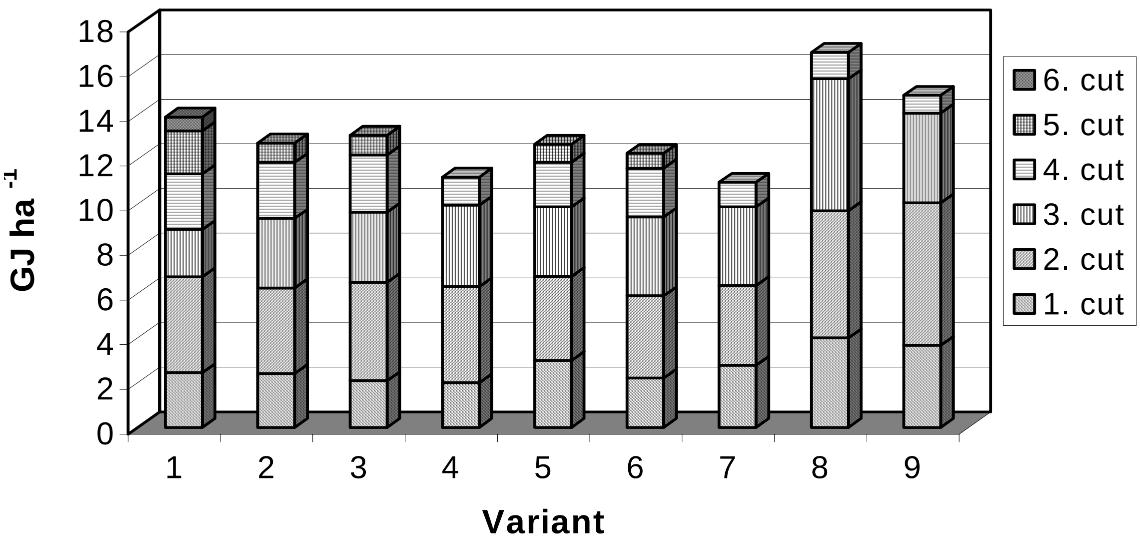

Figure 1. Average dry matter yields for the different growths in t DM ha^{-1} (2001 and 2002).

Conclusions

Highest cutting frequency gave highest dry matter and energy yields of grass-based swards. Optimum date of first cut in intensive grassland has effects on energy density, but there were no differences in energy yield. Similiar observations could be made for the comparison of early and late cultivars of *Lolium perenne* under the conditions of this grassland site. Four cuts were insufficient for producing highest dry matter and energy yields. Legume based grassland swards had much better results for nitrogen efficiency in South Germany. The use of legumes can be recommended even for producing highest energy contents.

First observations in 2003, a year with an exceptional drought, show, that the advantage for legume based grassland swards compared with grass based swards is still higher than in the first two experimental years.

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Effect of sowing strategy on clover performance in an organic red clover-grass mixture

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Abstract

In order to study the effect of splitting the seeding rate of red clover (*Trifolium pratense* L.), between establishing the sward and over-sowing subsequent dry matter production and clover content in mixed swards, two four-year field trials were carried out during 1999-2003 in eastern Finland. A split plot design was used with sowing strategy as a main plot and seed coat treatment as a subplot. In the main plots, seed-rates of 150 and 300 clover seeds m^{-2} were applied in a range of sowing strategies during three years: i) all seeds sown at establishment, ii) one third sown equally over each of the three years of the crop and iii) two thirds at establishment and one third before the second harvest year (two years after establishment). Half of the subplots were sown with clover seeds with no coating and half with seeds coated with lime and inoculated with *Rhizobium*. A pure grass plot without red clover was included. Sown at establishment, a seed-rate of one hundred red clover seeds m^{-2} was sufficient to form a dense sward. Neither the coat treatment, nor reserving some of the sown seed for over-sowing on the existing sward surface, increased the clover content or the dry matter production in the red clover-grass mixture.

Keywords: clover content, lime coating, over-sowing, seed-rate, *Trifolium pratense*

Introduction

Red clover (*Trifolium pratense* L.) is the most important perennial forage legume in Finland, but its content in a grass mixture declines by the second harvest year. The red clover content also varies during the growing season. It is low in spring but can be too high in autumn. In Europe, white clover is commonly over-sown into grassland to improve sward quality (Tiley and Frame, 1988). This method requires special machinery and it has not been commonly used in Finland. In New Zealand, white clover seed has been lime-pelleted and pre-inoculated before over-sowing into an existing sward surface without special machinery (Jones and Thomas, 1965). The effect of seed-rate, split sowing and coating treatment of red clover seed on the clover content and dry matter production in perennial mixed swards was studied over a five-year period.

Materials and methods

Two similar field trials were conducted at Juva Research Station (60° 53′ N, 27° 53′ E) during 1999-2002 and 2001-2003 by MTT Agrifood Research Finland. A split plot design with four replications was used with red clover sowing strategy as a main plot and seed coat treatment as a subplot. In the main plots, 150 and 300 red clover seeds m^{-2} were down in different timing patterns during three years (all seeds sown to establish the sward, one third sown at each of three years and two thirds to establish the sward and one third before the second harvest year (two years after establishment)). Half of the subplots were sown with red clover seeds with no coating and half with seeds coated with lime and inoculated with *Rhizobium*. Red clover was sown in a mixture with timothy (*Phleum pratense* L., 2200 seeds m^{-2}) and meadow fescue (*Festuca pratensis* Huds., 300 seeds m^{-2}). A pure grass plot without red clover was included. The plots (1.5 m × 10 m) were established with spring barley as a nurse crop. The initial seedbed was ploughed and harrowed. In sowings after establishment, red clover was over-sown into the existing sward surface without cultivation in early spring after the snow had thawed.

According to the Finnish soil classification, the soil was fine sand moraine in the first trial and silty moraine in the second trial. The soil fertility figures were moderate. Soil organic matter content was in the range 3-6 % and pH ($CaCl_2$) averaged 6.4 in both trials. During the field trials, the mean temperature of the growing season was higher (except 2001) with July 2001 being exceptionally warm. Precipitation was lower than long-term averages, with late summer every year being very dry. The number of red clover plants was counted three times per growing season. The dry matter yield and its clover content were determined. Statistical analyses were performed by the SAS Mixed Procedure.

Results and discussion

The soil characteristics were favourable for red clover establishment and the coating treatment had no effect on the red clover plant number. Over-sowing into the existing sward did not increase red clover plant numbers. Although over-sowing was performed in early spring before the start of sward growth, there was not enough open space for the red clover seedlings to develop.

The red clover seed-rate at establishment clearly affected the clover plant number (Table 1). A seed-rate of one hundred red clover seeds m^{-2} was sufficient to form a dense sward. The results of the two trials were similar and are in agreement with Huokuna (1966), who recommended a similar red clover seed-rate in mineral soils, when seeds were sown at a depth of one cm.

Table 1. Effect of red clover seed-rate at establishment (1999) and over-sowing on the existing sward surface in the following springs (2000 and 2001) on red clover plant number over a three-year period.

Red clover seed-rate			Red clover plants, plant number m^{-2}									
Seed number m^{-2}			Autumn	Spring	Summer	Autumn	Spring	Summer	Autumn	Spring	Summer	Autumn
1999	2000	2001	1999	2000	2000	2000	2001	2001	2001	2002	2002	2002
50	50	50	24.3	15.9	17.9	17.3	12.6	15.4	11.0	10.9	11.3	9.6
100	0	50	40.6	36.6	29.3	26.3	23.6	22.0	15.4	14.5	13.5	13.6
150	0	0	46.1	35.8	28.0	26.3	21.4	20.1	16.3	13.3	15.5	13.0
100	100	100	41.5	30.1	29.6	25.9	20.0	21.9	14.3	13.3	14.6	13.6
200	0	100	55.6	44.3	35.4	29.3	27.5	24.1	17.4	19.8	18.6	17.4
300	0	0	75.8	46.8	36.3	33.0	30.4	25.5	19.3	21.9	21.1	17.5
			***	***	**	°	***	**	ns	**	**	*

Statistical significance of the difference between seed treatments: ns = not significant, ° = $P < 0.1$, * = $P < 0.05$, ** = $P < 0.01$ and *** = $P < 0.001$.

In the trial established in 1999, the year had the greatest effect on the total dry matter production ($P < 0.001$). The effect of red clover seed number at establishment was nearly significant ($P < 0.1$) at the second cut. In the trial established in 2001, increasing the red clover seed number at establishment significantly increased the total dry matter production at the second cut (Table 2).

In the trial established in 1999, only the year had a significant effect on the red clover content of the dry matter. Increasing the red clover seed number at establishment almost significantly ($P < 0.1$) increased the red clover content in the dry matter of the first cut (in the trial established in 1999 and significantly so ($P < 0.05$) in the trial established in 2001 (Table 2).

Table 2. Effect of red clover seed-rate at establishment (2001) and over-sowing on the existing sward surface in the following springs (2002 and 2003) on dry matter production and red clover content in 2002 and 2003.

Red clover seed-rate			Total dry matter yield (kg ha^{-1})			Clover content in dry matter (%)	
Seed number m^{-2}			Cut 1	Cut 2	Sum	Cut 1	Cut 2
2001	2002	2003	2002	2002	2002-2003	2002	2002
50	50	50	2940	2430		8.4	63.3
100	0	50	2380	2480		13.5	66.7
150	0	0	2400	2650		11.9	67.3
100	100	100	2480	2810		9.2	70.9
200	0	100	2530	2970		17.0	74.0
300	0	0	2600	3100		26.1	70.9
			2003	2003		2003	2003
50	50	50	2810	2510	10680	51.1	50.2
100	0	50	2990	2670	10510	63.3	58.0
150	0	0	3130	2750	10930	57.8	62.4
100	100	100	3280	2850	11420	59.4	61.6
200	0	100	3470	2910	11880	65.9	68.0
300	0	0	3420	3370	12490	69.2	61.4
			ns	**	*	**	°

Statistical significance of the difference between seed treatments: ns = not significant, ° = $P < 0.1$, * = $P < 0.05$, ** = $P < 0.01$ and *** = $P < 0.001$.

Conclusions

A seed-rate of one hundred red clover seeds m^{-2} at establishment was sufficient to form a dense sward. Neither the coat treatment nor splitting the application of seed between sowing and over-sowing into the existing sward surface increased the red clover content or dry matter production in the red clover-grass mixture.

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Timothy and tall fescue mixtures increase forage yield and improve yield quality in comparison with pure timothy in Finland

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Abstract

Performance of tall fescue (*Festuca arundinacea* Schreb.) (Ttf) and red clover (*Trifolium pratense* L.) (Trc) with timothy (*Phleum pratense* L.) in comparison with that of pure timothy (T) was studied in one to four year old stands in Jokioinen, Finland, in 2002 and 2003. The total DM yield ranged from 4950 kg ha^{-1} to 10,500 kg ha^{-1} depending on mixture, age of stand and year. The yield of Ttf was higher than that of T and Trc in both years at all ages of stand. The difference between yields of T and Ttf was statistically significant in swards in the third and fourth year as well as in the second year, in 2002. The yield increase in favour of Ttf was based on significantly higher regrowth yields of Ttf than of T or Trc. The yield of Ttf ranged from 7670 to 10,500 kg ha^{-1} and the lowest yield was in the first year sward.

Differences in dry matter digestibility were small at the first cut. However, at the second cut digestibility of Ttf was significantly higher than that for T and Trc. Use of a tall fescue (cv. Retu) timothy mixture in comparison with pure timothy can increase both the yield and quality of sward in northern latitudes.

Keywords: digestibility, *Festuca arundinacea*, persistence

Introduction

Short-term leys, particularly when three years or younger, are characteristic of pasture production in Finland. Extending the duration of swards would be economically desirable. Studies of Nissinen and Hakkola (1995) showed, however, that extending the economical duration of sward was not feasible using current timothy and meadow fescue (*Festuca pratensis* Huds.) mixtures. Results for Finnish tall fescue *(Festuca arundinacea* Schreber) cultivar Retu, in comparison with meadow fescue cultivars, indicated that it might represent a possibility for extending the economical life span of Finnish swards (Niemeläinen *et al*., 2001).

This experiment was undertaken to study the performance of a timothy and tall fescue mixture in comparison with pure timothy and a timothy and red clover (*Trifolium pratense* L.) mixture.

Materials and methods

Three seed mixtures were studied: (T) pure timothy (cv. Tuukka), (Ttf) timothy with tall fescue (cv. Retu), and (Trc) timothy with red clover (cv. Betty). The stands were established in three successive years (1999-2001) at Jokioinen (60°49’ N, 23°30’ E), Finland. The experiment was arranged with six replicates as a split plot design with establishment year as the main plot and seed mixture as the sub-plot. Plot size was 1.5 m by 10 m. Sowing rates were: T timothy 20 kg ha^{-1}, Ttf timothy 15 kg ha^{-1} and tall fescue 10 kg ha^{-1}, Trc timothy and red clover 10 kg ha^{-1} and 5 kg ha $^{-1}$ respectively. The stands were sown into spring barley (*Hordeum vulgare* L.) and the entire barley crop was harvested in August. Soil at the experimental site was silt clay.

Nitrogen fertiliser was applied to T and Ttf at 100 kg ha^{-1} in spring and after the first cut, and to Trc at 60 kg ha^{-1} in spring and at 40 kg ha^{-1} after the first cut. The first cut was taken for T and Ttf when approximately one fifth of the timothy ears had fully emerged. The Trc mixture was harvested when the flower buds appeared in the main stem of red clover. The harvest date of first cut of T and Ttf was on 11.6.2002 and for Trc on 16.6.2002. All mixtures were cut a second time on August 19. In 2003 the harvest dates for the first cut were 24.6. for T and Ttf, 30.6. for Trc and 25.8. for the second cut for all mixtures. Dry matter was determined from a yield sample. Botanical analysis was carried out to determine the share of various sown species and weeds in the harvested yield. Quality analyses were carried out on samples from which weeds had been removed. Yields are represented as DM yield of sown species. Analyses of dry matter digestibility were carried out using the cellulose method. Results from 2002 and 2003 are presented in this paper. In 2002 the stands were one, two and three years of age, and in 2003 the age of stands was two, three and four years. The statistical analysis was carried out using SASPROC MIXED (Littell *et al*., 1996).

Results and discussion

Live ground cover in spring ranged from 63 % to 88 % in T, from 65 % to 91 % in Ttf and from 61 % to 85 % in Trc according to the age of stand and year. Ttf had the highest live ground cover percentage in spring except in the second year stand in 2003 (results not shown).

The total DM yield ranged from 4950 kg ha^{-1} to 10,500 kg ha^{-1} depending on mixture, age of stand and year (Table 1). The yield of Ttf was higher than that of T and Trc in both years at all age of stand. The difference between T and Ttf was statistically significant in third and fourth year swards as well as in the second year sward in 2002 (Table 1). The yield at the first cut ranged from 2390 to 3880 kg ha^{-1} in 2002 and from 2910 to 5900 kg ha^{-1} in 2003. Differences between the mixtures in the yield of the first cut were not statistically significant at same age of stand (data not shown). In the second cut yield the Ttf component was significantly higher that that of T and Trc in all cases except in the second year stand in 2003 (data not shown). However, the yield of Ttf decreased significantly from the second to third year sward in 2002 and from the third to the fourth year sward in 2003 (Table 1).

The sown species ranged from 71 % to 97 % in 1-3 year old stands. In the fourth year stands in 2003 the range was from 55 % to 89 %, but with Ttf it remained high for both cuts (84 and 89 %). The share of timothy in the yield of the first cut of the Ttf mixture ranged from 90 % to 42 %, decreasing gradually from one year old sward to four year old sward. In yield of the second cut the share of timothy ranged from 57 % to 12 % in Ttf. In Trc the share of timothy ranged from 85 % to 100 % in the first cut and from 51 % to 91 % in the second cut (data not shown).

Table 1. Dry matter yield (kg ha^{-1}) of timothy (T), timothy and tall fescue mixture (Ttf) and timothy and red clover mixture (Trc) in 2002 and 2003 in Jokioinen, Finland according to the age of stand.

		Age of stand			
Prod. Year	Mixture	1	2	3	4
2002	T	6970 ab, B	8030 b, A	7070 b, AB	-
2002	Ttf	7670 a, B	9790 a, A	8390 a, B	-
2002	Trc	6450 b, B	7600 b, A	5440 c, B	-
2003	T	-	8880 a, A	8000 b, A	5600 b, B
2003	Ttf	-	9260 a, AB	10500 a, A	8380 a, B
2003	Trc	-	7510 b, A	6470 c, A	4950 b, B

Means in the same column in the same year with the same lowercase letter do not differ significantly at $P = 0.05$.
Means on the same row with the same uppercase letter do not differ significantly at $P = 0.05$.

The digestibility of dry matter was high for the yield from the first cut (data from 2002 only) and differences between the mixtures were small (Table 2). However, for the yield of the second cut the digestibility of the Ttf mixture was significantly higher than that of T and Trc mixtures (Table 2). This was most likely due to the high proportion of tall fescue contributing to the yield of the regrowth. Under Finnish conditions tall fescue produces few or no stems after the first cut. Timothy can, however, produce stems after the first cut, particularly if the first cut occurs early in the season.

Table 2. Digestibility of dry matter (g kg^{-1} DM) of timothy (T), timothy and tall fescue mixture (Ttf) and timothy and red clover mixture (Trc) in 2002 at Jokioinen, Finland.

		Age of stand in year 2002		
Year 2002	Mixture	1	2	3
Cut 1 (11.6.)*	T	737 a	717 a	725 a
Cut 1 (11.6.)*	Ttf	739 a	717 a	718 a
Cut 1 (16.6.)**	Trc	722 b	713 a	716 a
Cut 2 (19.8.)	T	686 b	682 b	686 b
Cut 2 (19.8.)	Ttf	705 a	708 a	721 a
Cut 2 (19.8.)	Trc	667 c	669 b	675 b

Means in the same column in the same cut with the same letter do not differ significantly at $P = 0.05$.
* Approximately one fifth of the timothy ears had fully emerged.
** Flower buds appeared to the main stem of red clover.

These results indicate that using a mixture of timothy and tall fescue instead of pure timothy could increase both sward yield and yield quality at northern latitudes.

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Grassland renovation in Northwest Europe: current practices and main agronomic and environmental questions

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Abstract

During two international workshops on grassland cultivation and grass-arable crop rotations, central agronomic and environmental consequences relating to the ploughing of grassland were examined and discussed. Some initial questions could be answered yet; other questions still required significant scientific efforts. There was general agreement that experimental data, experiences and knowledge from different European countries needed to be synthesized in order to derive information that is relevant to different environments and farming practices. The present paper gives a brief overview on activities and first results of the EGF Working Group on Grassland Resowing and Grass-arable Rotations.

Keywords: grassland renovation, nitrogen, soils, crop rotation, leaching

Introduction

Ploughing and reseeding of grassland has become increasingly questioned with regard to environmental aspects such as nutrient loss and soil fertility. Scientists from seven Northwest European countries tried to identify present gaps of knowledge, and to work out solutions for sustainable forage production during a workshop on grassland cultivation held in Wageningen in April 2002 (Conijn *et al*., 2002). The term 'grassland cultivation' is used here as a common term for ploughing + reseeding of permanent grassland as well as for short-term grassland (leys) in rotation with arable crops. During the 19th EGF General Meeting in La Rochelle, France, a Working Group on Grassland Resowing and Grass-arable Rotations was officially launched. In February 2003, the Working Group met again in Kiel, Germany (Conijn *et al*., 2004). While the first workshop in Wageningen focused mainly on the relevance and reasons for grassland cultivation in different Northwest European countries, the second meeting in Kiel placed emphasis on agronomic and environmental consequences, with particular interest in N and C cycles, soil processes and crop performance.

Fields of work

The basic working hypothesis of the Working Group is illustrated schematically in figure 1. It is assumed that grassland productivity declines with increasing age of the sward, but increases during the first production years after cultivation. However, a significant yield loss is likely to occur in the year of grassland renewal. N losses are also likely to increase due to increased mineralisation after ploughing. Both magnitude and time scale of these effects depend largely on soil type, climatic conditions and cropping practices.
There exist a number of questions related to this hypothesis. In the following, general information gathered from the two workshops is summarized, and remaining questions which require further scientific efforts are formulated. Other specific topics that have been discussed and evaluated during the workshops are addressed in the respective publications.

Hypothesis: Grassland productivity decreases over time

Empirical data:

Apart from Danish cutting experiments, data from most Northwest European countries do not support this assumption. However, the time scale is an important factor in this context. In the case of very old grassland, which has not been cultivated for decades, productivity might be at a stable level. Different cropping practices hamper the comparison of experimental results. In Denmark, where grass-arable crop rotations are common, an ‘old’ sward is a sward of 3-5 years age. However, in Northern Germany, 50 % of the grassland is older than 30 years under climatic and soil conditions similar to Denmark.

Remaining questions:

- To what extent are grassland yields affected by climatic and soil conditions over time? How is this affected by: sward composition (pure grass, grass / clover, clover content, and varieties), management practices (cutting / grazing, stocking rate on pasture and fertilisation) and measures that maintain sward productivity (weed control, overseeding and cleaning cuts)?
- Which parameter (DM yield, energy / protein yield, herbage quality, animal intake, or animal production) is most important to the farmer and which should be used to describe sward productivity?

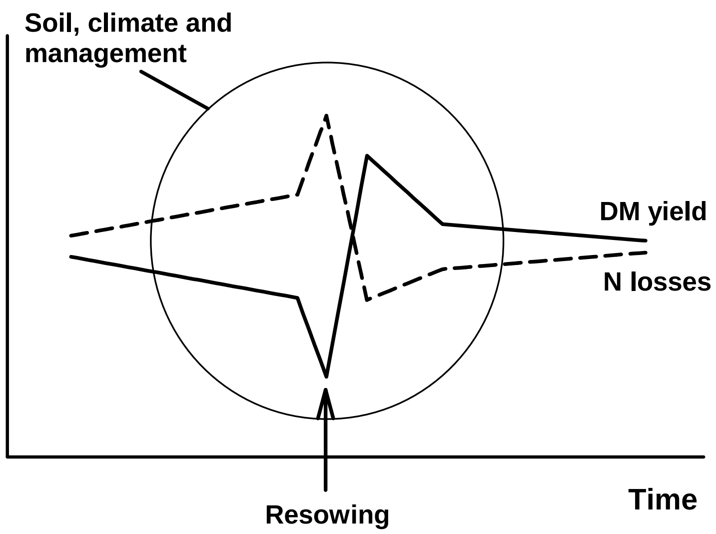

Figure 1. Working hypothesis: assumed effects of grassland renovation on DM yield and N losses.

Hypothesis: Grassland productivity increases after cultivation

Empirical data:

Even though many reasons for higher yields of newly established swards have been formulated (e.g., the use of new varieties, a higher feeding value and lower grazing losses), empirical data from different countries shows that the effect may be negligible. Again, an exception was found in Danish cutting experiments, where young swards exhibited significant increases in herbage production. Herbage quality was found higher, lower or similar after resowing compared to ‘old’ swards. Experiments from other countries supported a general trend towards a declining yield response to N fertiliser during the first years after cultivation.

Remaining questions:

- As for the first hypothesis, effects of soil and climatic conditions, sward composition and management practices need to be quantified. This holds true for both the young sward and the old sward which serves as ‘reference’ in the comparison.

Hypothesis: N losses increase after ploughing of grassland swards

Empirical data:

Concerning permanent grassland that is ploughed and reseeded in spring, there is no experimental evidence that cultivation leads necessarily to significantly increased nitrate leaching losses. First, the amount of N mineralised after ploughing was estimated between 120 and 400 kg N per hectare during the first year. This is not only due to site-specific and agronomic factors, but also to different methods of estimating N mineralisation. Second, newly established grassland accumulates a considerable proportion of mineralised N in herbage, stubble, roots and litter. However, small changes in soil organic N can have significant effects on N losses, and this requires further investigation. Concerning grass-arable crop rotations, experiments from Denmark and The Netherlands showed that nitrate leaching losses were higher during the arable phase than under grassland.

There is general evidence that grassland cultivation may significantly increase gaseous losses of N compounds such as N_2O or NH_3, and this aspect should be considered as well.

Remaining questions:

- To what extent does grassland management (cutting / grazing, fertilisation, sward composition and N_2 fixation) and abiotic conditions (soils, weather) affect changes in soil organic compounds (organic matter, N and C), mineralisation, and N losses after ploughing?
- Do N losses increase with increasing sward age?
- To what extent does the ratio between denitrification and leaching change?
- How can the methods of estimating mineralisation be harmonized?

Outlook

During the second meeting in Kiel, three specific groups were appointed. These groups will investigate the effects of grassland cultivation on

I. N and C cycles and soil quality dynamics (Vertès *et al*., 2004)

II. Crop / animal performance (Søegaard *et al*., 2004)

III. Farm-gate N balances (Kristensen *et al*., 2004).

The groups will continue working on the respective topics in order to synthesize the data from different Northwest European countries, provide further insight into the relevant processes and develop model approaches that may help to disentangle the environmental and experimental 'noise' which hampers the comparison of results from different countries. There was general agreement in the Working Group that more on-farm research was needed, and that the entire production chain from grassland DM yield to animal production required particular attention. A holistic approach that accounted for all agronomic, environmental and economic effects was expected to be much more meaningful than focusing on one or two aspects only.

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Effects of grassland renovation on crop and animal performance

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Abstract

Evidence for the expected increases in crop and animal performance following sward renovation of permanent grassland, and in the early grass phase of grass-arable rotations, is reviewed. There is considerable variation in actual yield increases obtained. Grassland management (e.g., fertiliser inputs, irrigation, utilisation methods, and botanical composition) influence the changes in herbage yield and animal performance over successive years, with implications for length of the grass-phase in the grass-arable cropping system. Opportunities for maintaining yield levels are less well documented and this aspect warrants further research.

Keywords: renovation, grass-arable, permanent grassland, yield-increase

Introduction

A substantial reason for grassland renovation is an expected improved crop and animal performance. Intensively used grasslands exist within grass-arable systems and in permanent grassland systems. The grass-arable rotation system, with a grass phase of 2-4 years duration, has its origin in the positive residual effects of the grass on the following arable crops, in terms of increased soil fertility and reduced crop diseases and weeds. These benefits are especially important in organic and other low-input systems, and for some climatic regions this grass-arable system is considered essential for adequate crop yield levels to be maintained. Furthermore, there is an assumption that higher yields will be obtained in the grass phase, when compared with longer term grasslands, and the net gain of the whole crop rotation is assumed to be higher than from crops in monoculture. Unlike grass-arable rotation systems, sward renovation in permanent grassland is for the sole objective of grassland improvement. Sward renovation usually involves complete reseeding after destruction and cultivation, but may also take a partial form, e.g., oversowing an existing sward with minimal disturbance. In all cases there is an assumption that net gains in herbage production and / or quality will offset the cultivation costs, short-term production loss etc. during establishment. Before the widespread availability of artificial fertilisers, ploughing and reseeding of old swards was advocated as a means of releasing accumulated fertility to enable increased production from new swards of improved cultivars. The aim of this paper is to review, if the expected yield increase takes place in the two grassland systems, respectively, and their implications for animal performance.

Grass-arable crop rotation

In most cases there is a reported decrease in annual dry matter (DM) yield over succeeding years, with the highest yield in the first harvest year, and often the decrease from the first to the second year is higher than between the other years. However, there is a great variation in the results reported, ranging from no decrease from first to third harvest year (e.g., Baars, 2002) to a decrease of 33 % (Gregersen, 1980). Some reports, however, show a lower yield in the first harvest year than in the second year. The time of establishment (spring, autumn) and also between-years differences may explain some of the different findings.

The decrease in yield over successive years can be attributed to many factors. In a nine-site experiment, irrigation, soil type and fertiliser N significantly influenced the yield decrease, whereas inclusion of clover in the sward had no effect (Gregersen, 1980). The yield decrease from year 1 to year 3 was 28 % and 37 % under irrigated and unirrigated conditions, respectively, and in pure grass the yield decrease at different level of fertiliser N (150, 300 and 450 kg N ha^{-1}) was 10, 17 and 21 %, respectively (Gregersen, 1980). Even though new cultivars with higher persistence have been bred, and a lower yield decrease could be expected, there still seems to be a yield decrease with these cultivars (Wilkins *et al.*, 2000). In some areas (e.g., cold climates) climate can be the main reason for low persistence, with winter damage being considered the main reason for yield decrease (Lien *et al.*, 2003).

The grass-arable system is characterized by a build-up of soil-N during the grass-phase, especially under grazing, and a decrease of soil-N during the arable phase. Although a greater yield-response to N at the beginning of the grass-phase might be expected, this has not been confirmed unambiguously. Nevens and Reheul (2003) found grass swards with a low clover content gave the highest response in the second year, whereas for grass-clover with a high clover content the highest response was in the first year (Frame and Boyd, 1984), and Schils (2002) found in some cases there was a constant response over the years and in other cases a decrease over the years. The management could have a contributory effect for the variable results, as Baars (2002) found that P and K level should be sufficient for a yield increase.

Permanent grassland

Early experiments and observations showed increased livestock production and grazing days following renovation, except where permanent swards contained high proportions of *Lolium perenne* and *Trifolium repens* (Williams and Davies, 1954). Subsequent research (reviewed by Dibb and Haggar, 1979) showed permanent swards could also respond to high inputs of N, highlighting the role of soil nutrient status, fertilisers and the cutting / grazing management, noting that reseeded grassland was frequently more productive as a result of nutrient inputs and utilisation, rather than age or botanical composition. Reseeding of permanent swards might not always result in net benefits. Permanent and reseeded grassland were compared in northern England, and increased productivity from sown swards under low N inputs was attributed to more clovers in the new sward, whereas under high N inputs (> 250 kg ha^{-1}) the DM production differences between sown and permanent swards were negligible, and *L. perenne* in the permanent sward increased in response to fertiliser inputs (Mudd, 1971).

The results of multi-site comparisons of permanent and sown swards under identical management showed that the amount of additional DM production obtained from sown swards depended not only on the level of fertiliser N input, but also on the stage in the reseeding cycle and on the botanical composition of the permanent sward and other site-specific factors (Hopkins *et al*., 1990; 1992). The following findings were of note:

Reseeded grassland had, on average, 40 % more DM yield ha^{-1} than permanent grassland in the year following reseeding. Differences in DM yield between the sward types were much reduced in subsequent years except under high inputs N (e.g., 450 kg ha^{-1}) and where *T. repens* was included in nil-N reseeds. Under 4-weekly harvesting, mean N response rate was 15 kg DM kg^{-1} N for permanent swards and 19 kg DM kg^{-1} N for *L. perenne* reseeded swards. In addition to DM yield there may be higher forage quality from reseeded grassland, improved ensilability and seasonal distribution of production, e.g., under 4-weekly harvesting, mean DOM values were 0.66-0.70 for permanent swards and 0.70-0.72 for *L. perenne* reseeded swards.

Animal performance

Productivity of permanent grassland and arable grassland under grazing is related to the herd and grassland management adopted, as well as the botanical composition and sward age. In addition, considerations of animal performance need to incorporate a broader view of the interactions with N losses, particularly leaching. Young stocks have a low N efficiency (about 10-15 %), compared with high yielding cows (possibly 25-30 %). The potential mobilization of N from the soil bulk is one of the main differences between arable and permanent grassland; this may sustain a short term higher DM yield, but also improve forage quality and thus provide opportunities for reduction in concentrate use (Bussink *et al*., 2002). Fertilisation level also affects the form of N in herbage, and N utilisation by ruminants and the relationships between sward type, species composition (which in turn may affect proportions of protein and water soluble carbohydrate), fertiliser use and stocking density have implications not only for animal production, but need to be considered when comparing the performance of animals fed on permanent or grass-arable areas.

Conclusions

For the time being, the information in the literature is scarce in terms of long-term effects on forage yield and quality stability of grassland renovation. Animal performance is closely related to the forage quality obtained and animals may be an interface between N utilisation by plants and N losses on grassland areas.

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Effects of grassland cultivation on N and C cycles and soil quality dynamics

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Abstract

Recent research on grassland cultivation in ley-arable rotations was reviewed in an EGF Working Group. This paper draws on that report and summarises the effects of ploughing grassland on C and N cycles and the interactions of soil organic matter with soil quality.

Keywords: grassland cultivation, soil quality, environmental impacts, nitrogen

Introduction

The cultivation of permanent pasture and re-sowing to grass leys has long been recognized as a means of exploiting the accumulated biological, chemical and physical fertility of the soil. However, the consequences of grassland cultivation are now also becoming increasingly important because of their environmental impacts. The recent reports of the EGF working group on grass-arable rotations reviewed and discussed those components (Conijn *et al*., 2002). This paper reviews the effects of grassland renovation on C and N cycles and soil quality.

Soil organic matter (SOM) and carbon cycling

SOM is vital for several functions, e.g., plant nutrition, structural stability enhancing rooting and water use, filtering effects influencing water and air quality, microbiological processes and biodiversity. Long-term SOM accumulation under grassland, especially grazed grassland, is well understood (Johnston, 1986; Conijn *et al*., 2002). However, the information on short term C and N storage (Whitehead *et al*., 1990; Velthof and Oemena, 2001) and the quality of this 'new' SOM, is rather scarce (Conijn *et al*., 2004). In permanent grasslands, SOM accumulation is often due to physico-chemical limitations on mineralisation. A high proportion of organic inputs is derived from roots, and grass roots are more resistant to degradation than roots of annual crops because of higher contents of lignin and phenolic compounds. Grass roots are also well protected from degradation within the undisturbed soil matrix, where high microbial biomass activity promotes aggregation and soil structural stability (Six *et al*., 2002). The SOM accumulation in ley-arable soils is less than in permanent grasslands, but greater than in continuous arable systems. It depends on the length of the grassland period, N inputs, type of crop and soil cultivation (Recous *et al*., 1997; Velthof and Oemena, 2001). Tillage of grassland increases the rate of breakdown of litter and SOM by disrupting aggregates and increasing soil aeration: high C losses have been recorded (up to 2.6 t C ha^{-1}) during 3 months after cultivation, i.e., twice the emission from the untilled soils (Eriksen and Jensen, 2001). Balesdent *et al.* (2002, in Expertise INRA) noted that if carbon loss is greatest just after ploughing (mean value 1 t C ha^{-1} y^{-1} released), it is still important after 20 years. However, when arable land is returned to permanent grassland, net C accumulation was only about 0.5 t C ha^{-1} y^{-1}. Carbon sequestration rate depends on sward age, and half the C accumulation potential is reached after about 6 years (range 4-11 years).

Nitrogen mineralisation

Cultivation of grassland increases the risk of nutrient emissions. Recent work has quantified N and C mineralisation, modelled the mineralisation kinetics after grassland destruction and explained the determining factors (Conijn *et al.*, 2002). Large variability in N mineralisation has been observed, varying with site, measurement methods, management and also vegetation (e.g., grass / clover vs. pure grass) and previous fertilisation. Some common features are a high N mineralisation (< 100 to 400 kg ha^{-1}) occurring during the 6 months following grass destruction. In grass-arable systems, the soil N supply of the cultivated grassland often exceeds the N uptake of the following crop (Nevens *et al.*, in Conijn *et al*., 2002). There are two phases: a short-term one, with high potential rate of mineralisation (1-2.5 kg N ha^{-1} d^{-1}) for 5-8 months, then a longer phase with rates equal or near to 'basal' soil mineralisation rates (Vertès *et al*., in Conijn *et al*., 2002). Between 3 and 10 years, grassland age is not a critical factor affecting mineralisation rates, but less N mineralisation occurs after cultivation of cut grass than after grazed grass. Incubation studies showed that N mineralisation of fresh plant residues accounted for only 20-30 % of total mineralisation, demonstrating the quantitative and qualitative importance of SOM accumulated in grassland. Comparisons between different managements must be made at a system scale, considering all the crops involved in a rotation, to test the most efficient way to benefit from nutrient release (economy on N fertilisers), and to reduce environmental risks by avoiding pollution swapping.

Soil quality as affected by ley-arable rotations

Physical properties, i.e., rooting capacity, water holding capacity, bearing capacity and susceptibility to soil compaction are linked to SOM characteristics. The effects of grassland cultivation on these physical components are variable, usually difficult to quantify and vary with soil type. For example, on peat soils in the Netherlands, some physical qualities (such as soil aggregate stability and bearing capacity) are generally negatively affected by grassland renovation (Schils *et al*., in Conijn *et al*., 2002). Rooting capacity is often improved in new grassland compared with old swards. Overall, renovation of permanent grassland has positive effects on the soil quality of sandy and clay soils, but a negative effect on peat soils. Treading or scorching damage causes bare patches, resulting in infestation by annual weeds or resistant species (e.g., *Elymus repens)*, and in soil compaction. A better understanding of the capacity of soil to resist compaction, or to recover previous porosity and associated processes would help to prevent soil and grassland degradation.

Biological activity, which is a key factor influencing the changes in soil physical properties, is also affected by soil cultivation. Lamandé *et al*. (2003) observed differences in the abundance and structure of earthworm populations in a 12-year-old, vs. a 3-year-old pasture (in short rotation with maize for 20 years), with higher effective soil porosity and better water circulation in the ley-arable rotation. Soil management affects the microbial community (Hatch *et al*., 2000), with large differences in functional diversity between grassland and arable crops (Garland and Mills, 1991) and with a decrease in microbial diversity after grassland cultivation. Moreover, some indirect positive effects of grassland cultivation on following crops, such as better resistance to fungal diseases (Eriksen and Jensen, 2001) may be linked partly to soil structural modifications.

Gaps in the knowledge and conclusion

Theoretical models are currently unable to explain fully the integration of 'new' OM in the SOM pool and the decay of the 'old' OM. The different factors associated with this are important, not only when OM accumulates, but also when there are changes, e.g., following cultivation. Theoretical compartments are needed to describe measurable SOM fractions.

Although significant results have been obtained from SOM fractionation methods, there is no general agreement on methodology. Finally, most SOM models are additive and little is known about the interactions between these compartments under field conditions.
Turn-over of roots under grassland is poorly understood, in terms of both rooting morphology and architecture. The location of 'new' SOM can affect C and N dynamics, and structural stability.
There are some methodological problems (which cannot be fully reproduced in laboratory tests) e.g., how far can results of soil incubations be used to understand field processes? Moreover, the role of living roots in determining i) N uptake and competition with microbial N immobilization, ii) root exudation, which is likely to interact with other OM substrates for microbial activity and iii) extension of the rhizosphere and interaction with the soil surface litter layer, cannot be fully reproduced in laboratory tests.
Biological activity (microbes and fauna) performs functions that not only influence C and N fluxes, OM transformations, and nitrification and denitrification potentials, but also explains the status and fate of mineral N. As all these components depend partly on farming practices (e.g., C inputs from cattle excreta and manures), the accuracy of C budgets needs to be improved to accommodate the requirements of environmental policies.
One of the challenges now is to develop a widely applicable scheme with measures to maintain or increase soil quality and decrease nutrient losses from grass-arable rotations under different conditions, using the ideas and results of studies in different countries. One requirement should be to optimize the length of the grass and arable period in a rotation, according to production needs and environmental considerations.

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C and N losses in sandy soils of NW Germany after conversion of grassland

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Abstract

Vast areas of NW Germany are covered by sandy soils with historically shallow groundwater. Under traditional grassland managements, these areas once accumulated huge stocks of organic matter (OM). Groundwater tables were lowered during 1970s and 80s when grassland was converted into arable land. This seems to be happening again due to the declining requirement for grass production in this area. The subsequent mineralisation of N caused problems with the leaching of nitrate, especially in groundwater catchment areas used for drinking water production. We studied a large water protection area (Fuhrberg fields, 308 km^2) focusing on how to predict the new steady state levels of C_{org} and N_{org} under arable conditions, and on the potential amounts of C and N to be released. Chronological sequences, including several hundreds of sites with different histories, revealed that it would take about 60 to 80 years to establish a new steady state in these sandy soils. For arable soils, the best indicator to predict the potential of N release was the bulk soil C to N ratio, and this is currently being tested for standing grassland.

Introduction, sites and methods

Historically, a large proportion of current NW German arable soils were originally used as grassland. They were mostly found under relatively moist conditions, which created huge stocks of organic C and N. Many sites were ploughed up during the last three decades of the last century after lowering the groundwater table by agricultural drainage, deepening of rivers, and by recovery of water by waterworks. Net release of N occurred as a consequence of the decline of the OM stocks under the subsequent arable use and this led to contamination problems in the study area with nitrate (seepage water) and sulphate (well waters) (Duijnisveld *et al*., 1989; Strebel *et al*., 1988, 1989; Frind *et al*., 1991). In the first few years after conversion the N losses amounted to several tons of N per hectare. However, they were assumed to be of minor importance thereafter (Strebel *et al*., 1988). Recent work has shown that the effects will persist for a much longer period and that the history of many sites is more complex than just being 'grassland' (Springob *et al*. 2001, Springob and Kirchmann, 2002, 2003). The focus of those earlier studies was the current arable land and its' potential for release of C and N. The studies used data from old arable land as the basic reference point and how this related to the OM stocks in the historical grassland. Here, the same problem is seen from the perspective of standing grassland, and information is collected on how to quantify its potential for release of C and N a priori, i.e., before being ploughed up. Such a decision support system is becoming increasingly necessary since there is, once again, a strong tendency towards conversion. Modern regulations also exist that enable authorities to prohibit conversion in water protection areas, and these are linked to financial compensation. In this context, the main aims of this study are:

1. to identify long-term steady state levels of organic matter in arable soils
2. to derive chrono-sequences of former grassland soils approaching these levels
3. to collect information on C_{org} and N_{org} stocks in the remaining, recent grassland
4. to estimate the N release potential before ploughing up the grassland.

The main study area was Fuhrberg fields which is an official groundwater protection area of 308 km^2 north of Hannover and typical of large parts of the sandy NW German plain. Detailed topographical maps (including land-use) are available dating back as far as 1780 ('Kurhannoversche Landesaufnahme' NLFB, 2000). Further maps (all digitised) exist for the years around 1901, 1950, 1962, 1972, 1982, 1991 and 1995. The latest survey (taken as the 'recent situation') was taken in 2000. The maps were used to attribute 'years under cultivation' to each site. Soil properties (0-30 cm) were measured according to standard laboratory procedures using mixed samples from fields and, for special questions, samples were taken from smaller areas with more distinctive properties. N release was determined in aerobic incubation experiments at 35 °C over 250 days. The resulting cumulative curves were spliced into N released from fresh OM and from non-fresh OM – the whole remaining (daily rates are used here, referred to as N_{slow} rates). Organic matter is C_{org} times 1.72 (for more information see Springob *et al.*, 2001, and Springob and Kirchmann, 2002, 2003).

Selected results and discussion

Assuming constancy of conditions, the chronological sequence of figure 1 suggests that it will take about 60 to 80 years before the lower C levels of the arable soils of today would be reached by former grassland soils. The reference levels are relatively high for this class of sandy soils and this is because of the presence of stable (refractory) OM inherited from centuries of cultivation. This is a special feature of NW German sands (Springob and Kirchmann, 2002). If the grasslands do not have such a history then they may approach a lower C level at steady state. Therefore, figure 1 represents the minimum probable losses of soil OM and also represents a 'best-case' scenario from the viewpoint of water protection. It is clear that there is still much OM left to be mineralised, even after decades.

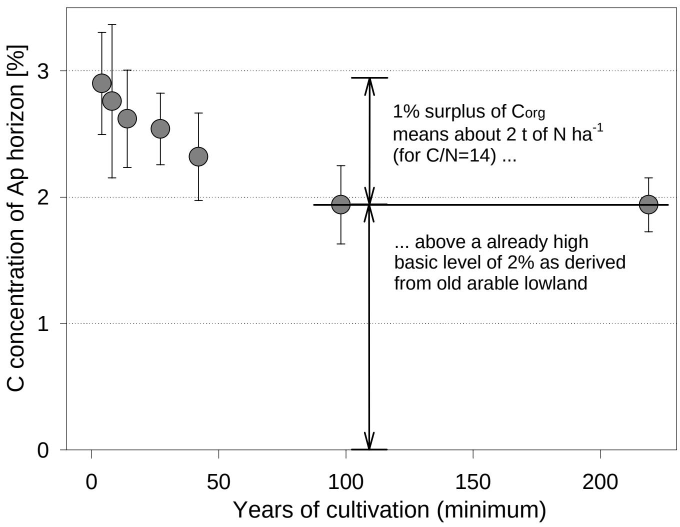

Figure 1. Average C contents of Ap horizons of former grassland and of old arable land (lowlands, from Springob *et al.*, 2001). Bars are 95 % confidence intervals of means.

In terms of N, the reference level 'old arable land' of figure 1 was equal to about 4.6 t N ha^{-1} (Ap = 28.5 cm). A recent survey in standing grassland (46 sites) yielded total N stocks ranging from 4 to 14 t ha^{-1} in the upper 30 cm, with a mean of 6.9 t ha^{-1} (extremely moist sites excluded), thus providing a minimum average potential of 2.3 t N ha^{-1} to be released after conversion.

In a separate study, in arable soils selected for a very wide range of C to N ratio, we showed that the N_{slow} rates (per gram of OM), waiting for N release from non-fresh OM, were closely correlated with C:N (Figure 2). The correlation with N_{tot} was much weaker (not shown). The bulk soil C to N ratio, seemed to be a promising indicator of the N releasing potential of sandy soils. However, it is still unclear whether this also holds true for soil material obtained from recent, standing grassland. Further investigation to resolve this question is under way.

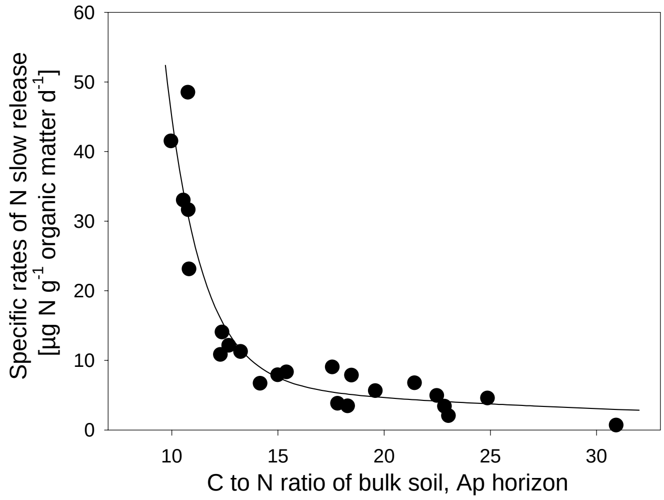

Figure 2. Relationship between the specific rates of N release from non-fresh soil organic matter and bulk soil C to N ratios (OM instead of dry soil as a basis) for 24 sandy sites from the North German plain (lowlands and uplands, from Springob and Kirchmann, 2003).

Conclusions

Stocks of organic N and C may still be declining decades after the conversion of grassland into arable land. The amount of N released is an important source of groundwater contamination. The ‘ploughing up’ of grassland remains should largely be avoided in groundwater protection areas although the potential for N release seems not to be as large as that of the historical, very moist grassland (Strebel *et al.*, 1988). However, some tons of N per hectare can still be released. The risk for a specific site could be measured on a total OM (or total N) basis, and the figure derived complemented with a quality indicator resulting from the bulk soil C to N ratio. Work on the last point is in progress. It must be borne in mind that these results are only valid for sandy soils which account for 95 % of the grassland in NW Germany. The exclusive focus on such soil types was probably the main reason that relationships described in this paper were so close.

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Reducing fertiliser N use by application of ley-arable rotations

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Abstract

On farm level as well as on soil level, the surplus in the N balance of Flemish dairy farms was reduced substantially during the past decade. This is good news considering the important policy focus on reduction of various N losses from agriculture to the environment. Still, more progress can be made: to come closer to a theoretically attainable N use efficiency of 70 % on soil level, the N-input to the soil would have to decrease by another 90 kg ha^{-1} (assuming an unchanged N-output). The most obvious track to save on N-input is the further reduction of fertiliser-N use. In a 35-year field trial, we investigated how much fertiliser-N could be saved in a three-year ley / three-year arable rotation relative to a system of permanent grassland and silage maize monoculture. Subsequently we applied the results on the 'average Flemish dairy farm', based on data from our national Farm Accountancy Data Network. We conclude that applying the ley / arable system could result in a saving of ± 50 kg mineral fertiliser-N per ha of silage maize. Applying the system on half of the Flemish maize land would save more than 4 million kg of fertiliser-N, while yields would be as high as before.

Keywords: fertiliser-N use, grassland, ley / arable rotation, N use efficiency, silage maize

Introduction

It is well known from literature that on dairy farms, the efficiency of N use can be tackled most effectively at the soil-plant level. On Flemish dairy farms, this soil-plant N use efficiency increased significantly during the past decade, mainly owing to a decrease in fertiliser-N use. Nevertheless, the attained N use efficiency of about 58 % (soil – plant level) in 2000 is still well below a technically feasible target of at least 70 %. So more progress can be made and the most obvious track to follow is a further reduction of fertiliser-N use (another 90 kg less N use ha^{-1} y^{-1} would be required to obtain the 70 % efficiency) (Nevens, 2003). A possibility to – at least partially – realise this objective is the (re-)introduction of ley/arable rotations: these successions of fertility build up under the short-term grasslands and fertility release during the following short term arable periods could be a serious option to cut fertiliser-N while maintaining high yield levels.

Materials and methods

In a long-term experiment (1966–2001) on a Flemish sandy loam soil, we compared a system of continuous grassland and continuous arable forage crops (mainly silage maize) with a three-year ley / three-year arable rotation system. We measured and compared the feed energy yields of the temporary and the permanent grasslands (both fertilised at an average rate of 300 kg N ha^{-1} y^{-1}). On the arable plots, we determined the forage crop dry matter yields and we calculated the economic optima of fertiliser-N use ('N_{opt}') based on response curves of yields to mineral N rates. More specific data on the experimental procedures and the results can be found in Nevens and Reheul (2001; 2002; 2003) and Nevens (2003).

Results and discussion

A first important result of the long-term rotation experiment was that the yields (expressed as feed energy) of the permanent grassland plots and the temporary grassland plots were comparable, at the same level of N-fertilisation (300 kg N ha^{-1} y^{-1}) (Nevens and Reheul, 2003).

Secondly, the average N_{opt} for silage maize on permanent arable land was 175 kg N ha^{-1} y^{-1}, on temporary arable it was 2, 139 and 154 kg N ha^{-1} y^{-1} in the first, second and third year following the three-year grassland, respectively. Thus, while attaining equal yields in both systems, during a three-year temporary arable land period 231 kg N (77 kg N ha^{-1} y^{-1}) could be saved compared to permanent arable land (Nevens and Reheul, 2002).

However, our experimental system only considered application of mineral N fertilisation and Flemish practice works different: slurry is applied and supplemented with mineral fertiliser-N. If we assume that on maize land, slurry is applied but limited to a maximum rate of 230 kg total N ha^{-1} y^{-1} at an N-use-efficiency of 60 % (Nevens and Reheul, 2004) this corresponds with 138 kg fertiliser-N ha^{-1} y^{-1}. As a result, the amount of fertiliser-N to be supplemented on ley/arable maize plots would be 0 (1^{st} year) + 1 (2^{nd} year) + 16 (3^{rd} year) = 17 kg N ha^{-1} (or 6 kg N ha^{-1} y^{-1}).
Thus, during the first season following the 3-year grassland, it would be advisable to go without slurry- and fertiliser-N. During the second season, slurry-N (230 kg N ha^{-1}) without additional fertiliser-N should do; during the third season small amounts of about 20 kg fertiliser-N are to be applied in addition to the slurry.

On the permanent maize plots the optimum amount of additional fertiliser-N in practice would be 175 (= N_{opt}) – 138 (efficient slurry-N) = 37 kg N ha^{-1} y^{-1}.

From these calculations, it can be concluded that growing maize in the ley / arable rotation could result in an average saving of 37 – 6 = 31 kg N ha^{-1} y^{-1}.

However, the actual average N-fertiliser use on the arable land of monitored Flemish dairy farms of the official Farm Accountancy Data Network (‘average’ farms usually apply slurry but few have ley-arable rotations) was 57 kg N ha^{-1}. Thus, even higher effective savings of N fertiliser input in maize of up to 50 kg ha^{-1} could be realised in practice when applying ley / arable rotations adequately. Applying 50 kg less N ha^{-1} on 25 % of the Flemish silage maize land would mean a yearly saving of more than 2 million kg of fertiliser-N.

The risk of excessive nitrate leaching following the cultivation of the three-year grassland can be reduced by using fodder beet or silage maize with undersown Italian ryegrass a catch crop following the grassland.

Conclusions

(Re-)introduction of ley / arable rotations (a typical but regrettably forgotten traditional Flemish agricultural practice) on dairy farms could be an effective tool for a significant further reduction of the use of external mineral N-input and an increase of the N use efficiency on Flemish dairy farms.

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Grass-legume mixtures in arable crop rotations

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Abstract

In the second year of the main utilisation of legume-grass mixtures, the average yield reached 12.172 t DM ha^{-1}, whereas the average total yield of forage (summing the year of sowing and one year of utilisation) reached the mean value of 20.598 t DM ha^{-1}. Grass mixtures with *Trifolium pratense* or / and *Trifolium repens* gave significantly higher yield than mixtures with *Medicago media*. In the studies carried out, the last (fourth) regrowth in the second year of sward utilisation was used as green manure. The total of 179 to 210 kg N ha^{-1} as well as 72 to 78 kg K ha^{-1}, 20-23 kg P ha^{-1}, 54-57 kg Ca ha^{-1}, 18-21 kg Mg ha^{-1} and 8-12 kg Na ha^{-1} were introduced into the soil together with the ploughed under biomass (sward + true roots, nodes at the base of shoots and stubble). The post-harvest productivity of grass-legume mixtures was also assessed based on the harvested yield of grain of winter wheat cv. *Kobra*. The average yield of 4.965 t of wheat grain per hectare was obtained, i.e., by 1.173 t ha^{-1} higher than in the case of the control object (maize as the previous crop).

Keywords: grass-legume mixtures, productivity, soil fertility, grain yield, winter wheat

Introduction

Concern for negative environmental impacts of excessive amounts of mineral N fertiliser used by farmers in the high-input agriculture have grown dramatically in the last two decades (Persson and Kirchmann, 1994). Leys, which have been for a long time the basis for many crop rotation systems in some European countries (Great Britain, Switzerland) could also be introduced in Central Europe. Grass / clover mixtures cultivated on arable soils are of economical importance for a farm because they result in saving considerable amounts of nitrogen fertilisers without negative effect on forage production, even increasing its nutritional quality. This kind of sward could be also used to decrease the negative environmental impacts of excessive amounts of mineral nitrogen N often found in arable soil, especially under forage production (Grzebisz *et al*., 2001; Kessler and Lehman, 1998; Wivstad *et al*., 1996).

The aims of the studies were: (i) to determine productivity of five grass-legume mixtures and (ii) to explore organic N of legumes or their mixtures with grasses as a potential N source for subsequently grown winter wheat.

Materials and methods

Three series of field experiments were conducted in the years 1996-2000 at the Research Center Brody of Agricultural University of Poznań. Experimental treatments comprised five grass-legume mixtures (Table 1) and maize treated as a control crop. The experimental design was a randomized, complete block with four replications. Plot size was 2.5 m wide and 10 m long. The soil was a sandy loam classified as *Albic Luvisols.* All cultivated crops were fertilised with: N - 120 kg ha^{-1} (4 x 30 kg), P - 35 kg ha^{-1} and K - 83 kg $ha^{-1.}$

In the second step, following forage production, the succession effect of grass-legume mixtures was estimated based on:

- quantities of N, P, K, Ca, Mg and Na introduced into the soil together with the biomass of plant residues left after harvest – roots, stolons and stubble and with the (last) fourth regrowth of the mixture sward.

- the grain yield of a subsequent crop of winter wheat (cv. Kobra), not fertilised with mineral nitrogen.

All data was analysed using a standard analysis of variance.

Table 1. Composition of seed legume / grass mixtures in experiments (% seed no.).

Species and cultivars	Mixture				
	M1	M2	M3	M4	M5
Trifolium pratense, cv.Ulka	50	50	20	-	-
Trifolium repens, cv. Romena	-	-	30	-	-
Medicago media, cv. Kometa	-	-	-	57	57
Lolium multiflorum, cv. Kroto	-	40	-	-	33
Lolium perenne, cv. Argona	-	-	20	-	-
Festulolium braunii, cv. Felopa	35	-	20	28	-
Dactylis glomerata, cv. Bara	-	10	-	-	-
Phleum pratense, cv. Obra	15	-	10	15	10

Results and discussion

Grass / legume mixtures were characterised by considerable yield-forming potentials, both in the year of sowing and in the year of full utilisation as evidenced by yields of 8.427 and 12.171 t DM ha^{-1}, respectively (Table 2).

Table 2. Yields of grass / legume mixtures, (mean of 1996-1999, t DM ha^{-1}).

Utilisation year	Mixtures					Mean
	M1	M2	M3	M4	M5	
Sowing year	8.064	8.166	9.384	8.164	8.360	8.427
Year of full utilisation	12.839	12.567	11.953	12.035	11.460	12.171
Mean	10.451	10.367	10.668	10.099	9.909	-

LSD $_{0,05}$ for utilisation year = 0.436; LSD $_{0,05}$ for mixture = 0.312; LSD $_{0,05}$ for utilisation year × mixture = 0.588.

In the year of sowing, the most productive combination was the M3 mixture composed of *Trifolium repens* and *T. pratense*. In the second year of utilisation, yields of the tested mixtures decreased in the following order M1 = M2 ≥ M4 = M3 ≥ M5. In the year of full sward utilisation, especially in the case of the sward composed of *Lolium multiflorum*, the specific yield compensation was observed, i.e., the higher yield harvested in the year of sowing, the lower was obtained in the year of full utilisation.

It is well known that grass-legume mixtures create very good conditions for successive crops. The main reason is a big amount of organic matter ploughed under. On average, about 195 kg N ha^{-1}, 22 kg P ha^{-1} and 75 kg K ha^{-1} were introduced into the soil together with considerable quantities of calcium, magnesium and sodium (Table 3).

In the studies, the fourth sward regrowth was treated as a specific kind of green manure. It constituted approximately 10 % of the annual biomass ploughed under. The ploughed under sward intensified the process of organic nitrogen mineralisation, thus creating good nutritional conditions for winter wheat. The mean yield of wheat grain followed grass-legume mixtures and without mineral nitrogen fertilisation reached 4.967 kg ha^{-1} (ranging over seasons from 3.943 to 6.058) and was 31 % higher than wheat grain yield followed maize. Yields of winter wheat were found to vary more in conditions when it was grown after grass-legume mixtures (Table 4).

Table 3. Macronutrients incorporated into soil with ploughed sward and roots of grass / legume mixtures (mean for 1997-1999).

Mixture	Mass of macronutrients (kg ha^{-1})					
	N	P	K	Ca	Mg	Na
1	184	20	72	57	21.2	8.3
2	179	23	73	54	21.1	9.0
3	199	23	74	57	20.2	9.0
4	204	21	78	56	18.0	9.4
5	210	22	75	54	19.0	11.7

Table 4. Influence of previous crop on grain yield of winter wheat (t ha^{-1}).

Year	Previous crop							Mean
	Grass-legume mixtures					Grass / legume	Maize	
	M1	M2	M3	M4	M5	(mean)		
1998	4.674	4.792	5.419	5.303	3.943	4.826	3.649	4.630
1999	6.058	5.400	5.117	6.050	5.050	5.535	3.950	5.271
2000	4.579	4.861	4.361	4.693	4.211	4.531	3.777	4.416
Mean	5.104	5.017	4.965	5.348	4.401	4.967	3.792	-

$LSD_{0.05}$ – years x previous crop = 0.607.

Conclusions

The significance of short-term grasslands is important not only from an economical but also from an environmental point of view. On the one hand, this type of arable land use deserves attention because of high productivity and the high nutritive value of fodder, especially for dairy farming. On the other hand, as it was found by performing these studies, legume-grass mixtures also meet the requirements expected from ‘ecological farming’. Legumes and grass-legume mixtures whose agronomical values have been recognized for centuries, may be recommended as the most ‘environmentally friendly’ farming system.

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Effects of defoliation regimes on yield and fodder quality in permanent grassland and short-term leys

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Abstract

Long-term field experiments with short-term leys and permanent swards were conducted from 1968 to 1990 on the south west coast (Særheim) and in the north of Norway (Svanhovd).
The experiments were subjected to three defoliation regimes. Results averaged over two years (1984, 1986) are reported, including: total DM yield, crude protein (CP), crude fibre (CF) and botanical composition. DM yields and CF content were lower at the northern than at the southwestern site. DM yields were similar, but CP contents were higher in the permanent swards compared with the leys. The defoliation regimes had no effects on yield levels, but affected fodder quality. Sheep-grazed swards had a higher content of CP and a lower content of CF than cut or cattle-grazed swards at Særheim, whereas CP was highest in the cut swards at Svanhovd, with no differences in CF content. Sheep-grazing on permanent swards resulted in increased amounts of *Lolium perenne* in the southwest, while the cut swards were dominated by the unsown *Agrostis gigántea* (Roth). At the northern site, *Deschampsia cespitosa* (L.) dominated the sheep-grazed swards while *Poa pratensis* dominated cut or cattle-grazed swards.

Keywords: Long-term grassland, DM production, crude protein, crude fibre, botanical composition, grazing, cutting

Introduction

Forage production in Norway is based mainly on silage from leys sown with *Phleum pratense* and *Festuca pratensis*. However, a large proportion of the grassland area is long-term or permanent, dominated by unsown grasses and herbs. Climate and soil conditions, and also management, determine the composition and how quickly new species invade the swards (Williams, 1984). To study the long-term effects of management on yield production, fodder quality and the botanical composition of permanent grassland compared with reseeded leys, experiments were established in 1968 at different sites, representing contrasting climatic conditions of the main grass-growing areas of Norway. The swards were subjected to three different defoliation regimes and two fertiliser levels (moderate and high). The results for two years (1984 and 1986) are presented here, from permanent swards and short-term *P. pratense*-dominated leys with different defoliation regimes and averaged over fertiliser levels.

Materials and methods

Long-term field experiments on permanent swards and leys reseeded every 3 years were established in 1968 on the southwest coast of Norway, on a loamy sand at Særheim Research Centre (58^{o}47'N, 5^{o}41'E) with 209 growing degree-days (GDD, temperature > 5 ^{o}C). Similar experiments were established on a peat soil under continental sub arctic conditions at Svanhovd Environmental Centre (69^{o}27'N, 30^{o}3'E) with 126 GDD. At Særheim, the permanent swards were established with a seed mixture of *P. pratense* (30 %), *F. pratensis* (40 %), *Poa pratensis* (20 %) and *Lolium perenne* (10 %). At Svanhovd, the same seed mixture excluding *L. perenne* was used, all with locally adapted varieties. The short-term leys were renovated in autumn every 3rd year with monocultures of *P. pratense* at both sites. From 1969 to 1990, three defoliation regimes were used: (D1) 3 silage cuts, (D2) 2 silage cuts and aftermath grazing with cattle, (D3) spring grazing with sheep, 2 silage cuts and autumn grazing with sheep. The first cut was made when *P. pratense* was heading. At Svanhovd the plots received one cut less than at Særheim. The experiments were arranged in a strip-split-block design with the permanent swards and the two ley rotations as vertical treatments, (6.0 m × 29.4 m), the three cutting and grazing treatments as horizontal treatments (9.8 m × 12.0 m), and the two fertiliser levels as subplots (3.0 m × 9.8 m), all replicated three times. DM yields and contents of crude protein (CP) and crude fibre (CF) were determined in the silage cuts and in the grazed herbage. The botanical composition was estimated visually before the first cut each year. Total DM, CP and CF were averaged over two years (1984 and 1986) and ANOVA performed using the Student-Newman-Keuls multiple range test to compare individual means.

Results and discussion

Table 1. Total DM yields and contents of CP and CF at the two sites. Results are means of two years (1984 and 1986), of both fertiliser treatments and of 3 replicates.

Site	Treatment	Total DM (t ha^{-1})	CP (g kg^{-1})	CF (g kg^{-1})
Særheim	Permanent sward	9.84 a	156.9 a	276.1 a
	P. pratense ley	8.31 a	126.3 a	312.1 a
	D1. Cut only	8.78 a	136.9 b	306.7 a
	D2. Cut and grazed with cattle	9.62 a	134.4 b	300.9 a
	D3. Cut and grazed with sheep	8.82 a	166.9 a	258.6 b
	Mean	*9.07*	*145.6*	*289.8*
Svanhovd	Permanent sward	5.87 a	155.6 a	223.3 a
	P. pratense ley	6.20 a	114.3 b	249.6 a
	D1. Cut only	5.91 a	145.6 a	235.2 a
	D2. Cut and grazed with cattle	6.32 a	131.3 b	236.1 a
	D3. Cut and grazed with sheep	5.88 a	138.1 ab	231.3 a
	Mean	*6.03*	*138.1*	*234.4*

Values with the same letters within treatments are not significantly different ($P < 0.05$).

Total DM yields were about 33 % lower at Svanhovd than at Særheim reflecting the considerably shorter growing season at Svanhovd (Table 1). CP content of the grass DM did not differ between the two sites, but CF content was significantly lower at the northern than at the southwestern site. The low temperatures during the growing season at the northern site may have decreased the formation of CF (Deinum *et al.,* 1968). There were no significant differences in DM yields between the permanent swards and the *P. pratense* leys at either site. CP was significantly higher in the permanent swards than in the short-term leys at Svanhovd, with a similar tendency at Særheim, while CF content was not significantly different. This is in agreement with other studies (Nesheim, 1986). Defoliation treatment had no effect on total DM at either site, but they affected fodder quality. At Særheim, the sheep-grazed plots had higher CP content and lower CF content than the other treatments. At Svanhovd, in contrast, CP was higher in cut only plots while defoliation regime did not affect CF.

Table 2. Botanical composition of the first cut of the permanent swards (% of DM yield) at the two sites. Results are the means of two years (1984 and 1986), of two fertiliser treatments and of 3 replicates.

Site	Defoliation treatment	*Phleum pratense* %	*Festuca pratensis* %	*Poa pratensis* %	*Lolium perenne* %	Unsown grasses %	Herbs %
Særheim	Cut only	8 a	8 a	11 a	5 b	60 a	8 b
	Cut and grazed with cattle	12 a	8 a	16 a	9 b	47 b	8 b
	Cut and grazed with sheep	7 a	6 a	12 a	24 a	32 c	19 a
	Mean	*9*	*7*	*13*	*13*	*46*	*12*
Svanhovd	Cut only	9 a	4 a	70 a	0	11 b	6 a
	Cut and grazed with cattle	8 a	2 a	67 a	0	16 b	7 a
	Cut and grazed with sheep	2 a	2 a	32 b	0	52 a	12 a
	Mean	*6*	*3*	*56*	*0*	*26*	*9*

Values with the same letters within treatments are not significantly different ($P < 0.05$).

The defoliation regime also significantly affected the botanical composition of the permanent swards (Table 2). At Særheim, sheep grazing led to more *L. perenne* and herbs than the other treatments, whereas the cut swards were dominated by unsown *Agrostis gigántea*. At the northern site, unsown grasses, mainly *Deschampsia cespitosa*, dominated the sheep-grazed swards while *P. pratensis* dominated cut or cattle-grazed swards. Sheep grazing had a larger impact on botanical composition than cattle grazing, mainly because the sheep grazed for a longer period than the cattle. Thus, the sheep-grazed swards were dominated by grass and herbs tolerant to grazing or avoided by the sheep. The impact of defoliation on CP and CF was similar whether the swards were short-term leys dominated by *P. pratense* or species-rich permanent swards.

Conclusions

DM production and the CF content were lower in the north than in the southwest of Norway. Yield production was similar and the amount of CP higher in the permanent swards compared with the short-term leys. This indicates that permanent grassland dominated by unsown species can be similar to sown leys in terms of productivity or quality. The defoliation regimes did not affect DM production, but affected fodder quality differently at the two sites and had large effects on botanical composition.

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Nfate: a N flux model for grassland resowing and grass-arable rotations

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Abstract

The model *Nfate* (*N*itrogen *f*luxes in *a*gricultural soils and *t*o the *e*nvironment) has been developed to offer a synthesis of all relevant nitrogen processes at field level related to grassland resowing and grass-arable rotations, and to calculate the effects of management on both the agronomic (e.g., crop N yield) and the environmental (e.g., nitrate leaching) aspects. The current version of the model calculates the dynamics of soil organic and inorganic nitrogen, and crop nitrogen for a number of years as a function of management decisions such as time of ploughing, ploughing depth, crop species and amount and type of applied fertiliser. The results of some calculations concerning grass and maize cropping on sandy soils in the Netherlands are presented here to illustrate the model. According to these results, total N input via fertilisation on cut grassland may amount to 350-400 kg N ha^{-1} y^{-1} without causing excessive N leaching. Calculations also indicate that first year maize on ploughed grassland needs additional measures to limit N leaching to acceptable levels, even if nil fertilisation has been applied.

Keywords: model, nitrogen, grassland renovation, maize, mineralisation, leaching

Introduction

Farmers regularly renovate their grasslands throughout a large part of Europe (Conijn *et al*., 2002). In most situations, grassland is ploughed before resowing with grass or another crop species. This has a large influence on all processes related to the nitrogen balance of the soil-crop system. Motive for grassland renovation is to produce sufficient high-quality animal feed, but the society is concerned about the risk of increased nutrient losses and pollution of the environment (e.g., ground- and surface water). It is necessary to develop management rules for grassland resowing and grass-arable rotations, which are acceptable for both farmers and society. A quantitative model that calculates all relevant nitrogen fluxes in the soil-crop system and links management decisions to nitrogen losses, has therefore been developed, in addition to experimental work. A short description of this model is given here, including preliminary results of some calculations.

Model description

Nfate calculates N yield, N losses and changes in the amount of N in the soil-crop system as a function of N inputs, soil characteristics and crop species. The in / outputs of the model refer to the field-level and a whole year. Three N pools have been distinguished in the model: soil organic N, soil inorganic N and plant N. For each pool, the inputs and outputs of N are determined and integrated over time and their dynamic behaviour can be studied.

The dynamics of the soil organic N pool are described by three fluxes: (1) net input of organic N via organic fertiliser application, (2) net input of organic N by plant residues and (3) output of nitrogen via net mineralisation from the soil organic N pool. In the model (3) is calculated as a fraction of the amount of soil organic N. This fraction has been derived from the N yield of unfertilised fields (Schröder and Van Keulen, 1997). The net inputs of organic N via organic fertilisers and plant residues refer to the amount of N which is still organically bound after one year. The fraction that mineralises within the first year has been modelled as a function of the N concentration of the organic material.

The dynamics of the amount of plant N also depend on three fluxes: (4) total plant uptake, (5) net N yield, i.e., the removal of N from the field and (6) the formation of plant residues which are left on the field. Net N yield is modelled as a function of the N yield of unfertilised fields, the applied amount of effective N and the apparent N recovery (Ten Berge *et al.*, 2000). Total plant uptake is calculated by multiplying (5) with a factor to account for the amount of N in non-harvested plant parts (6). In case of ploughing, (6) also includes the amount of N in the ploughed grass sward and after resowing, (4) also includes the extra N uptake that is needed to build up the new grass sward.

The dynamics of the soil inorganic N pool are determined by integrating seven fluxes over time. Two of them have already been mentioned, i.e., (3) and (4). The other five fluxes are: (7) net input of inorganic N by plant residues, (8) by organic fertiliser application, (9) by mineral fertiliser application, (10) by atmospheric deposition and (11) the output of inorganic N due to losses. The net input of inorganic N via plant residues (7) equals (6) minus (2) and the net input of inorganic N via organic fertilisation (8) equals the total N input via organic fertilisation minus (1). The size of the inorganic N pool is assumed constant between successive years, which means that total N loss (11) can be found by balancing the sum of the other relevant fluxes ((3), (4) and (7) up to (10)). After subtracting NH_3 volatilization (11a), the remainder of the N loss is distributed among denitrification (11b) and leaching (11c) by using a ratio that depends on soil type and crop management.

In cases where grassland is ploughed and resown with grass or an arable crop, several processes are influenced. This applies mainly to (3), because soil cultivation may enhance organic matter decay, to (5) due to loss of grass yield in the year of ploughing, but also due to expected higher yields of grass and arable crops after soil cultivation and to (6), where the amount of N in the old grass sward is added to the soil N pools. The outcome of the calculations also depends on the time of the year at which grassland ploughing takes place.

Results and discussion

The model is used to calculate the N fluxes in the crop-soil system of three typical cropping situations for one year (Table 1). The results apply to a sandy soil in the Netherlands with 3,000-4,200 kg organic N ha^{-1} in the upper 0.2 m (cf. Aarts *et al*., 2001; Schröder *et al*., 1996). Grass N yield equals 338 kg N ha^{-1} y^{-1} with a N fertilisation of 200 kg N ha^{-1} y^{-1} (mineral fertiliser) and 184 kg N ha^{-1} y^{-1} (slurry). Total losses amount to 127 kg N ha^{-1} y^{-1} of which 33 kg N ha^{-1} y^{-1} is lost by leaching. The amount of N in the soil organic pool decreases in this example. Table 1 also shows a situation of continuous maize cropping without a cover crop, where only slurry has been applied via injection (171 kg N ha^{-1} y^{-1}). Maize N yield is 145 kg N ha^{-1} y^{-1} and total N losses equal 112 kg N ha^{-1} y^{-1} of which 69 kg N ha^{-1} y^{-1} is lost by leaching. Also in this situation the amount of soil organic N decreases. In both cases the organic N inputs do not completely compensate for the calculated mineralisation (3). An equilibrium could be obtained by using more slurry; the results however correspond with the current trend in the Netherlands of decreasing animal manure application. As a consequence, the amount of organic N in the soil will decrease over time and both N yield and N loss are likely to be lower in the future, if N input is constant. This means that N leaching may decrease, while N field surplus (N input – N yield) increases. A relation between N surplus and N leaching is therefore difficult to interpret with respect to its predictive value without additional information on the possible changes in the soil organic N pool.

The third example refers to a situation where grassland is ploughed and maize is grown afterwards. For these calculations, it has been assumed that ploughing occurs at the beginning of April and that the net mineralisation from the soil organic N pool is stimulated with + 25 % in the first year. The results show that maize can benefit very much from the N released by the former grass sward, but also that the N losses are comparable to those calculated in the continuous maize cropping example, despite the fact that no fertilisers have been used. Both cropping strategies need additional measures to limit the N losses, e.g., a cover crop to extend the period of N uptake from the soil.

Table 1. The calculated N fluxes of the crop-soil system in three different situations of crop species and field history. The numbers in the first column are explained in the text.

N fluxes (kg N $ha^{-1}y^{-1}$)	Grass (permanent, cut only)	Maize (continuous cropping)	Maize after grass (1st year)
NorgManure (1)	56	52	0
NorgPlantRes (2)	84	29	92
NorgMinSoil (3)	181	120	164
Change in NorgSoil	*-41*	*-39*	*-71*
Nuptake (4)	548	199	200
Nyield (5)	338	145	146
NplantRes (6)	210	53	229[a]
Change in Nplant	*0*	*0*	*-175*
NminPlantRes (7)	126	32	136
NminManure (8)	128	119	0
NminFertiliser (9)	200	0	0
NminDeposition (10)	40	40	40
NminVolatilized (11a)	18	9	0
NminDenitrified (11b)	77	34	47
NminLeached (11c)	33	69	93
Change in NminSoil	*0*	*0*	*0*

[a] including the N content of the ploughed grass sward.

Significant uncertainties still exist in the values of some input parameters of the model. Notably, the extra mineralisation due to soil cultivation, the leaching fraction in various situations, the uptake of N in non-harvestable parts and the development of net crop N yields in the years after soil cultivation are difficult to assess. Further research is needed to overcome these knowledge gaps. Validation of the model outcome with experimental data will also be part of future research.

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Economy of grassland renovation: a model approach

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Abstract

Grassland renovation is a relatively expensive activity. However, a cost / benefit analysis is hard to make, since financial benefits are difficult to determine. The benefits involve mainly the temporary increase of net grass production. The focus of this paper is on a model simulating the grass production over time. It assumes that the gross grass production, the nutritive value and the intake of grass by cattle decline over time due to an increasing content of undesirable grass species, like *Poa trivialis* and *Elymus repens*. This model approach is the basis for the 'Grassland Renovation Guide', a computer program which runs on the Internet site of our institute (*www.asg.wur.nl*). Farmers can use this program for a cost/benefit analysis, depending on factors such as actual costs, present content of desirable grasses and clover, soil type, groundwater level, irrigation and N fertilisation level. The tool provides a cost benefit analysis and a nitrogen balance. For the given situation, it states whether grassland renovation is profitable under a wide range of circumstances

Keywords: grass, renovation, production, nutritive value, economy, nitrogen balance

Introduction

Farmers often do not have a clear insight into the costs and benefits of grassland renovation. Therefore, a computer program has been introduced, which is available on the Internet site of our institute (*www.asg.wur.nl*). This so-called 'Grassland Renovation Guide' is a practical tool, which calculates the difference between the financial costs and benefits of renewing for a time period of five years after renewing. The costs of renewing should at least be compensated by the benefits: a higher production level of the new grass sward, a higher nutritive value and a better intake of the grass during grazing. The benefits are difficult to determine, mainly because the increased net production level after renovation is temporary. The assumed effect of grassland renovation on the DM yield is schematically illustrated by Schils *et al*. (2002).
In this paper a model simulating the net grass production over time is presented. The Grassland Renovation Guide is based on this model.

Model approach

The main benefit of resowing is the increase of net grass production. To simulate this production, a model has been developed that estimates grass production over time. The model calculates the increase of production depending on the time of renewing in the year (spring or late summer), the growing conditions and the actual botanical composition. The growing conditions include soil type and groundwater table, use of irrigation and N fertilisation level. Usually a grass sward deteriorates over time and needs to be renovated at a certain moment. Concerning the development of net grass production over time the following facts are taken into account: 1) gross production declines with an increasing content of undesirable grass species, such as *Poa trivialis* and *Elymus repens*, 2) the nutritive value of grass and the intake by cows during grazing and as silage are influenced by the presence of undesirable grasses (Keating and O'Kiely, 2000) and 3) in the year of renovation the production is lower, because of the destruction of the old sward and establishment of a new sward. An example of the results of this model is given in figure 1 for a drought sensitive sandy soil over 30 years.

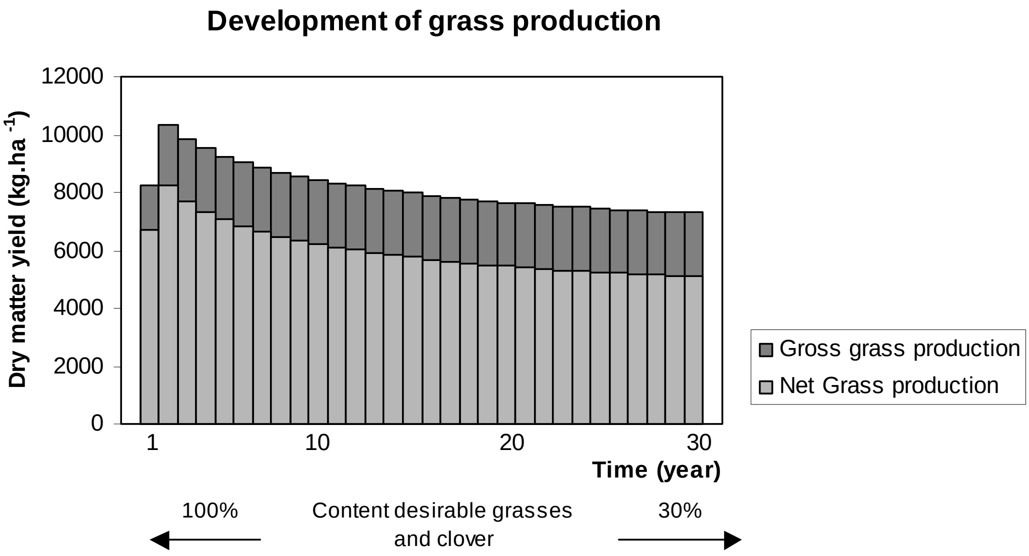

Figure 1. Model approach of the development of grass production (dry matter) for a long term period. Renovation during spring. Example for a drought sensitive sandy soil.

For the production curve two main reference points are chosen, namely a potential production and a long-term production level, where production is approximately in a steady state. Both levels are dependent on soil type and groundwater table. The potential production is defined as the production under optimal growing conditions, by a homogenous botanical composition of a sward consisting entirely of grasses and white clover with high agricultural value. Both potential production and the content of desirable grasses and clover are determined to be 100 %. The long-term production is characterised by a sward containing a high proportion of undesirable grass species, and a relatively low proportion of high-value grasses and clover of less than 40 %. The model is based on practical knowledge of a team of experts at our institute, literature (Korevaar, 1986) and unpublished research data.
In the model, the direct loss of production after renewing depends on the time of renewing in the year; during spring 25 % and during late summer 12.5 % of the total year gross production. In the first year of production following renovation, comparatively high production is assumed, namely an increase of 10 % compared to potential production (Luten *et al*., 1976).
After renovation nitrogen is immobilised in the new sward. This is assumed to be 150 kg N in spring and 300 kg N ha^{-1} in autumn (Vellinga, 2000). In the model these amounts are translated into a decrease of grass production.

Grassland Renovation Guide

The Grassland Renovation Guide is a program, which calculates a cost / benefit analysis, depending on factors such as costs, present content of desirable grasses and clover, soil type, groundwater level, irrigation and N fertilisation level. The tool provides an economic evaluation, a nitrogen balance and a recommendation on whether to resow or not. Cost benefit analysis and N balance are calculated over a time period of five years. To give an impression of the program, some calculated results are presented in table 1. The value to which the percentage of high-value grasses, including clover, needs to fall before renewing should be recommended is calculated for different combinations of soil type and hydraulic situation. As the importance of high quality grass also depends on nutritional requirements of dairy cows, the protein availability for dairy cow nutrition on farm level is also included in the program.

Table 1. Percentage of high-value grasses at which renewing is recommended. Fertiliser N input was 300 kg ha^{-1} on sand and clay soils and 200 kg ha^{-1} on peat soils (no irrigation).

Soil type	Sand		Clay		Peat	
Hydraulic situation	Moist	Dry	Moist	Dry	Moist	Wet
No protein shortage	52	40	56	48	55	40
Protein shortage	70	68	75	76	75	68

Protein availability has a major influence on the program results, as protein has more economic value than energy and the gain of protein by grassland renovation is significant. If there is a protein surplus, grass quality has to be very poor before renewing is economically beneficial. Furthermore, renovation is more profitable when the growing conditions can be improved by influencing the hydraulic situation.

Discussion and conclusions

The botanical composition of the sward is the most important factor influencing the cost-benefit of renovation, as calculated by the Grassland Renovation Guide. The protein availability at the farm level has a huge influence on the recommendations of the program, as renovation of grassland is more attractive with protein shortages on a dairy farm than with protein surpluses. Furthermore, grassland renovation is more profitable with an improved hydraulic situation. Finally, there is a need for research data concerning productivity and nutritive value related to the botanical composition of a grass sward in order to calibrate the model, as the net productivity is based on practical knowledge and unpublished data.

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Seedling growth, development and their survival ability after meadow renovation by overdrilling

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Abstract

Direct drilling into swards is becoming a more and more popular grassland renovation method in Poland. The aim of this study was to analyse early growth and development of mixture components and to determine their survival ability after overdrilling during two sowing periods: spring and late-summer. Mixture components were: *Dactylis glomerata, Festuca pratensis, Phleum pratense, Lolium perenne* and *Trifolium pratense.* Original sward competitiveness was reduced by low cutting and selective herbicides: Starane + Aminopielik, Roundup and rototiller. In moderately dry habitats of central Poland, overdrilling in late-summer appeared to be more effective than in the spring and it is likely that weather conditions and lower competition of the original sward were key factors. Growth and development of mixture components and seedling survival ability were better in treatments with glyphosate and rototiller than with fluroxypyr + 2.4 D or when herbicides were not applied at all. In the habitats covered in this study, species such as *Dactylis glomerata* and *Lolium perenne* were the most suitable for overdrilling into old swards.

Keywords: grass seedling growth, grass seedling development, herbicides, overdrilling, sowing period, sward establishment

Introduction

Direct drilling still remains a very risky method of grassland renovation in Poland and causes wide controversy (Dobromilski and Grabowski, 1991; Baryła and Sawicki, 1998). Seeds are introduced into an already existing sward; they germinate, become established as seedlings and develop into adult plants. The newly sown seeds have to counter competition from the old sward and sward improvement depends upon the colonising ability of the sown species. Success not only relates to their growth and development rates but also to the composition and competitiveness of the original sward. An important factor here is the abundance of weed species and their relative aggressiveness (Tiley and Frame, 1991; Rutkowska and Janicka, 1992; Grabowski *et al*., 1996). Herbicides and surface treatments may suppress competition from the old sward when the sown species are establishing (Wolski, 1998). This study took place using a meadow in a moderately dry habitat. The aim of the study was to determine the growth and development of mixture components in the period of a few weeks after overdrilling and to determine whether the survival ability of those species was affected by sowing period and sward treatment.

Materials and methods

The study was carried out during 2002-2003 at the Experimental Station at Jaktorów (central Poland), in a natural, moderately dry meadow site (water table below 150 cm), situated on a mineral soil (degraded black earth), poor in potassium and magnesium and with medium phosphorus concentration. The experiment was designed as a randomised complete block with four replications. Each plot was 15 m^2 in area. The experiment was carried out on a degraded permanent meadow which had been extensively managed and fertilised. The meadow had a low proportion of valuable grass species (less than 20 %) and had been infested with dicotyledonous herbs and weeds (more than 40 %). *Rumex acetosa, Achillea millefolium, Taraxacum officinale, Plantago lanceolata* and *Leontodon autumnalis.* Sward cover density was less than 50 %. Competitiveness of the original sward was reduced by the herbicides: Starane (1 l ha^{-1}) + Aminopielik (3 l ha^{-1}), active substances: fluroxypyr + 2,4 D and / or low cutting without herbicides (the cutting height: 2-3 cm). The sward had been treated with herbicides three weeks before over-sowing. Early growth and development of seedlings was also studied in late-summer time in two further treatments: after destroying the old sward with Roundup (5 l ha^{-1}; active substance: glyphosate) and after cultivating the sward layer with rototiller (twice). Direct drilling took place using the Vredo seed drill (Holland) which had drills that were 10 cm apart and a sowing depth of 1 to 2 cm. Oversowing took place on two dates: spring (6 May) and late-summer (27 August). The suitability of two mixtures was examined: M1 – *Festuca pratensis* (cv. Pasja), *Dactylis glomerata* (cv. Astera), *Lolium perenne* (cv. Argona) and *Trifolium pratense* (cv. Parada) sown at a seed rate of 29.5 kg ha^{-1}; M2 – *Phleum pratense* (cv. Kaba), *Dactylis glomerata* (cv. Astera), *Lolium perenne* (cv. Argona) and *Trifolium pratense* (cv. Parada) sown at a seed rate of 16.0 kg ha^{-1}. Grass and clover seedlings were counted four and six weeks after overdrilling in rows of 1 m length in 4 replications for each plot (16 for each treatment).

Results and discussion

First emergence of *Trifolium pratense* was recorded after 6 days and 7 days and grass emergence after 8 and 10 days for the spring and late summer respectively. The seedlings developed very slowly due to a period of dry hot weather and four weeks after overdrilling most of them had only two unfolded leaves and their height was only 3 cm. Six weeks after overdrilling, in the spring treatment, the seedlings had three leaves and none of the tested species achieved the tillering stage, whist in the late-summer experiment, the seedlings were better developed and the grasses had entered the tillering stage. The seedlings of M1 mixture were taller (4.5 cm) than the seedlings of M2 (3.5 cm). Pre-treatment with glyphosate and with rototiller caused the seedlings to grow and develop faster than those in treatments with fluroxypyr + 2.4 D or when herbicides were not used at all. *Lolium perenne* started to tiller 4 weeks after overdrilling which was one week earlier than the other grass species. Six weeks after overdrilling *Lolium perenne* had formed 3-4 tillers whilst *Dactylis glomerata* and *Festuca pratensis* had formed only 2-3 and *Phleum pratense* 1-2 tillers. *Phleum pratense* was the last to tiller irrespective of the treatment and showed low competitive ability. During this time the average height of plants was 7.5 and 5.5 cm in the M1 and M2 mixtures respectively. Seedlings of *L. perenne* and *F. pratensis* were much taller than *D. glomerata* and *P. pratense*.
A similar number of seedlings were found four weeks after overdrilling for both sowing dates, whilst after six weeks more seedlings (both grasses and clover) were noted in the late-summer sowing (Table 1). These differences are likely to result from unfavourable weather conditions in spring. High temperatures (30 ^{o}C) and lack of precipitation caused a check in seedling growth and development and a lot of seedlings were lost (as much as 60 %). Among the seedlings that survived *Dactylis glomerata* dominated (about 70 %), then *Lolium perenne* and then *Festuca pratensis, Phleum pratense* and *Trifolium pratense*. In the late-summer period the number of seedlings after 6 weeks increased when compared with the number after 4 weeks (in some combinations by more than 50 %, Table 1). This was probably related to early partial germination of seeds. In both sowing periods there were many more grass seedlings in mixture M1, in both measurement periods irrespective of sward pre-treatment. In the late-summer period, both 4 and 6 weeks after overdrilling, there were many more grass and clover seedlings in treatments with glyphosate and with rototiller than in treatments with fluroxypyr + 2.4 D or when no herbicides were used (Table 1). This probably resulted from better light conditions for growth.

Table 1. Number of grass and clover seedlings (seedlings m^{-2}), 4 and 6 weeks after overdrilling, depending on the existing sward treatment.

Weeks after overdrilling	Sward treatment	Mixture 1		Mixture 2		Average	
		grasses	clover	grasses	clover	grasses	clover
Spring							
4 weeks	A	366.1	33.7	130.0	16.9	248.1 a*	25.3 a
	B	223.1	13.2	95.7	11.9	159.4 b	12.6 b
	Average	294.6	23.4	112.9	14.4		
$LSD_{0.05}$ for mixtures NS; $LSD_{0.05}$ for treatments: grasses 68.3, clover 10.2							
6 weeks	A	118.7	22.0	63.6	12.5	91.1	17.3 a
	B	85.7	10.0	64.2	7.9	74.9	8.9 b
	Average	102.2	16.0	63.9	10.2		
$LSD_{0.05}$ for mixtures NS; $LSD_{0.05}$ for treatments: grasses NS, clover 7.7							
Late-summer							
4 weeks	A	169.4	15.0	137.5	13.7	153.4 a	14.4 a
	B	234.4	20.6	106.2	19.4	170.3 a	20.3 ab
	C	472.5	41.9	277.5	37.5	375.0 b	39.7 c
	D	525.6	30.6	413.1	37.5	469.4 b	34.1 bc
	Average	350.5 x*	27.0	233.6 y	27.2		
$LSD_{0.05}$ for mixtures: grasses 90.0, clover NS; $LSD_{0.05}$ for treatments: grasses 138.1, clover 15.6							
6 weeks	A	278.7	30.6	211.9	15.6	245.3 a	23.1 a
	B	306.9	28.7	166.9	22.5	236.9 a	25.6 a
	C	429.4	48.1	318.1	38.1	373.8 b	43.1 b
	D	465.6	31.2	373.7	39.4	419.7 b	35.3 ab
	Average	370.2 x	34.7 x	267.7 y	28.9 y		
$LSD_{0.05}$ for mixtures: grasses 52.3, clover 5.6; $LSD_{0.05}$ for treatments: grasses 122.5, clover 15.6							

A – low cutting (without herbicides); B – Starane + Aminopielik, active substances: fluroxypyr + 2,4 D; C – Roundup – glyphosate; D – rototiller; *figures indicated by the same letters do not differ significantly.

Conclusions

The results show that late-summer overdrilling was more successful than overdrilling in the spring, and this was most probably due to better weather conditions and lower competition of the original sward. Growth and development of mixture components and seedling survival ability were better in treatments with glyphosate and rototiller than with fluroxypyr + 2.4 D or when no herbicides are used. Species like *Dactylis glomerata* and *Lolium perenne* were the most suitable for overdrilling into old sward in moderately dry habitats.

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How does resowing of natural meadows affect yield, forage quality and botanical composition?

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Abstract

A split-plot experiment was conducted between 1999 and 2003 to examine how resowing of a natural meadow in Valdres, Norway, affected yields, forage quality and botanical composition. The most frequently occurring species in the meadow were *Agrostis capillaris*, *Poa pratensis, Alchemilla spp*., *Taraxacum officinale*, *Achillea millefolium* and *Rumex acetosa*. In large plots the undisturbed meadow was compared with resown *Phleum pratense, Bromus inermis* and *Trifolium pratense*, after spraying with glyphosate and tillage with a rotary cultivator. Four levels of nitrogen fertiliser, 0, 60, 120 and 180 kg N ha^{-1}, were applied to small plots. The natural meadow yields were stable at 7-8 t DM ha^{-1} y^{-1} at high N rates. Resowing increased yields by 1.5 t DM ha^{-1} y^{-1}, on average over five years, with largest effect occurring in the year after sowing. The natural meadow gave the highest energy value, and protein and mineral content. Increasing nitrogen rates reduced the legume content of the sward. In the resown plots sown species still dominated, but many species from the natural meadow gradually invaded. The experiment showed that natural meadows can give reasonable yields with high forage quality, and that resowing of such meadows is economically questionable.

Keywords: natural meadows, resowing, botanical composition, yield, forage quality

Introduction

In most grassland dominated regions of Norway, the number of farms and ruminants has decreased in recent years. With more grass area available, there is interest in more extensive and less costly production methods. Permanent grassland is an interesting alternative for many farmers, both for cutting and grazing. There have been few direct comparisons between permanent grassland and short-term leys in Norway. Therefore we examined the effect of resowing a natural meadow in terms of yields, forage quality and botanical composition.

Materials and methods

A natural meadow on moraine soil in Valdres, Norway (700 m asl), traditionally used as permanent pasture, was used in a split-plot design experiment with three replicates. Soil tests showed a loss on ignition of 11.4 %, pH 5.7, P-AL 1.5 and K-AL 9.7. In large plots the undisturbed meadow was compared with resowing after spraying with glyphosate and tillage with a rotary cultivator. Four levels of nitrogen fertiliser, 0, 60, 120 and 180 kg N ha^{-1}, were applied on small plots (1.5 m x 7 m), with 2 / 3 applied in spring and 1 / 3 after the first cut. 30 kg P and 100 kg K ha^{-1} were applied on all plots. A seed mixture of 7.5 kg timothy (*Phleum pratense* L.*),* 18 kg brome grass (*Bromus inermis* L.*)* and 7.5 kg red clover (*Trifolium pratense* L.*)* ha^{-1} was used.

The field was harvested twice per season over five years and yield was measured. Samples for dry matter determination were also used for forage quality analysis with NIRS (Marum, 1990), where digestibility was calibrated against the Tilley and Terry method (Tilley and Terry, 1963). Analysis of variance was performed for a split-plot factorial experiment with three replicates. The botanical composition was determined in 2002 and 2003 using two 2 m ×

10 cm frames along one diagonal of the plot, giving 40 squares (10 cm × 10 cm) per plot. All vascular plants were registered, and the result was expressed as appearance frequency (%). Thus, a number of 60 means that the species was present in 60 % of the small squares.

Results

In the natural meadow the dry matter yield was very stable, at a level of 7-8 t DM ha^{-1} at high N levels from year to year (Figure 1). After a small yield in the seeding year, the resown ley gave a very high yield in the first year after sowing. In the second year after sowing the yield dropped to the level of the natural meadow, while in the third and fourth year the yield increased again. Averaged over five years, the resown ley produced 1.50 t DM ha^{-1} more than the natural meadow.

The yield response after nitrogen fertiliser application was high in both grassland types. Averaged over five years, the yield increased from 6.66 t at 0 kg N to 8.78 t DM ha^{-1} at 180 kg N ha^{-1} in the resown ley, and from 5.43 t at 0 kg N to 7.53 t DM ha^{-1} at 180 kg N ha^{-1} in the natural meadow. The response was small from 120 to 180 kg N ha^{-1}, and very small in the sowing year compared to later years.

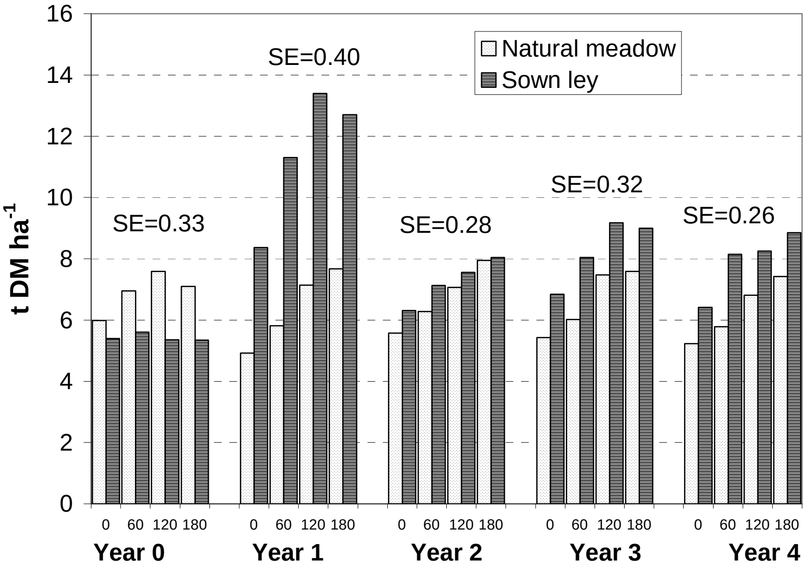

Figure 1. Dry matter yields at different level of N fertilisation (0 to 180 kg N ha^{-1}), for natural meadow and resown ley in the sowing year and four years after resowing. Average values of three replicates.

Forage quality was generally higher in the natural meadow than in the resown ley (Table 1). The difference was most pronounced for the content of total fibres (NDF) and for mineral content, where the content of Ca and Mg, in particular, was higher in the natural meadow (data not shown). N fertiliser application increased the protein content and reduced the mineral content. In the natural meadow the effect of N fertilisation on quality was small, while in the resown ley the 0 N treatment had higher quality than N fertilised treatments. This produced a statistically significant interaction between meadow type and N rates in many cases.

A total of 31 vascular species was found in the plots: 10 grasses and 21 herbs. The dominating grasses in the natural meadow were *Poa pratensis* and *Agrostis capillaris.* The most frequent herbs were *Taraxacum spp., Alchemilla spp.* and *Achillea millefolium.* Other frequent species were *Rumex acetosa, Carum carvi* and *Trifolium repens*. The resown ley was dominated by the sown species *Phleum pratense, Bromus inermis* and *Trifolium pratense*, with *P. pratense* occurring with the highest frequency. Four years after resowing, most of the species of the natural meadow also occurred in the resown ley, although in a smaller proportion. The grasses *Poa annua* and *Elytrigia repens* were frequent in the ley, but were rare in the natural meadow. *Alchemilla spp., Taraxacum spp., Rumex acetosa* and *Carum carvi* were the most frequent herbs, while *Achillea millefolium* established very slowly in the ley. The effect of nitrogen application was most pronounced in the case of *Trifolium repens*, which almost disappeared at the highest N rate. In the natural meadow the appearance of *T. repens* was 97 % at 0 kg N, while the number decreased to 58 % at 60 kg N, 18 % at 120 kg N and to 3 % at 180 kg N ha^{-1}. The other legumes present, *T. pratense, Vicia cracca* and *Vicia sepium,* showed a similar pattern.

Table 1. Dry matter digestibility, g kg^{-1}, and concentration of crude protein, neutral detergent fibres (NDF) and ash, g kg^{-1}. Average values over four years and three replicates.

	Digestibility		Crude protein		NDF		Ash	
Cut no.	1	2	1	2	1	2	1	2
Natural meadow N0	673	756	104	163	568	429	67	85
Natural meadow N60	683	762	109	154	540	431	68	81
Natural meadow N120	680	759	113	158	554	443	65	77
Natural meadow N180	677	764	120	172	563	437	62	76
Resown ley N0	668	749	101	163	587	468	58	76
Resown ley N60	648	751	86	138	627	516	50	65
Resown ley N120	647	735	96	144	632	528	52	66
Resown ley N180	650	726	105	151	623	542	51	63
SE	4.8	5.0	4.3	4.5	9.2	9.8	1.5	1.7
P value meadow types	0.02	0.04	0.02	0.09	0.001	0.009	0.005	0.01
P value N rates	0.29	0.18	0.02	0.02	0.20	0.005	0.007	0.001
P value type x rate	0.008	0.002	0.26	0.02	0.05	0.001	0.04	0.09

Discussion

Sown species like timothy and brome grass have a higher yield potential than natural meadows under Norwegian conditions. In the present investigation, the average yield increase was 1.5 t DM ha^{-1} y^{-1}. The profitability of resowing depends on the prices of yield, labour and seed. The costs are also dependent on the content of gravel and on the steepness of the field. The poorer forage quality in the resown ley and reduced botanical value must also be considered.

Natural meadows have typically produced higher protein contents and a lower content of fibre than short-term leys under Norwegian conditions (Nesheim, 1986). Natural meadows have a higher leaf/stem proportion and fewer straw-rich tall grasses, and the higher herb content will also result in lower NDF concentrations. The digestibility and net energy value has been both higher and lower than short-term leys, depending on botanical composition.

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The role of seed rate of *Festuca pratensis* and *Lolium perenne* in pasture overdrilling

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Abstract

An experiment was carried out during 2001-2002 to study the effect of different seed rates of *Festuca pratensis* and *Lolium perenne* (20, 30 and 40 kg ha^{-1}) on the success of overdrilling, using a Vredo drill on pastures situated on Histosols soils. A range of parameters were determined: the number of seedlings per 1 m^2, the proportion of introduced grasses in sward, DM yield and herbage quality using commonly applied methods. It was observed that an increase in the seed rate increased the number of seedlings of both species following overdrilling. It was found that increasing the seed rate of *Lolium perenne* (20, 30 and 40 kg ha^{-1}) increased the average proportion of this species in the sward during the first year of utilisation to 28.0 %, 37.1 % and 37.7 %, respectively. However, increasing the seed rate of *Festuca pratensis* had little effect, only increasing the proportion of this species to 9.8 % (mean of three seeding rates). Increasing the seed rate of both grass species did not significantly affect DM yields. However, in the case of *Lolium perenne,* increasing the seed rate from 20 to 30 kg ha^{-1} was found to have a significant effect on the quality of herbage, by increasing crude protein and reducing the fibre content of the herbage.

Keywords: forage quality, overdrilling, pasture renovation, seed rate

Introduction

In recent years, unfavourable climatic conditions occurring in the region of Wielkopolska have contributed to a rapid degradation of pastures in that area. In the case of dairy farms, a relatively easy method of improving the botanical composition of swards is overdrilling. Many factors affect the success of this undertaking (Sheldrick, 2000). One, easily adjustable factor is that of seed rate.

Materials and methods

A study was carried out during 2001-2002, at Brody Experimental Station (52º26’ N, 16º18’ E) of the August Cieszkowski Agricultural University, Poznań, to evaluate the effect of different seed rates (factor I: 20 vs. 30 vs. 40 kg ha^{-1}) of two grasses (factor II: *Festuca pratensis* cv. Lifelix vs. *Lolium perenne* cv. Barylou) on the success of overdrilling. The pastures used in the experiment were situated on poorly mineralised Histosols soils (pH_{KCl} = 6.5, N_t = 0.62 %, P_2O_5 = 67.9 mg 100 g^{-1}, K_2O = 30.0 mg 100 g^{-1}, Mg = 7.1 mg 100 g^{-1}). Plot size was 8 m × 2.5 m and each treatment was replicated four times in a plot block-design. The area was prepared by using a rototiller followed by rolling. The seeds were sown in spring (early April 2001) using a Vredo drill. Weather conditions were favourable for the growth and development of seedlings following overdrilling. The monthly mean temperature and amount of precipitation (mm) for April, May and June 2001 was 8.1, 14.8, 15.3 ˚C and 37.3, 34.7, 75.6 mm respectively. The yearly mean temperature and total of precipitation for 2001 and 2002 was 9.0, 9.7 ˚C and 648.2, 750.5 mm respectively. Fertiliser was applied each year at a rate of: 160 kg N ha^{-1}, 80 kg $P2O^5$ ha^{-1}, 140 kg K_2O ha^{-1} and 4-5 regrowths were harvested. The effectiveness of overdrilling was evaluated on the basis of the number of seedlings per 1 m^2 after 25 and 50 days from sowing as well as the proportion of introduced grasses in the sward (samples were separated and the fractions were weighed). Dry matter (DM) yield was measured on an area of 15 m^2. The herbage was dried in a forced-draught oven at 60 °C. Crude protein (CP) and acid detergent fibre (ADF) were also measured on selected plots using commonly accepted methods (Kjeldahl, and Soest and Marcus (1964) respectively). Tests of the main effects were performed by F-tests. Means were separated by the LSD and were declared different at the $P < 0.05$ level.

Results and discussion

The botanical composition of the experimental sward at the time of overdrilling was: *Poa trivialis* – 26.5 %, *Poa pratensis* – 20.5 %, *Agropyron repens* – 17.5 %, *Festuca pratensis* – 3.8 %, *Lolium perenne* – 5.2 %, *Trifolium repens* – 2.3 %, other grasses and herbs – 24.2 %. Increasing the seed rate of both grass species resulted in a greater number of seedlings per unit area, 25 days after overdrilling, with greater seed rates leading to greater seedling numbers (Table 1). Although seedling number dropped by an average of 45 % by the time the second seedling measurement was taken (Fifty days after overdrilling), differences in the number of seedlings per unit area continued to be very clear. In comparison with the treatment where 20 kg ha^{-1} of seed was sown, the doubling of this seed rate resulted in 133 % increase of *Festuca pratensis* seedlings and 129 % of *Lolium perenne*.

Table 1. Effect of seed rate of *Festuca pratensis* and *Lolium perenne* in pasture overdrilling on the number of seedlings per 1 m^2.

Seed rate	After 25 days from sowing		After 50 days from sowing	
(kg ha^{-1})	*Festuca pratensis*	*Lolium perenne*	*Festuca pratensis*	*Lolium perenne*
20	350	329	195	169
30	575	542	325	290
40	728	742	456	387
$LSD_{0.05}$	62.5	51.6	29.4	31.0

In the sowing year, declining proportions of *Festuca pratensis* were recorded in consecutive regrowth periods. This species is known to be subject to autumn infections of fungal pathogens such as rusts and this may affect its competitive ability. The average proportion of *Festuca pratensis* during the sowing year ranged from 18.0 % to 22.4 %, depending on the seed rate (Table 2). During the first year of utilisation, the proportion of *Festuca pratensis* in the sward yield was relatively low and the impact of the applied seed rate on this parameter was negligible. In the case of *Lolium perenne*, a consistent proportion of this species in the sward yield was observed, both in the year of sowing and during the first year of pasture utilisation. In addition, a positive correlation was observed between the proportion of *Lolium perenne* in the yield and seed rate used for overdrilling in the sowing year. Increasing the seed rate from 20 to 30 kg ha^{-1}, also increased the proportion of this species in the sward during the first year of utilisation from 28.0 % to 37.1 % respectively. A similar relationship was found in our earlier investigations on the increased seed rates used to establish new grasslands (Goliński and Kozłowski, 1996).

Increasing the seed rate of both the species did not have a significant effect on sward yields (Table 2). However, higher sward yields were recorded during the first year of utilisation where *Lolium perenne* was the introduced species. The improvement of the sward botanical composition obtained following the introduction of *Lolium perenne* exerted a significant impact on herbage quality. Over the two-year period of investigations it was found that increasing the seed rate from 20 to 30 kg ha^{-1} resulted in a significant increase in protein concentrations (from 178.5 to 190.7 g kg^{-1} DM) and a decline in ADF content (Table 3). It is worth emphasizing that much better herbage quality was obtained when *Lolium perenne* was used for pasture overdrilling than *Festuca pratensis*.

Table 2. Effect of seed rate of *Festuca pratensis* and *Lolium perenne* in pasture overdrilling on the proportion of sown species in the sward and DM yield in sowing year (SY) and first year of utilisation (U).

Seed rate (kg ha^{-1})	Proportion in sward (%)				Total yield of DM (kg ha^{-1} y^{-1})			
	Festuca pratensis		*Lolium perenne*		*Festuca pratensis*		*Lolium perenne*	
	SY	U	SY	U	SY	U	SY	U
20	18.0	9.8	32.2	28.0	4,620	9,840	4,680	10,060
30	21.0	10.0	35.4	37.1	4,950	9,760	4,430	9,900
40	22.4	9.6	38.6	37.7	4,790	9,240	4,890	10,460
$LSD_{0.05}$	1.35	ns	0.76	1.14	ns	ns	ns	ns

Table 3. Effect of seed rate of *Festuca pratensis* and *Lolium perenne* in pasture overdrilling on CP and ADF contents of the herbage (means from two years of pasture utilisation).

Seed rate (kg ha^{-1})	CP (g kg^{-1} DM)		ADF (g kg^{-1} DM)	
	Festuca pratensis	*Lolium perenne*	*Festuca pratensis*	*Lolium perenne*
20	159.5	178.5	262.6	280.3
30	157.2	190.7	284.6	260.3
40	159.0	193.3	271.2	268.4
$LSD_{0.05}$	ns	2.45	ns	2.14

Conclusions

Increasing the seed rate of *Festuca pratensis* and *Lolium perenne* used in pasture overdrilling increased the number of seedlings per unit area of both experimental grass species. In the case of *Festuca pratensis*, this failed to have a positive impact on the proportion of this species in the sward yield during the first year of pasture utilisation. However, increasing the seed rate of *Lolium perenne* from 20 to 30 kg ha^{-1} resulted in a significant increase in the proportion of this species in the sward and an improvement of herbage quality. Increasing the seed rates of *Festuca pratensis* and *Lolium perenne* from 20 to 40 kg ha^{-1} for pasture overdrilling had little effect on sward yields.

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Effect of different surface improvement measures on yield and quality of pastures in Lithuania

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Abstract

Different treatments (herbicide application, fertilisation, oversowing) were investigated in an old pasture during 2000-2002. All measures used for sward improvement significantly increased pasture yield and improved pasture botanical and chemical composition. Spraying with herbicide decreased the proportion of forbs in the sward by 11.8-13.7 %. Fertilising with 120 kg N ha^{-1} increased dry matter (DM) yield of the sward by 1.82-1.85 t ha^{-1} and decreased the proportion of forbs by 6.0-7.9 %. Additional oversowing increased sward DM yield by 0.63-0.67 t ha^{-1} and proportion of legumes by 5.5 %. N fertilisation and additional oversowing increased accumulation of crude protein in the herbage.

Keywords: pasture, oversowing, fertilisation, herbicide, yield, forage quality

Introduction

Pastures can be improved in two ways. An old pasture can be ploughed and resowed or it can be improved without ploughing. Investigations carried out in different places of Lithuania with the aim of improving pastures suggest that it is not necessary to resow pastures with 60-70 % of desirable grasses. It is possible to improve them by surface treatments (Zimkus, 1992; Butkuvienė and Zableckiene, 1997). The renovation of degraded pastures in south-west Poland with two methods of sward renovation, namely herbicide use in combination with direct drilling and full tillage, proved to be suitable. Direct drilling was a more successful method of sward renovation in terms of dry matter yield than full tillage (Wolski and Stypinski, 2001). The renovation of permanent grasslands by overdrilling into the old sward results in the incorporation of valuable grass and legume species and leads to an improvement in herbage quality and yield (Komárek and Kohoutek, 1998; Goliński and Kozlowski, 2000). Successful oversowing of legumes results in similar yields to grass sward fertilised with 60 and sometimes even 120 kg N ha^{-1} (Frame, 1992; Zimkus, 1995). Legumes also ensure an ecologically cleaner environment and enrich fodder with protein.
Researches in many countries have shown that one way to increase pasture productivity is by fertilising with mineral fertilisers, especially with nitrogen. Nitrogen fertilisers in limed pasture, regardless of phosphorus and potassium fertiliser rates, increased pasture productivity and improved forage quality. N fertilisation with 120 and 240 kg ha^{-1} increased DM yield by 2.19 and 3.38 t ha^{-1} respectively (Daugeliene, 2002).

Materials and methods

Different improvement measures were investigated in a 10-12 year old pasture where grasses were dominant. Legumes (white clover, *Trifolium repens* L.) accounted for about 10-20 % and forbs for 30-35 % (mainly dandelion, *Taraxacum officinale* L., yarrow, *Achillea millefolium* L. and creeping buttercup, *Ranunculus repens* L.). The soil was a *Hapli-Albic Luvisols (LVe-ha)*. The topsoil has a pH_{KCl} of 5.9-6.2 and contains 100-184 mg mobile P_2O_5 kg^{-1}, 104-117 mg K_2O kg^{-1} and 2.9-3.7 % humus.
Research was carried out on two different areas, one sprayed in autumn, at the beginning of the research with herbicide MCPA (3.7 l ha^{-1}), the second one not sprayed with herbicide.

On both areas, we compared 3 treatments: i) a control with no improvement measures, ii) fertilisation with 120 kg N ha^{-1}, iii) oversowing with a white clover and timothy (*Phleum pratense* L.) mixture. The seed rates of white clover (cv. 'Atoliai') and timothy (cv. 'Gintaras II') were 4 and 2 kg ha^{-1} respectively. The legume-grass mixture was sown with a disk drill straight into the pasture sward. After oversowing the weather conditions were not favourable for growth and development of seedlings.
Each treatment had four replications and was fertilised annually with 60 kg P_2O_5 and 60 kg K_2O ha^{-1} in spring. Nitrogen fertilisers (treatment receiving 120 kg N ha^{-1}) were applied in two equal applications: after the 1st and 2nd grazings.

Results and discussion

Three years' average data from both experiments are presented in this article. Results showed that spraying herbicide decreased the proportion of forbs (16.2-25.6 %) in the sward in the 1st year of use (Table 1). Legumes also suffered following spraying. However, they recovered by the 2nd year of the study when their proportions were similar in both sprayed and non-sprayed pastures. Over the three years' average data, spraying decreased the proportion of forbs in the sward by 2.0-2.2 times or 11.8-13.7 %. Applying nitrogen fertilisers also decreased the proportion of forbs in the sward. However, spraying was more effective than fertilising. Legumes died out as a result of fertilising with N.

Table 1. Effect of improvement methods on botanical composition of the sward.

Measure of improvement	Legumes (%)				Forbs (%)			
	1st year	2nd year	3rd year	3 years mean	1st year	2nd year	3rd year	3 years mean
Non-sprayed background								
Control	19.6	29.7	11.2	20.2	33.8	28.0	26.0	29.3
Fertilisation N_{120}	5.2	4.8	0.9	3.6	23.6	23.8	16.6	21.4
Oversowing	25.2	38.6	13.2	25.7	28.8	25.1	23.4	25.8
Sprayed background								
Control	1.3	30.2	20.4	17.3	8.2	19.8	18.6	15.6
Fertilisation N_{120}	0.4	1.4	1.4	1.1	7.4	10.7	10.6	9.6
Oversowing	2.0	40.4	26.5	22.9	8.8	15.0	17.4	13.7

Oversowing with legume-grass mixture increased the proportion of legume in the sward by 5.5-5.6 % (3 years mean) in both pastures. The amount of forbs was non-significantly lower in oversown swards.
Average data shows that, nitrogen fertilisation and oversowing significantly increased pasture yield (Table 2). The highest yield increase (1.82-1.85 t ha^{-1}) was obtained when fertilising with nitrogen in both sprayed and non-sprayed pastures. Oversowing increased pasture dry matter yield by 0.63-0.67 t ha^{-1}.
A significant increase in metabolisable energy was obtained when improving pasture by fertilisation with 120 kg N ha^{-1} or oversowing with a white clover and timothy mixture. The highest metabolisable energy yield (58.4-58.6 GJ ha^{-1}) was obtained with nitrogen fertilisation.
After oversowing more legumes appeared in the pasture and this increased the accumulation of crude protein. Fertilising also increased the crude protein concentration. The crude fibre concentration did not change significantly after pasture improvement by different methods.

Table 2. Effect of improvement methods on pasture yield and chemical composition.

Measure of improvement	Dry matter yield (t ha^{-1}) total	Dry matter yield (t ha^{-1}) legumes	Metabolisable energy (GJ ha^{-1})	Crude protein (g kg^{-1} DM)	Crude fibre (g kg^{-1} DM)
Non-sprayed background					
Control	4.07	0.82	41.9	120	220
Fertilisation N_{120}	5.92	0.21	58.6	128	229
Oversowing	4.70	1.21	48.4	137	218
LSD_{05}	0.11	0.02	1.13	15.2	8.2
Sprayed background					
No treatment	4.09	0.71	42.1	116	234
Fertilisation N_{120}	5.91	0.06	58.4	120	246
Oversowing	4.76	1.10	49.0	126	323
LSD_{05}	0.12	0.01	1.24	15.1	12.0

Conclusions

The results show that fertilising with 120 kg N ha^{-1} is the most effective mean to improve pastures. The DM yield increased by 1.82-1.85 t ha^{-1}.

Oversowing of white clover (4 kg ha^{-1}) and timothy (2 kg ha^{-1}) is also a good means to improve pastures. This increases not only the productivity of pasture, but also the proportion of legumes in the sward.

Fertilising with nitrogen and additional oversowing increased accumulation of crude protein in the sward.

Spraying with herbicide (MCPA, 3.7 l ha^{-1}) decreases the proportion of forbs in the sward by 2.0-2.2 times.

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Effect of light conditions and renovation method on greenness floristic changes in Falenty Palace-Park area

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Abstract

The subject of the study was the renovation of park-palace turf areas under different light conditions. Three methods of renovation (oversowing, full cultivation and intensive cutting) were compared. The turf botanical composition was assessed before renovation during the year of renovation and one year after. It was observed that light conditions influenced more turf establishment speed and method of renovation influenced more sward floristic changes. Turf improvement was faster under condition of higher sunshine.

Keywords: turf renovation, oversowing, light conditions, floristic changes

Introduction

The parks and recreational gardens arranged near the residential houses and palaces are important elements of Polish rural landscape. The persistence of the park elements in the defined area determines their environmental, landscape and cultural values. A lot of parks were totally or partially destroyed between 1945-1990 (Zaniewska *et al.*, 2000). Low and even greenness is one of the most important compositional elements and often decides the object character. The green areas in the parks are extremely difficult to keep because of differentiated photic conditions and they often require renovation (Wysocki, 1994; Rutkowska and Pawluśkiewicz, 1996). The aim of the paper was to compare the effects of different renovation methods on the floristic changes in the grass area of the Falenty Palace-Park.

Materials and methods

The grass-areas localised in the Palace-Park Complex of LRGF (IMUZ) is the object of the study. The residence was established in 17th century and rebuilt in the middle of 19th century. The former park composition scheme has significantly changed. But the composition axe, with quartering-share near the palace and singular old trees (e.g., 2 oaks with the status of nature monuments), was preserved. The present plant communities' character is determined by the large ponds surrounding the park and by constant synanthropic pression on the area.
Two study areas (P1 and P2) were chosen in the near-palace tree-row. P1 was located in an area with more intensive sunshine and less humidity (groundwater level below 100 cm). The characteristic tree stand was formed by limes. The P2 area, located near the pond, was characterised by less intensive sunshine and more humidity (groundwater level at a depth of about 60-70 cm). The tree stand was formed by English oaks. The light conditions were defined on the base of the total radiation, using a thermostat in the sunny days and an albedometer in the cloudy ones. The solar radiation intensity (T) was figured out with the following calculations: $T = 245 + 4.21 \times n$ (number of readings) for thermostat and $T = 245 + 4.21 \times n \times 0.129$ for albedometer (Table 1).

Table 1. Solar radiation intensity (T) [Wm^{-2}] of the studied grass areas.

Area	Min.	Max.	Average value
P1	417.2	604.1	506.1
P2	257.2	293.0	278.1

Three renovation methods were compared: oversowing with verticulator (A), full cultivation with rototiller (B) and grassland management with 5 cuts (C). The renovation was carried out in Spring 2002. Two mixtures of turf-grasses were used: foreign mixture produced by Barenburg company (m_1) and Polish-mixture (m_2). m_1 contained *Lolium perenne* (Figaro 16 %, Stadion 14 %), *Poa pratensis* (Nimbus 15 %) and *Festuca rubra* (Bargena 30 %, Bernica 15 %, Barskol 10 %,). m_2 comprised *Lolium perenne* (Nadmorski 50 %), *Poa pratensis* (Balin 10 %), *Festuca rubra* (Areta 10 %, Leo 20 %) and *Festuca ovina* (Spartan 10 %). The treatments were arranged in randomized blocks with 4 replications and each plot had an area of 4 m^2.

The grass-areas were investigated before the renovation and in the first and second year after renovation. The following parameters were evaluated: turf growth and overall aspect, floristic composition of the turf (botanical and gravimetrical analyses periodically during the vegetation period) and plants living forms according to Raunkiaer (1934).

Results and discussion

Table 2. The floristic composition (%) of the investigated areas' greenness before and after renovation (see text for the legend of the renovation method).

Renovation method	R*		A m_1	A m_1	Am_2	A m_2	B m_1	B m_1	B m_2	B m_2	C	C
Year		2001	2002	2003	2002	2003	2002	2003	2002	2003	2002	2003
Area P1												
Agrostis gigantea Roth.	H	7.4	0.1	-	0.2	0.7	-	0.2	-	0.4	6.4	6.6
Festuca rubra L.	H	7.4	1.1	1.0	0.9	2.2	1.9	2.8	0.5	1.4	1.3	5.3
Lolium perenne L.	H	0.6	53.3	82.8	62.9	66.2	89.4	89.2	91.3	87.2	0.4	0.9
Poa pratensis L.	H	11.3	2.4	3.2	2.9	10.4	1.3	2.5	0.1	0.4	7.1	14.4
Dactylis glomerata L.	H	8.0	6.7	4.4	5.7	5.9	0.1	0.1	0.3	1.1	9.5	15.5
Elymus repens (L.) Gould	G	16.3	1.5	0.3	0.8	0.2	1.2	0.2	0.2	0.1	6.4	5.1
Achillea millefolium L.	H	12.1	1.5	0.7	2.1	3.0	0.5	1.0	0.2	0.9	0.7	5.4
Aegopodium podagraria L.	G,H	7.2	4.7	2.5	3.7	-	0.2	-	0.5	0.2	17.0	-
Convolvulus arvensis L.	H(G)	4.0	2.8	0.3	5.0	1.1	0.6	0.2	0.8	0.5	1.1	0.6
Cirsium arvense (L.) Scop.	G	4.5	2.6	-	2.7	-	-	-	1.5	-	1.7	0.7
Urtica dioica L.	H	5.5	3.6	-	2.5	-	1.7	-	0.6	-	6.3	0.9
Others		12.2	19.7	4.8	10.6	10.3	3.1	3.8	4.0	7.8	42.1	44.6
Area P2												
Agrostis stolonifera L.	H	5.9	10.3	1.8	0.1	0.9	-	0.2	-	0.2	2.3	4.1
Festuca rubra L.	H	4.8	3.7	1.8	0.9	0.8	2.8	1.5	0.9	1.2	11.1	11.3
Lolium perenne L.	H	-	64.0	63.1	68.7	65.3	88.5	81.2	94.1	87.2	0.2	3.3
Poa pratensis L.	H	3.9	-	5.4	3.1	5.8	0.9	3.3	0.5	2.7	6.1	5.8
Dactylis glomerata L.	H	3.8	8.1	8.2	2.8	0.7	2.2	0.6	0.1	0.6	8.4	17.5
Elymus repens (L.) Gould	G	3.8	-	6.1	10.1	0.2	2.9	2.3	2.0	1.3	25.1	3.2
Phleum pratensis L.	H	3.7	4.7	0.5	4.1	-	0.1	-	0.1	0.1	2.9	1.5
Aegopodium podagraria L.	G,H	11.4	2.0	0.3	0.4	-	1.0	0.3	-	0.4	6.2	6.0
Glechoma hederacea L.	G,H	11.6	0.1	0.2	-	0.3	0.2	1.3	-	1.1	0.2	4.7
Ranunculus repens L.	H	17.5	0.1	-	0.2	0.2	0.1	-	-	0.2	1.1	1.6
Urtica dioica L.	H	6.0	-	0.1	0.5	0.1	-	-	-	-	11.6	4.1
Veronica chamaedrys L.	C	3.8	-	1.0	-	-	-	-	-	-	0.1	1.0
Equisetum arvense		5.5	-	0.3	0.3	-	-	-	-	-	0.2	0.2
Tree seedlings		3.3	-	0.4	-	-	0.3	0.1	-	-	-	-
Others		15.0	7.0	11.0	8.8	25.7	1.0	9.2	2.3	5.0	24.5	35.7

*) Raunkiaer spectrum

Before the renovation (2001) the grass area was defined as poor for representative and landscape functions. The plant species covered about 30-40 % of the soil surface, with the dominance of high and semi-high species. Despite the high biodiversity of the sward (more than 30 plant species, mainly hemicryptophytes) the proportion of grasses reached 26 (P2) to 51 % (P1; Table 2). The ruderal and scrubby species were dominant among the dicotyledons. The proportion of the recommended grass species (*Lolium perenne*, *Poa pratensis* and *Festuca rubra*) was as low as 9 (P2) to 19 % (P1).
Oversowing (A) and full cultivation (B) improved the greenness just 2 months after seeding. The renovation effect in the year of seeding was determined more by applied method than by light conditions. 70-80 % of greenness was acquired under better light conditions (P1) and by using the Polish mixture (m_2). The new grassland management (C) did not improve significantly the greenness in the first year of study, light conditions determining the results in the next year (2003). Independently of the renovation method the greenness was poorer under the shaded conditions (P2), especially in the Spring- and Fall period (15-28 % in average). In that year of study (2003) significant greenness improvement was noticed in only mown plots (C). On those plots plants species covered 60-65 % of the soil surface.
The floristic composition of the turf renovated by oversowing and full cultivation method has changed markedly just in the year of seeding (Table 2). *Lolium perenne* proportion was about 90 % in full cultivation method (B) and about 60-70 % in oversowing method (A). The seeding was advantageous for the species, which had not reached 1 % before renovation. Independently of the light conditions floristic changes were especially quick on the plots renovated by the full cultivation method. The speed of changes was determined by the light conditions in the oversowing method. The renovation only by grassland management (C) limited the dominant dicotyledonous species, but the proportion of low and semi-high grasses was not satisfying (below 30 %). A significantly higher proportion of *Dactylis glomerata* and of species which formerly occupied less than 1 % were noticed. The area with high solar radiation (P1) was characterised by especially rich greenness.
Studies on the effect of solar conditions and renovation methods on another object have shown similar results (Pawluśkiewicz and Zastawny, 2002).

Conclusions

The light conditions and the renovation method have shaped the state and the speed of greenness changes. In the first year after treatment better greenness was gained in the more intensive light conditions. The full cultivation method was better than the oversowing one, but only in the year of seeding. The floristic changes in greenness were dependent on the renovation method rather than on light conditions. A high (up to 90 %) proportion of low grasses, mainly *Lolium perenne*, was obtained just in the year of seeding, but the species number was limited. Grassland management affected the biodiversity of the sward.

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Technical and economic evaluation of oversowing technology in upland grassland

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Abstract

In Slovakia, 83 % of grasslands are situated in the upland and mountain regions. Difficult terrain, inclination and shallow rocky soils are characteristic of the working conditions and thus, they require the use of special technology and machinery equipment for grassland renovation. Over the last twenty years a range of oversowing techniques have been developed such as: row oversowing, slot oversowing, band oversowing and total (wide) oversowing.
The main objective of this paper is to compare these technologies by means of technical and economic evaluation. Technological principles, response to agri-technological requirements and working economy were analysed in 2002 and 2003. Three machine systems of no-tillage drill have been developed since 1985. Recently, the SP16 drill was evaluated in shallow rocky soils for its effectiveness and working reliability. The technical and economic evaluation is based on the operating test results of the four technologies which were carried out and compared in the upland and mountain conditions of Slovakia.

Keywords: grassland, no-tillage technologies, oversowing, shallow rocky soil

Introduction

A no-tillage technology of direct oversowing is one of the real possibilities to rejuvenate grassland production on sites with shallow rocky soils. Tillage conditions are limited by slope inclination (< 12°) and the shallow soil layer 150-200 mm (Tiley and Frame, 1988). Actually, more than 350,000 ha of Slovakian grassland is situated at such unfavourable sites.

Materials and methods

Two drill types were developed for oversowing grassland in upland and mountain regions of Slovakia: SPP-6 drill (in 2000) and SP16 drill (in 2002). The SPP-6 drill was developed for band oversowing and is equipped with six tool heads, which have replaceable L-shaped blades. The SP-16 drill is for a narrow-strip (slot) technology (Gonda, 2002). It has 16 rotavating cutting discs with replaceable carbide spikes. Both drills were compared with foreign drills VREDO 125.07.05 (the Netherlands) and HORSCH SE3 (Germany). The four different technologies of row-, strip- and band-oversowing and total (wide) oversowing were applied on shallow rocky brown soil at the co-operative farm of Smrecany (altitude 40-600 m asl, slope inclination 12°). A common grass/clover mixture (80 % grasses + 20 % white clover) was used for the four types of oversowing at a total seed rate of 40 kg ha^{-1}.

Results and discussion

Results of the compared technologies are shown in two tables: Technology costs (Table 1) and response to agricultural and technical requirements (Table 2). The parameters studied were chosen as a consequence of the soil and climatic conditions prevalent in the upland and mountain regions of Slovakia.

Table 1. Comparison of the technological and economic costs of four drill types used in direct oversowing of upland pasture.

Technology	Machinery	Ratio of engine power (kW) to working width (mm)	W_{04} productive power efficiency (ha h^{-1})	Price (EUR)	Technological costs	
					(EUR h^{-1})	(EUR ha^{-1})
Row oversowing	Tractor ZETOR-7540	57.0	-	31,010	23.74	19.79
	Drill VREDO 125.07.05	2500.0	1.20	15,973		
Slot oversowing	Tractor ZTS 123 45	90.5	-	39,346	32.68	38.91
	Drill SP 16	2400.0	0.84	15,444		
Band oversowing	Tractor ZTS 163 45	121.0	-	48,892	41.50	44.63
	Drill SPP 6	2700.0	0.93	26,649		
Total (wide) oversowing	Tractor ZTS 183 45	136.0	-	80,504	50.51	50.51
	Drill SE 3 HORSCH	3000.0	1.00	26,165		

Table 2. Evaluation of agri-technological parameters of four direct oversowing techniques (1 to 4 = best to worst).

Technology	Degradation degree of original sward	Soil conditions	Restoration of original turf (%)	Microrelief stage after oversowing	Possible contamination and erosion	Rooting conditions	Economical evaluation	Total evaluation - rank
Row oversowing	4	4	4 (5)	1	1	4	1	19-4
Slot oversowing	3	1	3 (20)	2	2	3	2	16-1
Band oversowing	2	2	2 (38)	4	4	1	3	18-3
Total (wide) oversowing	1	3	1 (100)	3	3	2	4	17-2

From the viewpoint of agricultural, technical and economical parameters given in tables 1 and 2, the compared technologies of grassland renovation are evaluated as follows:

1. Row oversowing technology is suitable for less-demanding soil conditions and unsuitable for highly degraded grassland because it only partially destroys the turf (5 %) and the microrelief stays undestroyed. However, the simplicity of the drill makes this technology low in energetic and economic requirements.
2. Slot oversowing is the most suitable for shallow rocky soils and for degraded grassland. It does not destroy the microrelief, and does not cause soil erosion or contamination of herbage. This technology is average as far as energetic and economic requirements are concerned; it is the most flexible of all the compared technologies.
3. Band oversowing technology is suitable mainly for deep soils without stones and considerably degraded grassland. It destroys turf (by 38 %) and creates very good conditions for the developing root system of oversown grass species. However, its use is not recommended on sloping sites with an inclination of more than 12°, and this is mainly due to an increased possibility of erosion. The microrelief after oversowing is considerably damaged and requires several rollings to prevent contamination of herbage by soil. The technology is economically and energetically demanding.

4. Total (wide) oversowing is suitable for the most severely degraded grassland, where total destruction of the original root system is needed, together with the creation of ideal conditions for development of a new dense sward. It cannot be used on shallow and rocky soils. Its' energetic and economic requirements are the highest of the four technologies.

Conclusions

Following the evaluation of agricultural, technical and economic parameters of the four different oversowing technologies used in upland grassland, it was concluded that the technologies were not competitive to one another but rather represented a range of choices. Each of them has advantages and disadvantages. The user should choose the technology not only according to its price and/or its universal application but also according to specific local climatic and soil conditions.

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Establishing a grass-clover sward in arable land and ploughed down grassland

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Abstract

The performance of grass-clover established (spring 2002) under four nitrogen levels and in four fields with different preceding crops was studied in Melle during the growing seasons 2002 and 2003. Nitrogen supply levels were 0, 100, 300 and 400 kg N ha^{-1} y^{-1}. Background treatments were: (1) 35 year old grassland, (2) 3 year old grassland, rotating with 3 year old arable land, (3) 35 year old arable land, and (4) 3 year old arable land rotating with 3 year old grassland. Additionally, the performance of the newly established grass-clover was compared to the 35 year old permanent grassland. Dry matter yield (DMY) in the year of establishment (2002) was lower for the four background treatments as compared to the 35 year old permanent grassland due to the spring sowing. The lowest yield under all nitrogen levels was found when grass-clover was introduced into 3 year old arable land. During the year of establishment the highest clover content was found under low N-input (= < 100 kg N ha^{-1} y^{-1}) when the sward was established in arable land. Establishing grass-clover in a ploughed down grassland keeps the clover content low. The conflict between clover performance and N-mineralisation explains the differences during the establishment year.

Keywords: resowing grassland, grass-clover, nitrogen mineralisation

Introduction

Research into grassland science in North-western Europe has moved away from maximizing the forage yield (based on a very high nitrogen input) towards a more sustainable use of nitrogen. An appropriate proportion of white clover in the sward is a prerequisite in order to benefit from the advantages of the clover. A good establishment of white clover after sowing is the first step to success. In order to guarantee the persistence of the mixture, Loiseau *et al*. (2001) recommend that the N-supplying capacity of the soil should be taken into account prior to sowing a new pasture.
We have established a mixture of perennial ryegrass (*Lolium perenne* L.) and white clover (*Trifolium repens* L.) into four fields with a different preceding crop, ranging from permanent arable land (35 years old) to permanent grassland. We studied the evolution of white clover in these different backgrounds during the first 2 seasons after establishment. In this contribution we will discuss the results of the year of establishment. During the Meeting of the European Grassland Federation, the results of the first full year after establishment will also be presented.

Materials and methods

The experiments were conducted on a sandy loam soil in Melle (11 m asl) at the experimental farm of Ghent University (Belgium). During spring 2002 we sowed a mixture of 40 kg perennial ryegrass (cvs. 'Plenty' + 'Roy') and 4 kg white clover (cv. 'Huia') in ploughed arable land and in ploughed down grassland. Part of the arable land had been arable land for 35 years (PA), part of it was arable land in a 35-year rotation of 3 year grassland – 3 year arable land (TA). Part of the ploughed grassland was permanent grassland (PG) (for 35 year) and part of it was grassland in a 35-year rotation 3 year arable land – 3 year grassland (TG). The performance of the newly established grass-clover was compared to the permanent

grassland (PGG). A part of the prepared seed bed was left uncultivated (fallow) to study the N-mineralisation of soil organic matter. The trial design was a split plot; the preceding crop being the main factor. Swards were fertilised with 0, 100, 300 and 400 N. P and K were supplied at an appropriate amount to avoid shortages. Plots were mown 5 or 6 times in 2002. DMY as well as the clover content were determined each time. At the end of the growing season the mineral N content of the soil profile (0-90 cm) was determined.
The plant available nitrogen from mineralisation was calculated as available nitrogen under fallow plots minus N amount under 0 N plots (both measured on a monthly basis).

Results and discussion

A. Dry matter (DM) yield and clover content of mixed swards of perennial ryegrass and white clover.
None of the resown swards outyielded the permanent grassland (PGG), due to the spring sowing (Table 1a). Swards established in TG were the least productive when averaged over all mineral N applications. The clover establishment and its persistence were dependent on the mineral N application rate and on the preceding crop of the newly sown plots. Under low N fertilisation (0 N, 100 N), the clover content differed significantly with the preceding crop. We found the highest clover content when the sward was established in arable plots (Table 1b).

Table 1a. DM yield (kg ha^{-1} y^{-1}) in 2002 in swards of *Lolium perenne* L. and *Trifolium repens* L. under four different N-fertilisation rates and five different preceding crops.

Preceding crop	Yield DM (kg ha^{-1} y^{-1})				
	mineral N fertilisation (kg N ha^{-1})				
	0	100	300	400	*Average*
TA	8,175^{b}	8,903^{ab}	11,503^{a}	12,901^{ab}	*10,371*
PA	7,983^{b}	10,203^{bc}	11,718^{a}	13,325^{b}	*10,807*
TG	6,133^{a}	8,213^{a}	11,253^{a}	12,118^{a}	*9,429*
PG	9,193^{b}	9,523^{ab}	11,595^{a}	12,000^{a}	*10,578*
PGG	8,529^{b}	11,280^{c}	15,154^{b}	15,389^{c}	*12,588*
Average	*8,003*	*9,624*	*12,245*	*13,147*	*10,755*

[a]values within the same column with different letters are significantly different at alfa = 0.05 (Duncan's T-Test).

Table 1b. Clover content (g kg^{-1} DM) in 2002 in swards of *Lolium perenne* L. and *Trifolium repens* L. under four different N-fertilisation rates and five different preceding crops.

Preceding crop	Clover content (g kg^{-1} DM)				
	mineral N fertilisation (kg N ha^{-1})				
	0	100	300	400	*Average*
TA	770^{c}	410^{d}	70^{ab}	40^{a}	*323*
PA	780^{c}	600^{e}	140^{b}	110^{b}	*408*
TG	210^{a}	20^{a}	0^{a}	10^{a}	*60*
PG	410^{b}	150^{c}	40^{a}	40^{a}	*160*
PGG	140^{a}	70^{bc}	60^{a}	30^{a}	*75*
Average	*462*	*250*	*62*	*46*	*205*

[a]values within the same column with different letters are significantly different at alfa = 0.05 (Duncans's T-Test).

The clover content in the sward of 0 N plots was related to the plant available N amount in the soil during the growing season (Figure 1). Arable backgrounds are characterized by a significant lower plant available N content. Averages in the period July–October 2002 were: TA 10 kg N; PA 17 kg N; PG 129 kg N and TG 142 kg N ha^{-1}.

B. Amounts of residual soil nitrate N following the grassland cultivation.

The residual soil N never exceeded the limit of 90 kg ha^{-1} (data not shown), a legally defined threshold in Flanders. The low nitrate residue found in the swards established after TG was surprising. Nevens and Reheul (2001) found a high release of mineralised nitrogen in the growing season following the ploughing-down of a 3-year old grass sward. Probably, a large part of this N was taken up by roots of the new grass sod and fixed to soil particles (Velthof and Hoving, 2003). The residual soil N at the end of 2002 under high N fertilisation (400 N) was lower in swards with a preceding arable crop than in swards with preceding grassland. About 50 to 98 % of the total residual N was present in the upper soil profile (0–30 cm).

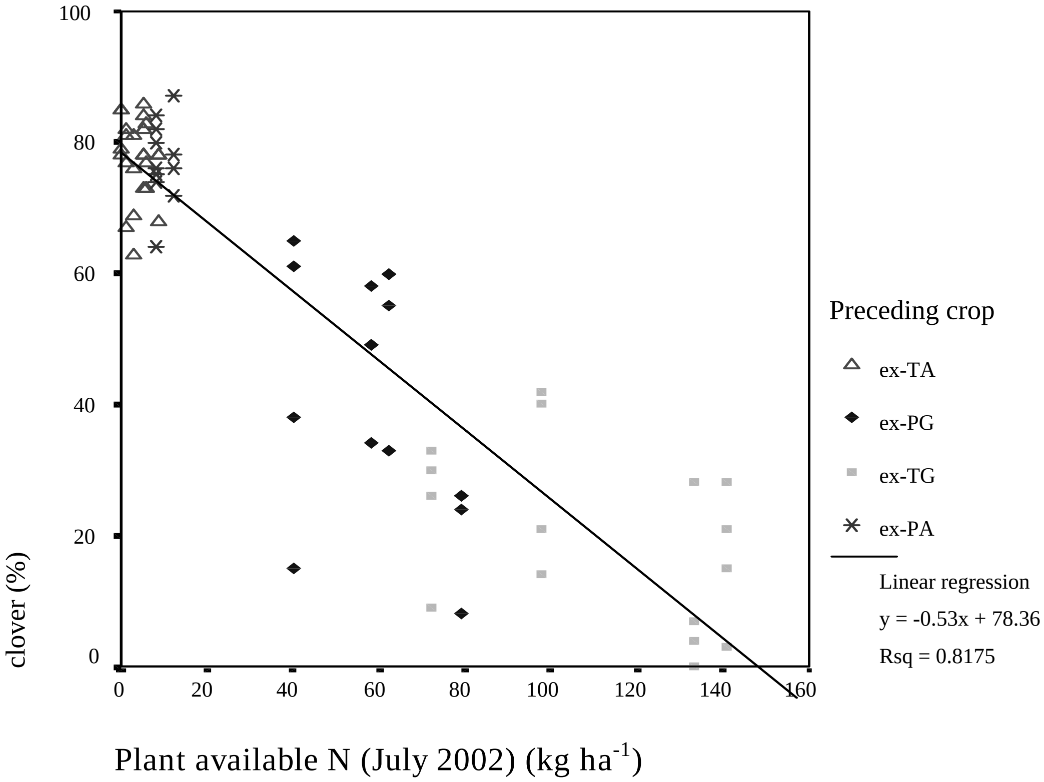

Figure 1. Clover content (% in total DM) during year of establishment of 0 N plots as a function of the plant available N in July 2002.

Conclusions

The yield performance of permanent grassland was higher than the yield performance of the newly installed swards during spring 2002. The establishment and the persistence of white clover were related to the mineralised soil nitrogen. We found the highest clover content when a sward was installed in arable land.

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Performance of potatoes established in ploughed down grassland of different ages

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Abstract

Ploughing down grassland releases nitrogen available for the following crops and / or is prone to leaching. At the experimental site of Ghent University, we installed in 2002 potatoes following three different crops: (1) 3-year old grassland (TG), (2) 35-year old grassland (PG), and (3) maize grown on permanent arable land (PA). Nitrogen levels applied to the potatoes were 0, 75 and 200 kg N ha^{-1}. The ranking of dry matter yields for potatoes fertilised with 200 kg N ha^{-1} was TG = PA > PG; the yield ranking for potatoes fertilised with 75 kg N ha^{-1} was PA < PG < TG. The nitrogen fertiliser replacement value (NFRV) for the potatoes in PG was half of the NFRV in TG. The residual NO_3-N in the soil profile was always highest after PG and lowest after PA.

Keywords: grassland, rotation, nitrogen mineralisation

Introduction

From previous research we know that 3-year old ploughed grassland releases high amounts of nitrogen (Nevens and Reheul, 2002). We demonstrated that, after ploughing down 3-year old grassland, both silage maize and fodder beet produced high yields without any supplied nitrogen. We wanted to know if the potato crop can be recommended as a first crop following ploughing down of grassland. In the research presented here, we monitored (1) the yield and quality of the potato crop, (2) the nitrogen mineralisation pattern during the growing season, (3) the final nitrogen uptake by the potato crop, and (4) the residual nitrogen in the soil profile during the autumn.

Materials and methods

The experiments were established on a sandy loam soil at the experimental farm of Ghent University in Melle (Belgium, 11 m asl). In spring 2002, we planted potatoes after forage maize grown in permanent arable land (PA) and in ploughed down grassland (spring ploughing). Part of the grassland was permanent grassland (PG) and part of it was in a rotation of 3 years arable land – 3 years grassland (TG). Permanent means 35 years. A part of the prepared seed bed was left uncultivated (fallow, bare soil) to study the N-mineralisation of the soil organic matter. The trial was of a split plot design with four replicates. The different preceding crops (PA, PG, TG) was the main factor; the N-fertilisation prior to planting (0, 75 or 200 kg N ha^{-1}) was the sub-plot factor. To avoid deficiency, P and K were applied at 80 kg P_2O_5 ha^{-1} and 250 kg K_2O ha^{-1}. Tuber dry matter (DM) yield and total N uptake by the tubers were determined at the end of the growing season. We calculated the nitrogen replacement values (NFRV) of the ploughed grassland, on the basis of quadratic response curves. At the end of the growing season the mineral N content of the soil profile (0-90 cm) was determined.
The plant available nitrogen from mineralisation was calculated as available nitrogen under fallow plots minus N under 0 N plots (both measured on a monthly basis; May-September 2002).

$Y = Sum[(N_{fallow,t} – N_{0,t}) – (N_{fallow, t-1} – N_{0,t-1})]$

Where Y is plant available nitrogen from mineralisation over the period May till September 2002; $N_{fallow,t}$ and $N_{fallow,t-1}$ is mineral N (nitrate + ammonium) content in the soil profile (0- 90 cm) under fallow plots in month t and t-1, respectively; $N_{0,t}$ and $N_{0,t-1}$ is mineral N (nitrate + ammonium) content in the soil profile (0-90 cm) under 0 N plots in month t and t-1, respectively.
The N supply was then calculated as the sum of the plant available nitrogen from mineralisation and mineral N application.

Results and discussion

1. Dry matter yield, yield responses to mineral N fertilisation and N uptake during 2002 (Table 1): On average, the DM yield ranking was TG > PG > PA.
At 200 kg N ha^{-1} PA out-yielded significantly PG which was not significantly different from TG. At 75 kg N ha^{-1} and 0 kg N ha^{-1}, TG gave the highest yields: TG out-yielded PG and PA with 5 and 18 % respectively at 75 kg N ha^{-1} and with 15 and 90 % at 0 kg N ha^{-1}.
Potatoes grown after preceding grassland took no advantage of N fertiliser application since yields did not differ significantly at 0, 75 and 200 kg N ha^{-1}.
Using a quadratic N response curve, we calculated the NFRV values of the ploughed swards to be 172 kg ha^{-1} for TG and 85 kg ha^{-1} for PG.

Table 1. Potato tuber yield (kg DM ha^{-1} y^{-1}) on the permanent arable plots (PA), on the plots after temporary grassland (TG) and after permanent grassland (PG) in 2002.

Preceding crop	Mineral N fertilisation (kg N ha^{-1} y^{-1})				
	0 N	75 N	200 N	Average	*Relative*
PA	6,855	10,982	13,084	10,317	*100*
TG	13,011	12,940	12,975	12,975	*126*
PG	11,274	12,366	11,279	11,640	*113*
Average	10,390	12,096	12,446	11,644	
Relative	*100*	*116*	*120*		

lsd (P = 0.05) within same preceding crop = 1,110 kg ha^{-1}; lsd (P = 0.05) within same mineral N fertilisation = 1,705 kg ha^{-1} (SAS Statistical Package).

Table 2. Nitrogen uptake (kg ha^{-1} y^{-1}) by potato tubers on permanent arable plots (PA), on plots after temporary grassland (TG) and after permanent grassland (PG) in 2002.

Preceding crop	Mineral N fertilisation (kg N ha^{-1} y^{-1})				
	0 N	75 N	200 N	Average	*Relative*
PA	51	111	199	120	*100*
TG	147	183	258	196	*163*
PG	157	205	230	198	*165*
Average	118	166	229	171	
Relative	*100*	*141*	*194*		

lsd (P = 0.05) within same preceding crop = 22.2 kg ha^{-1}; lsd (P = 0.05) within same mineral N fertilisation = 29.6 kg ha^{-1} (SAS Statistical Package).

Compared to PA, the average nitrogen uptake by the potato tubers was higher in TG and in PG: 63 % and 65 % respectively. The comparison with the N unfertilised plots shows that at a fertilisation rate of 75 kg N ha^{-1} on average 64 % of the applied nitrogen is recovered in the tubers; at a fertilisation rate of 200 kg N ha^{-1} on average 55 % is recovered (Table 2). Figure 1 shows the relationship between the N-supply (0-90 cm) and the N-uptake by the tubers. The slope of the relationship N-uptake/N-supply (Figure 1) illustrates that only half of the N-supply (mineralisation + external dressing) had been taken up by the potato tubers.

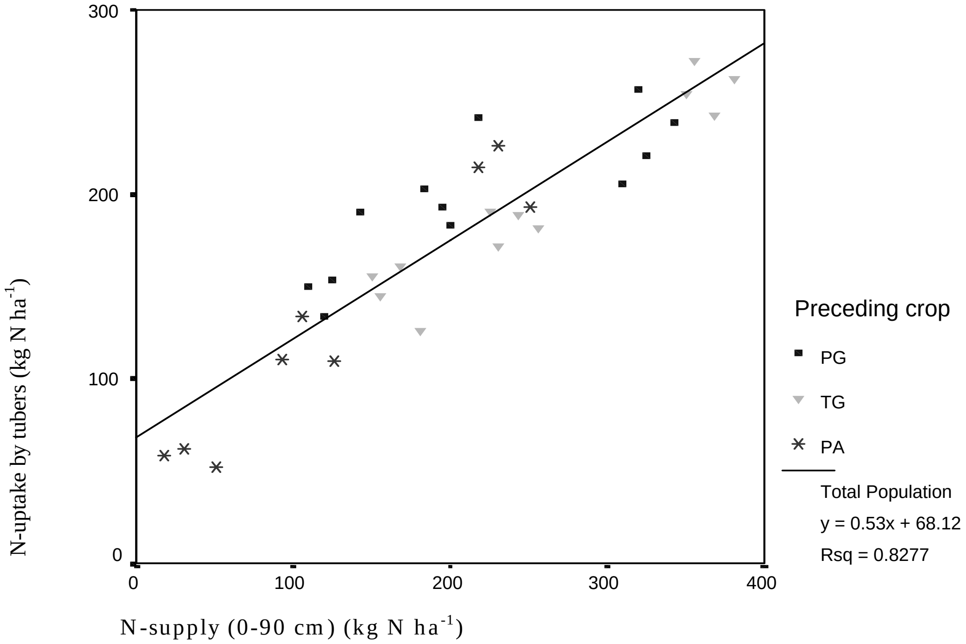

Figure 1. N-uptake by potato tubers (kg ha^{-1}) as a function of the N supply (kg ha^{-1}) in 2002.

2. Amounts of residual soil nitrate-N: In October 2002 (one month after the growth stopped), residual soil nitrate-N was very low in PA (Table 3), but we found very high figures in TG and PG fertilised with 200 kg N ha^{-1}. In all cases, more than 50 % was located in the upper zone of the soil profile (0-30 cm) (data not shown).

Table 3. Residual nitrate-N (kg ha^{-1} y^{-1}) in the soil profile (0-90 cm) on the permanent arable plots (PA), the plots after temporary grassland (TG), and after permanent grassland (PG) in October 2002.

Preceding crop	Mineral N fertilisation (kg N ha^{-1} y^{-1})			
	0 N	75 N	200 N	Average
PA	16	25	24	22
TG	49	62	102	71
PG	77	90	153	107
Average	47	59	93	66

lsd (P = 0.05) within same preceding crop = 28.7 kg ha^{-1}; lsd (P = 0.05) within same mineral N fertilisation = 20.9 kg ha^{-1} (SAS Statistical Package).

Conclusions

The less nitrogen is applied, the higher the positive yield effect of TG and PG. Both at 0 and 75 kg N ha^{-1}, TG out-yielded PG and PA. At 200 kg N ha^{-1} PA gave the highest yield.
N-supply corresponded well with the nitrogen uptake by the tubers. Owing to the high residual nitrogen concentrations in the soil profile, our preliminary results recommend potatoes should not be grown after PG.

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Effects of livestock breed and stocking rate on sustainable grazing systems: 1. Project description and synthesis of results

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Abstract

Changes in European agricultural policy, make it timely to examine the ecological and economic effects of managing extensive grazing systems primarily for biodiversity rather than primarily for efficient livestock production. In particular there is a need to ensure that appropriate grazing management systems and animal breed types are used. Management practices need to be both ecologically and economically sustainable in order to protect and enhance environment and landscape while maintaining farm incomes and sustaining rural economies. This paper and 5 related posters report initial results from an EU project based on an integrated experimental programme at 5 sites (France, Germany, Italy, Spain, UK) that examines the effects of management intensity (stocking rate) and breed of grazing animal on natural and semi-natural grassland systems. Integrated measurements of animal foraging behaviour, agronomy, animal production, botanical, structural, invertebrate and vertebrate biodiversity and socio-economic outcomes will allow a mechanistic and thus generalisable understanding of the effects of these factors within a wider systems context. Effects of breed on biodiversity outcomes have been small to date, compared with effects due to grazing intensity. Data from subsequent years are needed to confirm these results but they appear to have significant implications for the design of agri-environmental subsidy schemes.

Keywords: biodiversity, grazing, sustainability, breed

Introduction

Natural and semi-natural grazed grasslands are an important biodiversity and landscape resource in Europe but have diminished considerably in area during recent decades because of intensification of grazing or abandonment. These highly valued plant communities, the fauna that depend on them and the landscapes of which they form a part, are the subject of numerous agri-environmental and nature conservation schemes. It is important that appropriate grazing management systems and animal breed types are used in such schemes. Management needs to be both ecologically and economically sustainable, enhancing the environment and landscapes while maintaining farm incomes and sustaining rural economies. Unfortunately, the management of many schemes is based on anecdotal evidence or, at best, on empirical studies with limited applicability. There is a need for integrated study of the behavioural ecology of grazing animals, the community ecology of the grazed plants and the impacts of their interactions on other trophic levels in grassland ecosystems, to form a generalised conceptual framework for the management of this important resource.

This paper and 5 related posters report initial results from an EU Framework 5 project (QLK5-2001-00130 FORBIOBEN) based on an integrated experimental programme at 5 sites across western Europe that examines the effects of management intensity (stocking rate) and breed of grazing animal on natural and semi-natural grassland systems. Further details of the project are available at *http://www.iger.bbsrc.ac.uk/Forbioben/index.html.*

Materials and methods

The sites chosen were previously being extensively managed but not with biodiversity explicitly in mind. Such areas provide an important resource for relatively rapid restoration of biodiversity because of their lower soil nutrient status and better seed bank compared with areas with more intensive management. It was also expected that meaningful differences between treatments would be more likely within the time scale of the project if these initial conditions were used. At each site there are 3 replicate paddocks of 3 treatments. Treatment 1 is a grazing management system designed to optimise livestock production using a commercial breed but without fertiliser use. Treatment 2 is a grazing management system designed to optimise biodiversity using a commercial breed. Treatment 3 is a grazing management system designed to optimise biodiversity (same as 2) but using a traditional/rustic breed. All plots at a site were in the same initial condition at the start of the experiment. This had been created by previous management, which was similar to that adopted for treatment 1. Management systems and breed at each site are tailored to suit local conditions. The experiment will run for 3 grazing seasons.

The experimental sites are in Devon, UK (50°N, 3°W, altitude 100 m, lowland mesotrophic grassland, continuous variable stocking with growing cattle, commercial breed – Charolais × Holstein-Friesian, traditional breed – North Devon); Auvergne, France (45°N, 3°E, altitude 1,100 m, natural upland grassland, continuous fixed stocking with growing cattle, commercial breed – Charolais, traditional breed – Salers); Solling Uplands, Germany (51°N, 9°E, altitude 500 m, mesotrophic hill grassland, continuous variable stocking with growing cattle, commercial breed – Limousin × Friesian, traditional breed – German Angus); Pordenone, Italy (46°N, 12°E, altitude 400 m, natural grassland, rotational stocking with sheep, commercial breed – Finnish, traditional breed – Karst); Asturias, Spain (43°N, 5°W, altitude 1,000 m, natural heather/gorse/grassland vegetation, continuous stocking with goats, commercial breed – Cashmere, traditional breed – local).

At the British, French, German and Italian sites, stocking rates for treatments 2 and 3 are lower than for treatment 1 as these areas have lost biodiversity due to intensive grazing. At the Spanish site, treatments 2 and 3 have a higher stocking rate as the heather-gorse community in this area is undergrazed and this has reduced biodiversity. Because the Spanish site is different the accompanying posters report results only from the other 4 sites where treatments 1, 2 and 3 are designated MC (moderate stocking, commercial breed), LC (lenient stocking, commercial breed) and LT (lenient stocking, traditional breed) respectively.

Integrated measurements of animal foraging behaviour (vegetation selected, bite rate, step rate), agronomic production (herbage mass, herbage quality, live weight change, condition score), botanical diversity (from cover estimates in fixed 1 m^2 quadrats), structural heterogeneity (from both random measurements of sward surface height (SSH) and from SSH measurements along fixed transects), invertebrate (butterflies, grasshoppers and ground dwelling arthropods) and vertebrate diversity (foraging birds and lagomorphs), will allow a mechanistic and thus generalisable understanding of the effects of the treatments within a wider systems context.

In addition to the experimental programme the socio-economic implications of adopting these biodiversity-targeted systems is being studied in each of the 5 countries, by analysing the direct economic outcomes of the experimental treatments, by surveying farmer attitudes to the adoption of such systems and by using multipliers to asses the effect on the wider rural economy.

Results

Results from the first grazing season are presented in detail in the accompanying posters. Here we attempt to synthesize these results. The results relate to the first year of the experiment only and must therefore be treated with some caution. To date there is little evidence that the breed of animal used to manage grasslands will have an important effects on biodiversity outcomes. Although it is unsurprising that no effects have yet been seen on botanical diversity, it is clear that sward structural heterogeneity and invertebrate populations were not affected by breed even though they might have been expected to show treatments effects more quickly (and did show some effect of grazing intensity). Further, little direct effect of breed on animal behaviour has been evident. If these results are confirmed in subsequent years of the experiment, it can be concluded that the choice of breed in such situations should be made on the basis of other factors than their effect on biodiversity.

There is some evidence from the results of differences in economic performance of commercial and traditional breeds in some cases with traditional breeds performing less well. Taken with the general reluctance to use traditional breeds revealed by the survey of farmer attitudes, this further suggests that there is limited benefit to the use of traditional breeds. However, other factors such as the hardiness of the breeds and the availability of subsidy payments for conservation of animal genetic resources will also play a part in the decisions of farmers.

Grazing intensity effects have been more marked than breed effects to date, particularly on structural heterogeneity and on invertebrate populations, both of which would be expected to respond relatively quickly to management changes. The results show that populations and species richness of most invertebrate taxa respond favourably to reduced grazing pressure but some taxa appear respond adversely. This highlights the importance of prioritised outcome targets in agri-environmental schemes with management being targeted to achieve the most desirable of these outcomes, if necessary at the expense of others or by integrating different target outcomes at a larger spatial scale. Clearly, lower grazing intensity reduces economic output and this is one of the main reasons for farmer resistance to these systems, though they would lower intensity with appropriate subsidy regimes. Again it is important that the target biodiversity outcome is clearly understood in order to set appropriate subsidy levels.

Conclusions

Effects of breed on biodiversity outcomes have been small to date, compared with effects due to grazing intensity. Data from subsequent years are needed to confirm these results but they appear to have significant implications for the design of agri-environmental subsidy schemes.

Foraging behaviour of sheep rotationally grazing annual ryegrass (*Lolium rigidum* Gaudin)

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Abstract

The effect of rapidly changing pasture characteristics on the foraging and performance of dairy sheep were evaluated in three plots of self-reseeded annual ryegrass (*Lolium rigidum*, Gaudin) rotationally grazed during autumn-winter. Each plot was divided into three sub-plots grazed for 7 d in a 21 d grazing cycle. Five dry, non-pregnant Sarda sheep were allocated to each plot. Compressed sward height (CSH), herbage mass, herbage composition, LAI, feeding behaviour (IGER Behaviour Recorders) and intake (double weighing technique) were measured on days 1 (B), 4 (I) and 7 (E) of the grazing week on two occasions. SSH decreased linearly over the grazing period ($P < 0.01$) but green herbage mass and LAI showed a marked drop only after day 4 of the grazing week ($P < 0.05$ between E and I = B). The behavioural responses to the changing pasture characteristics were not significant in terms of grazing, ruminating or idling times ($P > 0.05$). In contrast, intake rate, total intake and estimated digestible DM intake were all affected, with significantly lower values in E than B and I ($P < 0.05$). To avoid the under nutrition of sheep, annual ryegrass pastures should not be defoliated below 60 mm CSH or 0.8 t DM of green herbage mass during slow-growth periods.

Keywords: grazing, sheep, feeding behaviour, intake, *Lolium rigidum*

Introduction

The development of long-term grazing management techniques require an understanding of plant-animal interactions. Mediterranean pastures are often based on annual grasses featuring slow growth in winter followed by a spring flush with an associated drop in nutritive value. Whilst there has been some recent research on Mediterranean annual grasses under continuous stocking (reviewed by Molle *et al.*, 2002) there is still a shortage of knowledge on the dynamics of these pastures under rotational grazing. The aim of this study was to evaluate the effect of rapid changes in the sward structure on feeding behaviour and performance of sheep rotationally grazing an annual grass-based pasture.

Materials and methods

The experiment was carried out at Bonassai farm, (NW Sardinia, Italy) on a flat calcareous soil. A 1.35 ha paddock sown in September 1998 with annual ryegrass (*Lolium rigidum*, Gaudin, ecotype Nurra) was divided into three 0.45 ha plots. Each plot was split into three homogeneous sub-plots (0.15 ha each). From November 10, 1998 to January 12, 1999 the sub-plots were grazed under a rotational scheme, with each sub-plot being grazed for 7 d in a 21 d grazing cycle. Fifteen dry, non-pregnant mature Sarda ewes weighing (means ± SEM) 46.7 ± 3.9 kg and scoring 2.68 ± 0.05 BCS units, were blocked by liveweight (LW) and randomly allocated to the three five-ewe groups. Each group was then allocated to one plot replicate. Access to pasture was 24 h daily throughout the experiment. Water points were available on each sub-plot. No supplement was offered to the sheep. Sward height (n = 30 measurements per sub-plot) using a weighted square plate and herbage mass (cutting three 0.5 m^2 quadrats per sub-plot to ground level with clippers), were measured on the days of the behaviour measurements (see below). The herbage mass was partitioned into weed and pure ryegrass which in turn was sub-sampled and divided into leaves, stems and dead matter. On the same sub-samples, LAI was measured using a planimeter. IGER behaviour recorders (IBR, Ultrasound advice, London, UK), developed by Rutter *et al*. (1997) were fitted to one ewe per group during weeks 1 and 6, on day 1 (beginning), 4 (intermediate) and 7 (end) of the grazing period. All 24 h records (N = 18) were downloaded on to a PC and analysed using 'Graze 0.8' software (Rutter, 2000) in order to measure grazing (GT), ruminating (RT) and idling time (IT). The intake rate (IR) was measured on all sheep during week 4 on days 1, (beginning), 4 (intermediate) and 7 (end) of the grazing period. Immediately after these observations the herbage selected by the sheep was hand-plucked and stored at -20 °C prior to chemical analysis. DM was measured by oven-drying the samples at 60 °C and dried sub-samples were used for CP, NDF, ADF, ADL (AOAC, 1990) and *in vitro* DM digestibility (IVDMD) using the pepsine-cellulase method. The energy value of the selected herbage, expressed as feed units (1 feed unit = 1.7 Mcal NE) and sheep requirements, were evaluated on the basis of INRA (1998) guidelines. The herbage intake was calculated as the product of IR and grazing time during 24 h. Digestible DM intake was estimated by multiplying herbage intake by IVDMD. The results were averaged per replicate and submitted to analysis of variance to test the effect of the grazing day (three levels, days 1, 4 and 7 of the grazing period) on pasture and animal response variables.

Results and discussion

As expected, sward height decreased from the beginning to the end of the grazing period (Table 1). The ryegrass green mass as well as leaf percentage and LAI decreased significantly during the grazing period ($P < 0.05$). This decrease was apparent only from day 4 in the case of green mass and LAI. An opposite trend was shown by dead matter. Weeds basically consisted of *Gramineae* such as *Avena* and *Hordeum* spp.

Table 1. Pasture characteristics and chemical composition of herbage hand-plucked samples on days 1, 4 and 7 of the grazing period.

	Day 1	Day 4	Day 7	SEM	*P* <
Sward height (mm)	74 a	63 b	53 c	2.80	0.01
Herbage mass (t DM ha^{-1})	1.15	1.29	0.72	0.11	0.09
Green herbage mass (t DM ha^{-1})	0.79 a	0.87 a	0.43 b	0.08	0.05
Weeds % DM	16.8	8.9	19.0	0.02	NS
Leaves % DM	57.4 a	41.9 b	34.4 b	0.03	0.01
Stems % DM	29.8	32.0	35.0	0.02	NS
Dead Matter % DM	12.8 a	26.1 ab	30.6 b	0.03	0.05
LAI	0.92 a	1.33 a	0.45 b	0.11	0.05
DM %	17.6	17.1	17.5	0.61	NS
OM % DM	89.4 a	89.0 a	87.1 b	0.30	0.05
CP % DM	25.1	22.3	20.5	1.08	NS
WSC % DM	9.1	12.3	14.4	1.27	NS
NDF % DM	45.3	45.0	48.7	1.12	NS
ADF % DM	20.0 a	20.9 a	22.9 b	0.45	0.01
ADL % DM	1.4 a	1.5 a	1.8 b	0.07	0.05
IVDMD %	83.8 a	81.4 a	72.6 b	1.53	0.01

Different letters following values in individual rows are significantly different at specified *P* value.

Herbage chemical composition (Table 1) showed a decrease in OM and IVDMD while NDF ($P > 0.1$) ADF and ADL increased over the grazing period, particularly after the fourth day. The behavioural data did not show any significant effect of the number of days of grazing

(Table 2). These results are in keeping with those by Penning *et al*. (1994) who found that under rotational grazing, unlike continuous stocking, sheep do not compensate for the drop in IR by increasing GT during the pasture defoliation process. Intake rate, herbage intake, digestible DM as well as net energy intake and energy balance were all affected by the number of days grazing ($P < 0.05$). In particular it is apparent that after 4 days grazing, with sward height below 60 mm, there was a dramatic fall in intake rate and in overall nutrient intake resulting in a negative energy balance. Molle *et al*. (1998) also showed a fall in herbage DM intake in lactating sheep continuously stocked at 40 mm compressed sward height as compared with counterparts grazing a pasture maintained at 60 mm sward height during winter.

Table 2. Behavioural and intake responses by non-lactating sheep on days 1, 4 and 7 of the grazing period.

	Day 1	Day 4	Day 7	SEM	*P* <
Grazing time (min d^{-1})	385	414	432	20	NS
Ruminating time (min d^{-1})	234	301	279	22	NS
Idling time (min d^{-1})	821	724	729	31	NS
Intake rate (g DM grazing min^{-1})	4.2 a	3.8 a	2.4 b	0.2	0.001
Herbage intake (g DM)	1661 a	1554 a	998 b	115	0.05
Herbage intake (g DM/LW $^{0.75}$)	86 a	81a	52 b	5.9	0.05
Digestible DM intake (g)	1397 a	1260 a	724 b	105	0.01
Crude protein intake (g)	426 a	343 a	204 b	38	0.05
Net energy intake (Feed units $head^{-1}$ d^{-1})	1.78 a	1.61 a	0.92 b	0.1	0.01
Energy balance (Feed units $head^{-1}$ d^{-1})	0.83 a	0.66 a	-0.03 b	0.1	0.01

Different letters following values in individual rows are significantly different at specified *P* value.

Conclusions

To avoid the under nutrition of sheep, annual ryegrass pastures should not be defoliated below 60 mm sward height or 0.8 t DM of green herbage mass during the slow-growth period. However longer-term studies are needed for evaluating the impact of different rotational schemes on the overall sustainability of the grazing system.

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Observed spatial and seasonal patterns of cattle activity versus simulated effects in an exclosure experiment

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Abstract

Cattle activity or grazing s.l. can be subdivided into three components: dung deposition, herbage removal (foraging or grazing s.s.) and trampling. All these actions modify vegetation. At medium or large scale, the pattern of cattle activity is generally described only as the foraging behaviour. Such a description implicitly consider grazing as the principal behaviour of the three primary activities. Our purpose was first to determine in an observational study the medium-scale distributions of dung-pat density, trampling effect and herbage removal in a mountain wooded pasture. These distributions were related to 'natural structures', such as slope, vegetation openness, cover of trees, shrubs and rock outcrops, fodder potential, and 'management-induced structures', such as distance to fence or to the nearest watering place. Results showed that the three variables describing cattle activity exhibited significantly different spatio-temporal patterns. Moreover, the relative influence of environmental factors was different for each activity. Secondly, in an exclosure experiment we simulated the fine scale effects of these factors, separately or in combination, and compared them with cattle grazing over a one-year period. Multivariate analyses of vegetation data in the first year showed an overwhelming seasonal shift and significant differences induced by treatments. Thus, grazing alone appears to be an unrealistic indicator of cattle activity and it might be necessary to consider dunging, trampling and grazing separately in spatially explicit models of vegetation dynamics.

Keywords: herbage removal, trampling, dunging, vegetation dynamics, mountain pasture

Introduction

Cattle activity or grazing s.l. can be subdivided into three components: dung deposition, herbage removal (foraging or grazing s.s.) and trampling. All these actions modify vegetation. At medium or large scale, the pattern of cattle activity is generally described only as the foraging behaviour. Such descriptions implicitly consider grazing as the principal behaviour of the three primary activities. Our purpose was first to determine in an observational study the medium-scale distributions of dung-pat density, trampling effect and herbage removal in a mountain wooded pasture and to relate these distributions to various environmental explanatory factors. Secondly, in an exclosure experiment the objective was to assess at fine scale the effects of these three factors, separately or in combination, and to compare them with cattle grazing over a one-year period.

Materials and methods

First, to determine the medium-scale distributions of cattle activities, we subdivided a paddock into a regular grid of 404 square cells of 25 × 25 m. In each cell, we collected data about cattle activities (dung-pat density, trampling effect on the ground and herbage removal) after every pasturing rotation, three times in one year. Furthermore, to relate these distributions with various environmental factors we recorded in each cell the 'natural structures' such as slope, vegetation openness, cover of trees, shrubs and rock outcrops, fodder potential, and the 'management-induced structures' such as distance to fence or to the nearest watering place. Secondly, to asses the effect of cattle activity at fine-scale, a set of controlled treatments simulating the three components was applied: (i) repeated mowing with three levels; (ii) monthly trampling with two levels; (iii) monthly manuring with a liquid mixture of dung and urine with three levels. All treatments were applied homogeneously to the entire surface of each of 40 plots (2 × 2 m) inside the exclosure during the pasturing period. Additionally, 10 plots outside the fenced area represented reference plots with regular cattle pasturing. The multivariate response of species composition was assessed three times with the point-intercept method: in first spring before the treatments, in autumn after one season of treatments and again in spring of the following year after winter rest. All these studies were conducted in the Jura Mountains of northwestern Switzerland.

Results and discussion

At medium scale, results showed that the three variables describing cattle activity exhibited significantly different spatio-temporal patterns. Many high correlations were observed between dung density and natural structures (Table 1). For each rotation, significant negative correlations occurred with slope and rock cover and positive correlations with fodder potential. Positive correlations with vegetation openness appeared only during the second rotation. At the third rotation, significant negative correlations were found for tree and shrub cover. Concerning management-induced structures, a significant positive correlation appeared with the distance to the fence at the second rotation. Tree, shrub and rock cover were significantly and positively correlated with trampling (Table 1). Conversely, this activity was negatively correlated with fodder potential and vegetation openness. Hence, a high effect of trampling was mainly found under the trees. Concerning herbage removal, only few correlations were significant (Table 1). At the third rotation, tree cover was negatively and fodder potential positively correlated with this activity. Negative correlations with distance to the fence were observed at the first and second rotations.

Table 1. Correlations between cattle activities and paddock structure (N = 393 cells). The *P*-value of the Spearman rank correlation coefficient (r_s) was corrected for spatial autocorrelation by Dutilleul (1993) procedure (* $P < 0.05$, ** $P < 0.01$ and *** $P < 0.001$). VO: vegetation openness, Tcov: tree cover, Scov: shrub cover; Fpot: fodder potential, Rcov: rock cover; DW: distance to the nearest watering place; DF: distance to the nearest fence; D: dung-pat density; T: trampling (percentage cover of bare soil), H: herbage removal; 1, 2, 3: rotation (adapted from Kohler *et al*., submitted).

	Natural structures						Management-induced structures	
	VO	Tcov	Scov	Fpot	Rcov	Slope	DW	DF
D1	0.401	-0.067	-0.229	0.152*	-0.265*	-0.476*	-0.382	0.184
D2	0.486*	-0.156	-0.208	0.232**	-0.277**	-0.537*	-0.317	0.177*
D3	0.372*	-0.202**	-0.220*	0.244***	-0.366**	-0.498*	-0.260	0.318
T1	-0.491***	0.636***	0.290***	-0.462***	0.475***	0.191	0.152	-0.051
T2	-0.494***	0.499***	0.273**	-0.380***	0.370**	0.247	0.181	-0.029
T3	-0.439***	0.465**	0.219**	-0.351***	0.366**	0.192	0.119	-0.017
H1	-0.006	0.006	0.032	-0.051	0.213	0.192	-0.032	-0.544**
H2	-0.293	0.035	0.154	-0.002	0.196	0.365	0.201	-0.189*
H3	0.127	-0.149**	0.001	0.110*	-0.071	0.095	0.021	-0.158

At fine scale, multivariate analyses of vegetation data in the first year showed an overwhelming seasonal shift and significant differences induced by treatments. Abandoned and manured plots showed the largest deviation from the cattle-grazed reference. Herbage removal, simulated by repeated mowing, appeared as the most important factor for maintaining vegetation texture. Considering plant traits (Figure 1), mowing was related to rosette species, small height and large lateral spread. On the opposite, manuring was characterized by semi-rosette species with small lateral spread and tall growth. Concerning taxonomical groups, forbs were related to abandonment, grass to manuring and legumes to trampling.

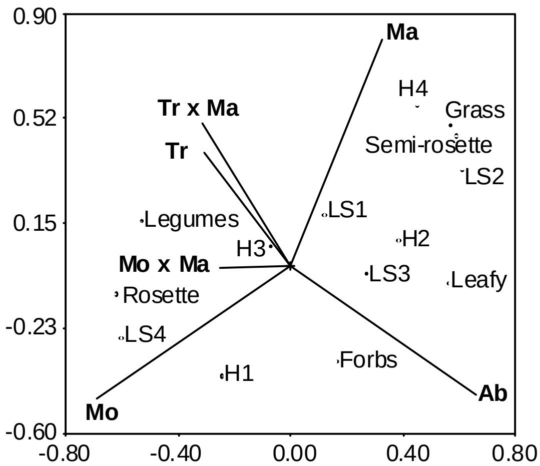

Figure 1. Scatter diagram of the Redundancy analysis of vegetation relevés made in autumn after one season of treatments. Treatments are indicated in bold (Mo: repeted mowing; Ma: manuring; Tr: trampling; Ab: abandoning). For more legibility only plant traits-arrows (included in analysis as passive species) are represented by the ending point of their vector (LS (1 to 4): lateral spread (none to large); H (1 to 4): height (small to tall)) (adapted from Kohler *et al.*, in press).

Conclusions

Because of this clear spatial and ecological segregation of patterns of the three components of cattle activity, grazing alone appears to be an unrealistic indicator of cattle activity at community or landscape scale. Furthermore, at fine scale there are clearly separate effects of the three components on vegetation dynamics. By applying homogenously the treatments on 4 m^2 plots, we artificially created large patches of mown, trampled and manured surfaces, thus decomposing the successional sequences which may occur in a cattle grazed pasture intermingled in a very fine vegetation mosaic, or else, on larger patches of pasture units. In the successive years, the cattle activity over the summer period may change spatially. This induces various dynamics of the herbaceous layer and creates a shifting mosaic.
These two results show the importance of considering dunging, trampling and grazing separately in spatially explicit models of vegetation dynamics in wooded pastures.

Acknowledgements

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Using grassland resources for dairy production with low concentrates in humid Spain

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Abstract

Traditional low input systems of dairy production based on the use of farm resources are in regression against intensive production, increasing problems of slurry management and under utilisation of grassland areas in Galicia.
Two groups of 20 Friesian cows, grazing a ryegrass-white clover sward, were studied during the whole lactation, receiving 1400 and 750 kg of concentrate, to quantify the potential of a high forage system. Milk yields of cows were 6400 and 5700 kg cow^{-1} with a similar grazing pressure of 4.0 and 3.6 cow ha^{-1} in spring. Grazing with high herbage on offer to maximise grass intake per cow, gave a mean utilisation of herbage of a 54 % with good parameters of sward quality during the lactation. After silage feeding in summer, autumn grazing in November and December increased milk yield.
The test of urea was done in each group with figures between 150-350 mg kg^{-1} showing a balanced grazing ration. It can be concluded that there is no need to be intensive as the grazing system gave similar results but at lower inputs.

Keywords: milk yield, grazing pressure, pasture management, low concentrate, urea test.

Introduction

Grazed grass is the cheapest source of nutrients for dairy herds in the humid northwest area of Spain. Grassland is the main forage crop on farms, 11 % of the region (330,000 ha), but purchased forages and concentrates are increasing mainly in the more intensive farms.
There is considerable scope to improve animal performance from diets based on grazed grass following recent improvements in the understanding of factors that influence both grass intake and digestion (Peyraud and González, 2000).
It is necessary to achieve a high level of herbage intake per animal by studying critical factors affecting intake, with maximum exploitation of the potential from grazed grass, that will improve the performance of dairy systems, reducing the quantity of concentrates required during the grazing period. When grazing is intensive, the intake is also regulated by non-nutritional factors, such as herbage availability (amount on offer, ease of browse). A leafy sward of good digestibility is essential for large voluntary intakes and high individual performances (Delagarde *et al.*, 2001).
Under practical conditions low input dairy systems need to be improved in humid Galicia by increasing the use of farm resources for milk production. With mild winters, extending the grazing season beyond the normal period, in late autumn and also early spring, can be an option for farms, as the cost of grazed grass is lower than conserved forages or concentrates. This work is part of an evaluation of parameters affecting the performance of the grazing cow during a whole lactation at two levels of concentrate.

Materials and methods

Two groups of twenty spring calving (early March) Friesian cows were maintained in an integrated grazing and cutting system on pastures of perennial ryegrass (*Lolium perenne* L.) and white clover (*Trifolium repens* L.). All cows received 6 kg of concentrates per day

(180 g CP kg^{-1}) until the groups were formed in early April. Group A received 6 kg and group B only 3 kg per cow during three grazing rotations until the end of July 2001. During the summer period all cows were housed for 100 days and fed grass silage, around 12 kg DM per cow, and concentrate 4 and 2 kg for A and B respectively. The same concentrate was maintained at turnout to grass in the autumn, using the whole area from end October until mid December. The management of the cows was the same in both groups, grazing at 15-20 cm and leaving the paddock with 5 cm. Cows stayed 2-3 days per paddock in spring. The grazing pressure, or number of cow grazing days, was used as a measure of the potential output from the pastures.
Daily milk yields per cow were recorded throughout all lactations and weekly milk samples analysed for crude protein, butterfat and the milk urea test. Pasture production was measured with pre- and post-grazing samples, using five quadrates (0.5 m^2) per paddock. Pre-grazing samples were used to determine botanical composition, by hand separation, dry matter content and analysed for crude protein, fibre contents and digestible organic matter by NIRS.

Results and discussion

Table 1 shows the milk production, fat-corrected milk (FCM), per period in both groups with different rates of concentrate, 1400 and 750 kg cow^{-1} y^{-1}. The total milk yield was 6400 and 5700 kg cow^{-1} during the whole lactation. The milk urea content was satisfactory in the range of 160 and 350 mg kg^{-1}. Low values of milk crude protein (CP) were found in spring and summer, showing perhaps some energy deficit. Milk yield and CP increased in autumn when cows returned to graze. The concentrate used represented only 220 and 130 g kg^{-1} of the milk produced in the A and B treatments. Intensive farms in Galicia are using more than 350 g kg^{-1} with milk yields of 7000 kg per cow. Intensification of dairy production increased in the last 15 years in Galicia. At the same time, the proportion of milk produced from forages has declined from 60 % to 20 %. A lack of confidence in the value of grazed pastures is generating an inefficient use of forages (Barbeyto, 1999).

Table 1. Milk yield, quality, and urea test of a dairy grazing system with two concentrate levels.

	Spring grazing		Summer (silage)		Autumn grazing		s.e. of mean
	A	B	A	B	A	B	
Concentrate (kg cow^{-1})	6.1	3.0	4	2	4	2	
Milk yield (FCM4) (kg cow^{-1})	28.7	25.5	16.1	13.5	16.2	15.9	1.11
Milk CP (g kg^{-1})	287	279	292	282	354	347	0.28
Milk urea (mg kg^{-1})	268	235	210	165	355	213	8.9
Grazing pressure (cow ha^{-1})	4	3.6	-	-	2.3	2.0	
Grass DM Intake (kg cow^{-1})	10.8	12			14.6	16.8	0.72

In this trial we tried to maintain a high herbage allowance in order to achieve the maximum intake and milk yield per cow. A stocking density of 4.0 and 3.6 cows ha^{-1} were supported by both groups respectively during the spring and 2.3 and 2.0 during the autumn. The total herbage DM on offer was 12 t ha^{-1} with low clover content, 73 % of pasture was produced in 3 rotations in the spring, with 2.5-3.5 t ha^{-1} per rotation.
The results of pasture quality seems to be good, 180 g kg^{-1} CP, 250 g kg^{-1} ADF and 780 g kg^{-1} DMO in early spring and 115 g kg^{-1} CP, 330 g kg^{-1} ADF and 760 g kg^{-1} DMO at the end of spring, despite the high allowances. In autumn these figures were 203 g kg^{-1} CP,

280 g kg^{-1} ADF and 810 g kg^{-1} DMO. The chemical results did not reflect the real maturity of the sward when pasture accumulation was observed at the end of spring.

The final percentage of utilisation was low, only 54 %. One important factor affecting that result was to maintain cows for more than one day in the paddock. Increasing herbage allowance in early season also increased residual sward height. Extra cattle were used as followers for grazing these residues at the end of spring.

When high rates of concentrate are used during the grazing period in Galicia, under utilisation of sward becomes a quite extensive problem on farms. Topping or grazing with low-producing animals is the most usual method to maintain high quality in pastures, but it is time consuming for farmers, while the home produced pasture replaces concentrates to maintain milk yield.

The mild weather in autumn and winter in the coastal area of Galicia can be exploited by dairy farms, maintaining grazing until to the end of December and less concentrate may be required at the end of lactation, as in previous experiments (González, 2003)

A good solution for farmers should be to adopt a more restricted grazing regime in spring and to feed supplementary concentrates more efficiently, trying to increase grazing pressure and at the same time to reduce concentrate feeding. A research challenge would be to develop a strategy for sward structures that ensures high intakes are maintained under the limitations of a low residual sward height. These data are helping in the development of a decision support system software in an EU project aiming to increase farmers confidence in grazing (Mayne *et al*., 2004). More information on the website *http://www.arini.co.uk/grazemore/*.

Conclusions

Dairy production could be based on farm resources; good milk yield results were obtained by grazing perennial ryegrass/white clover swards with low use of concentrates. This reduction of inputs is possible if good pasture management is observed at grazing.

The level of utilisation of herbage by the animal was low due to a high herbage allowance and a low stocking density imposed to increase forage intake per cow. The analytical parameters of pasture were good, without reflecting the importance of the characteristics of sward, like leaf content or stage of growth, when pasture was accumulated at the end of spring.

Increasing stocking density in spring is recommended to improve cow performance from grazed grass. The mild climate in late autumn permitted an extended grazing season and improved the milk output from the system.

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Improving the sustainability of milk production systems in Europe through increasing reliance on grazed pasture

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Abstract

A European Union funded research project (Grazemore) has developed a grazing decision support system (DSS) to assist dairy farmers in improving their reliance on grazed grass for milk production. Initially, a mathematical model was produced to predict seasonal herbage production from forecasted meteorological inputs and knowledge of N fertiliser inputs. A further model was then developed to predict herbage intake of grazing dairy cows, based on a wide range of plant and animal parameters. Finally, a DSS for use on dairy farms has been produced based on a plant/animal interface model derived from the grass growth and intake models. The DSS is currently being validated using data from grazing trials and will also be assessed on dairy farms throughout NW Europe in 2004.

Keywords: grazing, intake, grass growth, decision support, milk production

Introduction

Milk production systems based on a high reliance on grazed herbage offer a number of economic, animal welfare and environmental benefits. However, output from grazed grass at farm level is relatively low, reflecting the fact that full exploitation of the potential of grazed grass requires a knowledge of grass growth rates and effective grass budgeting during the grazing season. In order to encourage and facilitate increased reliance on grazed grass in the European Union, there is a need for reliable decision support systems (DSS) which will enable accurate prediction of grass growth and herbage intake for a range of soil and climatic conditions.

Materials and methods

The project involves 6 partners from 5 countries with personnel drawn from research and systems/extension groups in each country. All partners are represented on a Project Management Group which is responsible for the co-ordination of three major elements of the project:

i) Development of a European Herbage Growth Prediction Model (HGM).
ii) Development of a European Herbage Intake Prediction model (HIM).
iii) Integration of the HGM and HIM to produce a grazing management Decision Support System (DSS).

i) *Development of herbage growth model*
Following a detailed evaluation of three current grass growth models, using test data from throughout Europe, a new model has been developed based on the LINGRA model of Schapendonk *et al*. (1998). The HGM (Barrett *et al*., 2004) is a mathematical, predictive model which predicts seasonal herbage production from forecasted meteorological inputs, in addition to N fertiliser inputs. Herbage production is calculated and iterated on a daily basis, enabling estimation of herbage DM accumulation following a previous grazing or cutting. The model also enables prediction of herbage quality, in terms of organic matter digestibility (OMD) and crude protein (CP) content, as these are important parameters for prediction of herbage intake.

ii) *Development of herbage intake model*
Whilst a large number of models are available to predict food intake of dairy cows, few models have focussed on intake prediction in the grazing dairy cow. Consequently, a new model has been developed (Delagarde *et al*., 2004) based on the principle of the INRA Fill Unit System (Dulphy *et al*., 1989) but adapted for the grazing situation. The new model takes account of a wide range of animal (potential milk yield, liveweight, body condition score, stage of lactation, stage of gestation, body reserves and protein status) and plant factors (herbage allowance, pregrazing herbage mass, sward height and access time to grazing).

iii) *Development of a decision support system*
The overall objective of the DSS (Hetta *et al*., 2004) is to assist farmers in planning their grazing management through the provision of information on grass growth and intake. The DSS provides prediction of grass growth rates based on data input to the HGM, whilst also predicting the extent of grass removal through grazing (via the HGM). Inputs to the DSS include information on meteorological data and fertiliser nitrogen application, paddock size and animal characteristics and the DSS predicts growth rates, herbage intake and animal performance on a daily basis.

Results and discussion

Validation of Herbage Growth Model

The HGM was independently validated using two data sets based on grass growth monitoring at the Agricultural Research Institute of Northern Ireland and at Wageningen, the Netherlands. Results of the validation are presented in table 1.

Table 1. Validation of the herbage growth model (Barrett *et al*., 2004) against actual growth rates in Northern Ireland and the Netherlands.

	Average growth rate (kg DM ha^{-1} d^{-1})						Proportion of MSPE		
	Actual	Predicted	Bias	R^2	MSPE	MPE	Bias	Line	Random
N Ireland	50.1	47.5	-2.6	0.85	99.0	0.20	0.07	0.009	0.92
Netherlands	44.0	54.0	10.0	0.76	522.5	0.52	0.19	0.002	0.81

Detailed analysis of the results indicates reasonably good prediction of overall grass growth rate at both sites, although the model tended to over predict grass growth in the latter part of the season at Wageningen. Nonetheless the precision of the model is sufficiently accurate to enable it to be used in grass budgeting and decision support systems for grassland management.

Validation of Herbage Intake Model

A series of validation tests were undertaken on the HIM and results indicate that the model is particularly sensitive to variations in sward characteristics (herbage mass and nutritive value) but provides accurate prediction of the effect of animal characteristics (milk yield, liveweight etc.) and the interaction between plant and animal factors. For example, substitution rate (reduction in herbage intake with concentrates) increases with increasing herbage allowance from 0 to 0.8 kg herbage kg^{-1} concentrate dry matter (DM) over the range from 10 to 60 kg herbage DM allowance per cow. The model also predicted lower substitution rates (0.2 vs. 0.7 kg herbage DM kg^{-1} supplement DM with concentrates compared to forage supplements. The HIM is also able to simulate the evolution of DM intake and milk yield over the complete lactation.

Decision Support System

The grazing management DSS integrates information from the growth (HGM) and intake (HIM) models into a simulated whole farm system. The approach adopted is similar to a series of bank accounts, with the ‘accounts’ (paddocks) being replenished with grass calculated from individual growth rate (‘interest’ rates). Removal of grass through cutting or grazing acts as ‘withdrawals’ from the accounts. The DSS also takes into account the effect of other sources of feed, and the interaction between these sources, in relation to herbage intake and milk production. Initial tests of the DSS against experimental data indicate that the model can accurately simulate the whole farm situation. Further tests on farms throughout Europe are being undertaken during the 2004 grazing season.

Conclusions

A Decision Support System to assist farmers in management of grazing for dairy cows has been developed. The DSS enables farmers to predict grass growth and herbage intake of dairy cows and consequently should enable increased confidence in, and reliance on, grazed grass for milk production. This approach will be increasingly important given the current proposals for the mid term review of the Common Agricultural Policy.

Acknowledgement

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Effects of the stocking rate on steer performance and vegetation patterns on mountain pastures

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Abstract

The new Swiss agricultural policy is leading to an expansion of extensively managed areas, especially in the mountain regions. Using these areas for extensive beef production might preserve an open landscape and favour biodiversity. A grazing experiment was conducted with steers on an unfertilised mountain pasture in the Swiss Jura from 2000 to 2003. The aim was to study the effects of a reduction of stocking rate (SR) on the growth of the animals and on the evolution of the vegetation. Three SR, high, medium and low (1.8, 1.2 and 0.6 animal unit (AU) per ha, respectively), were applied. Decreasing the stocking rate lead to a longer grazing period, to a higher daily gain per animal over the whole grazing season and finally to more than doubling the cumulative live weight gain (LWG) per animal. LWG per ha was highest at 1.2 AU ha^{-1} and lowest at 0.6 AU ha^{-1}. The effect of a reduction of the SR on the botanical composition has been of limited extent up to now. At the end of the grazing season the amount of residual forage and its spatial variability were the largest in the low-SR treatment.

Keywords: Extensive grazing, beef, stocking rate, vegetation dynamics, mountain pasture, meat production

Introduction

As a consequence of increasing economic pressure on Swiss agriculture, marginal areas are threatened by abandonment, especially in the mountain regions. Using these areas for extensive beef production might preserve an open landscape and favour biodiversity.
A grazing experiment was conducted with steers on an unfertilised mountain pasture in the Swiss Jura to study the effects of a reduction of SR on the evolution of the vegetation and on the growth of the steers.

Materials and methods

The grazing experiment took place on a mountain pasture in the Swiss Jura that has not been fertilised since 1987 (Les Verrières, 1126 m asl, mean total precipitation from May to September: 675 mm, mean July temperature: 14.6 °C, vegetation dominated by *Festuca rubra* L. and *Agrostis capillaris* L.). No supplementary food was offered with the exception of minerals. The animals (crossbred steers Limousine x Red Pied) had no access to housing. The experimental area was divided into 3 sections grazed at fixed SR of 1.8, 1.2 and 0.6 AU ha^{-1} (1 AU = 600 kg liveweight). Each section was subdivided into 3 paddocks, which were grazed in rotation. The animals were blocked by weight at turnout (approximately 400 kg) and randomly assigned to SR treatments.
The rotations were synchronized for the three groups of animals on the basis of grass offer at the highest SR. However, the first and the last rotations were not synchronized because start and end of the grazing period were set independently for each stocking rate, based on grass availability.

The animals were weighed at the beginning of each rotation and at the end of the grazing period. The evolution of the sward composition was measured in the springs of 2000 and 2002 along 30 fixed lines of 10 m, using the method described by Daget and Poissonet (1969). At the end of the grazing season, the residual dry matter yield was measured by cutting the remaining biomass at a height of 2 cm with electric shears. Six, 13 and 19 samples of 1 square meter each (0.10 m x 10 m) were taken at 1.8, 1.2 and 0.6 AU ha^{-1}, respectively.

Results and discussion

The average cumulate liveweight gain (LWG) per animal is presented in figure 1. The initial average daily gains (ADG) were generally higher than 1000 g d^{-1} for all SR. This indicates adequate grass quality and quantity. As reported by Neuteboom *et al.* (1994), the herbage quality on unfertilised pastures is not necessarily a problem for animal growth in spring. Nevertheless ADG decreased drastically in summer. At the highest SR, this can be explained by a shortage of grass on offer. At the two lower SR, however, this is rather due to a reduction of the grass quality, as shown by the large patches of senescent grass caused by the imbalance between grass demand and grass offer.

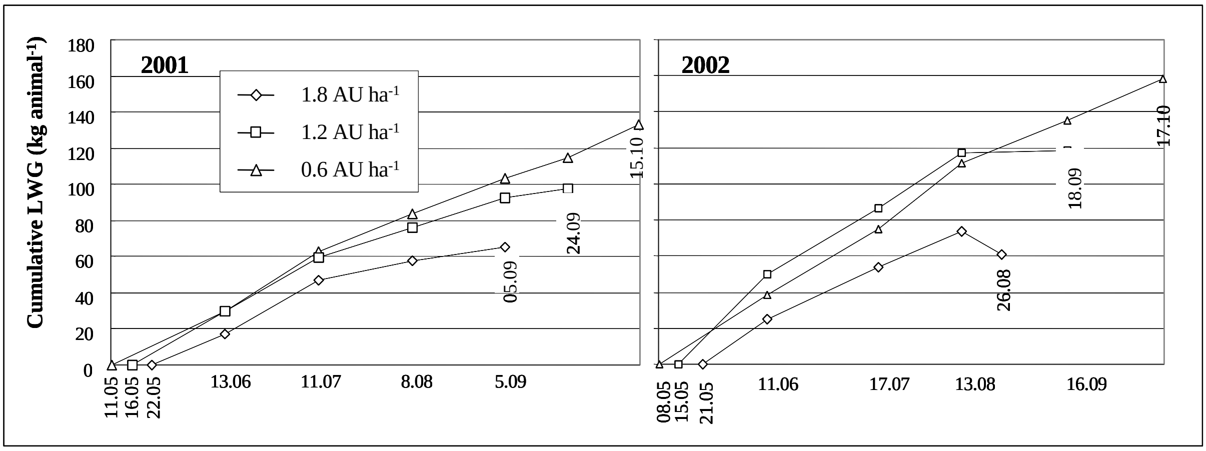

Figure 1. Cumulative mean liveweight gain (LWG) per animal at three stocking rates during the grazing period in Les Verrières (1,126 m asl).

With decreasing SR from 1.8 to 0.6 AU ha^{-1}, the length of the grazing season could be extended by 43 % and 69 % in 2001 and 2002, respectively. There was an extension of the grazing period both in spring and autumn. As a consequence, and combined with a higher ADG, the cumulative LWG per animal realised on the unfertilised mountain pasture was more than doubled in both years at 0.6 compared to 1.8 AU ha^{-1}.

At the lowest SR the proportion of the main plant groups (grasses / legumes / herbs and weeds) did not change from 2000 to 2002 (Table 1). In this treatment, there was high spatial variability of grazing pressure. In the areas where the grazing pressure was very low, the proportion of some species, e.g., *Festuca rubra*, *Dactylis glomerata* and *Ranunculus friesianus*, increased between 2000 and 2002, whereas the opposite occurred for *Cynosurus cristatus*, *Prunella vulgaris* and *Trifolium repens*. At the higher SR treatments (medium and high), the proportion of grasses decreased in favour of both legumes and herbs.

Table 1. Evolution of the botanical composition from 2000 to 2002 at three stocking rates (Les Verrières, 1,126 m asl).

	Stocking rate (600 kg AU ha^{-1})					
	High (1.8)		Medium (1.2)		Low (0.6)	
Plant group	2000	2002	2000	2002	2000	2002
Grasses (%)	74	62	73	64	72	71
Legumes (%)	5	12	6	10	7	6
Herbs and weeds[1] (%)	21	26	21	26	21	22

[1]Including *Cyperaceae* and *Juncaceae*.

The stocking rate had a marked effect on the amount and on the spatial variability of residual herbage at the end of the grazing period (Table 2). Both parameters were maximal at the lowest SR. Due to grass growth in autumn after the animals have been removed, the amount of residual herbage was higher at 1.8 than at 1.2 AU ha^{-1}.

Table 2. Amount of residual herbage at the end of the grazing season (t DM ha^{-1}) at three stocking rates in 2002 and 2003[1] (Les Verrières, 1,126 m asl; for the high SR, the values include grass growth after the animals have been removed on 26 August 2002 and 22 August 2003).

Stocking rate (600 kg AU ha^{-1})	2002 (24 October)	2003 (12 Sept. / 6 Oct.)
	t DM ha^{-1}	
High (1.8)	0.9 (0.6 – 1.9)[2]	0.6 (0.3 – 0.9)
Medium (1.2)	0.8 (0.1 – 1.5)	0.5 (0.1- 1.2)
Low (0.6)	1.2 (0.2 – 2.4)	1.3 (0.1 – 3.1)

[1] Dates of measure in 2003: 12 September at the high and medium SR, 6 October at the low SR.
[2] Values are means (minimum – maximum).

Conclusions

Up to now the reduction of the SR had a very little effect on the botanical composition of the sward. A reduction of the stocking rate had beneficial effects on the individual performance of the steers and on the duration of the grazing period.

This study tends to show that the extensive use of mountain pastures in Switzerland to fatten crossbred steers can be an interesting alternative to abandonment of these areas.

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Technical and economical evaluation of grazing systems for high altitude sheep pastures in Switzerland

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Abstract

About half of the 420,000 sheep raised in Switzerland are summered on high-altitude pastures. There are various interests in the ecologically sensitive zone of the alpine regions, such as those of agriculture and of the protection of the environment. Uncontrolled grazing could be the origin of long-term ecological damage. Little information and data exist regarding the management of high-altitude sheep pastures with fenced paddocks or by a shepherd. A grazing system with paddocks and a strict grazing rotation was studied between 2000 and 2002 on two high-altitude pastures (> 2,000 m). Electric fences were used and tested under difficult conditions. Another study carried out in 2002 on a high-altitude sheep pasture with permanent shepherding revealed that the shepherd needs a great diversity of skills and that his lodging conditions are important. The creation of paddocks and the shepherding lead to a more homogenous grazing intensity. This in turn decreases the grazing pressure on the higher levels of the pasture. The costs of these two systems were compared with the subsidies allowed by the Swiss Government.

Keywords: sheep, grazing systems, paddocks, shepherd, mountain pasture, economical evaluation

Introduction

During the last 40 years, the Swiss sheep flock has increased from 200,000 to 420,000 animals. Half of them are summered at high altitude. Since 1950, permanent shepherding has often been abandoned and replaced by uncontrolled grazing. As a consequence, the pressure on high pastures, characterized by sensitive plant communities, has increased and the vegetation is overgrazed. On the other hand, some of the surfaces in the lower parts are no more visited by sheep. Under-grazing provokes problems with shrub and then forest expansion. The solution to these problems has to be found in a better herd management, whether with permanent shepherding by a shepherd (Chatelain and Troxler, 2004a) or with the creation of paddocks and the starting of a rotational grazing system (Chatelain and Troxler, 2004b). This paper describes and compares these two alternatives and is based on results obtained during several years in the Swiss Alps. It was possible to estimate the cost and the impact of these alternative management systems on the vegetation. The trials led to recommendations for the use of fences and for permanent shepherding in high-altitude regions.

Materials and methods

Trials on the creation of fenced paddocks (rotational grazing) were carried out from 2000 to 2002 on two high-altitude pastures in Valais (Vasevay, 46°01'N, 7°21'E and Niven, 46°21'N, 7°42'E). With 248 and 800 ha respectively, the pastures in Vasevay and Niven were stocked with 750 and 1,100 sheep during 70 and 90 days. Permanent paddocks were built with electric fences on wide pastures, accessible only by foot, at altitudes varying between 2,000 and

2,400 m asl. In Vasevay, 4 paddocks were enclosed with 2,900 m of fences and by about 3,500 m of natural barriers. In Niven, the 5 paddocks were entirely enclosed with 8,800 m of fences. Fences were composed of two synthetic wires, placed at 35 and 90 cm above ground level, and of two aluminium wires, placed at 20 and 50 cm. Metal posts were fixed every 3 to 4 metres. The electrification functioned with solar captors producing 10,000 V . The botanical composition was observed on permanent plots (12.5 or 25 m^2) and the daily increase in the weight of the lambs was measured. All work and costs resulting from the installation, maintenance and removing of fences were precisely recorded.

A further study was carried out in 2002 on a 178 ha pasture situated in the heart of a glaciated valley between 1,500 and 2,500 m asl. (Trient, 46°01’N, 7°00’E). The summering lasted 110 days. A shepherd with the help of two dogs kept 630 sheep from dawn to dusk. He managed the herbage allowance according to the herd's needs during the whole season and cared for animal's health. He stayed in a caravan based below the pasture. At the higher altitudes he made use of a second caravan. However, he had to walk a long distance to join the herd in August.

Results and discussion

The work required for building, maintaining and removing 100 m of fences was almost twice as high in Vasevay (13.5 hours) than in Niven (7.6 hours) because of the uneven ground. On the other hand, thanks to the natural barriers, the required time per sheep was similar on both pastures (respectively 31 and 35 minutes in Vasevay and Niven). The costs of the system were obtained by adding the labour costs (salary: 15 € $hour^{-1}$) to the cost for the material (depreciation value: 8 years). Costs were situated between 8.7 € (Vasevay) and 10.7 € (Niven) per sheep for fences.
From mid-June to early August, the fenced paddocks were grazed successively during the first grazing rotation. In August sheep were allowed to graze freely on unfenced surfaces above 2,300 m asl Then they spent a second period on the lower paddocks till mid-September. The pasture rotation and the creation of paddocks allowed a better distribution of the stocking density and reduced the risk of over-grazing and under-grazing in relation to the free-range grazing. The grazing pressure on the lower parts of the pasture could easily be adapted to the growth of the herbage and to the quantity of herbage on offer. The grazing pressure decreased on the higher parts of the pasture. With this system of pasture rotation it was possible to achieve an optimum sward state before defoliation began. The number of plant species determined on 93 plots (41 in Niven, 52 in Vasevay) reached 212 in Niven and 249 in Vasevay with an average index of diversity (Shannon-index) of 3.3 and 3.9 respectively. The average daily gain per lamb varied between 110 and 148 g d^{-1}, a correct gain for this type of pasture.
Management with shepherding needed the full employment of one person during the whole summer. The cost for the shepherd was 90 € per day, including social taxes. The transport of the caravan by helicopter to the high altitude costs 930 €. These fixed costs are the same regardless of herd size. In Trient, the cost of a shepherd is 18 € per sheep, including 1.5 € for animal’s care. That means that the supplementary costs for the pasture management reach 16.5 €.
In June sheep grazed the lower pastures, zone after zone, under the control of the shepherd. Every evening, the flock was grouped in a night paddock. In July, animals grazed day and night more or less freely in three large areas naturally delimited by rocks. In August, the sheep grazed freely on two zones at high altitude. In September, they made a second rotation on the lower pastures.

A comparison between forage production and herd requirements shows that the stocking rate in Vasevay was rather low but there is no need to modify it. In Niven and in Trient, the stocking rate should be lower, by -5% and -35% respectively. In comparison with the vegetation development, the grazing started one week too late in Niven, four weeks too late in Vasevay and at the right time in Trient. An earlier beginning of grazing in Niven and Vasevay would require a reduction of the stocking rate.
In 2003, in order to encourage a better management of high altitude pastures in Switzerland, the Government introduced financial contributions to promote permanent shepherding and rotational grazing (Table 1).

Table 1. Subsidies for alpine sheep pasture in relation to pasture system (OFAG, 2002).

Pasture system	Subsidies per unit (€)[1] and 100 days grazing (PN)	Subsidies per sheep (€)		
		Vasevay	Niven	Trient
A Continuous grazing	80	4.5	5.9	7.6
B Rotational grazing (paddocks)	147	8.2	10.7	14.0
C Permanent guided flock	200	11.2	14.7	18.9
Difference (B - A)	*67*	*3.7*	*4.8*	-
Difference (C - A)	*120*	-	-	*11.3*

[1)] 1 PN ('pâquier normal') = 1unit grazing during 100 days, 1 unit = 600 kg liveweight, 1 sheep = 0.0861 unit.

For the two systems B and C, summering contributions cover more or less the supplementary costs. But a financial support is also available when animals graze uncontrolled on mountain pastures, so that it does not really encourage rotational grazing or shepherding. Uncontrolled grazing should no longer be supported because it is not ecologically sustainable. Contribution for fencing or shepherding should be differentiated according to the conditions prevailing on each mountain pasture.

Conclusions

Our trials showed that the fencing of large, not easily accessible and sloping surfaces is possible. Fences allowed rotational grazing management on several paddocks. Nevertheless, installation and maintenance of fences has to be carried out with care. In this case, electric wires are as efficient as wire mesh for controlling lambs and ewes. A shepherd can control a large herd with dogs in a difficult environment. However, it's necessary that the shepherd has a good knowledge of sheep, vegetation and herd management.
Both systems allow a better utilisation of the lower areas of mountain pastures and reduce the pressure on higher areas that are grazed during a short time in August. In any case, the flock's size and the grazing period have to be adapted to the available forage and to the development of the vegetation.
Fenced paddocks are more convenient for compact and homogeneous surfaces with good productivity. This system does not require permanent supervision. Continuous shepherding is well adapted to mountain pastures with dispersed areas of low productivity. In this case the lodging for the shepherd has to be assured close to the flock.

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Weight gain and vegetation preference of cattle grazing semi-natural pastures with different grazing regimes

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Abstract

The aim was to develop grazing regimes that combined the preservation of biodiversity in semi-natural grasslands with maintained animal production in circumstances where, in the future, there might be a shortage of grazing animals. A long-term multidisciplinary experiment was started to compare a conventional grazing regime with two alternatives, one in which fewer animals maintain the same area of grassland (grazing every second year), and other that promotes biodiversity of late-flowering species (late grazing). Three experimental years have been completed with the three grazing regimes using 23-29 steers. The weight gains of animals during the first two experimental years were similar in the three treatment groups, between 0.59 and 0.64 kg animal^{-1} day^{-1}, but a lower weight gain of 0.47 kg animal^{-1} d^{-1} was observed in the late grazing group during the third year.

Keywords: semi-natural pastures, grazing, cattle, preference

Introduction

The aim of the project was to develop grazing regimes which combine the preservation of biodiversity in semi-natural grasslands with maintained animal production. Special focus was put on the possible future situation of having insufficient animals to graze the pasture areas that need to be maintained, and on strategies that resemble traditional management of grasslands. Traditional management with mowing in late-July gave many vascular plants a period of undisturbed growth during which they could flower and set seeds. This traditional management has in most cases been replaced by grazing.

A long term experiment (five years) was initiated to compare conventional grazing with two alternatives in which lower numbers of animals were used to maintain the same area of semi-natural grasslands (grazing every second year) or which more closely resemble traditional management (late season grazing). Three experimental years have now been completed. This report places its focus on animal production results and will only briefly mention effects on biodiversity.

Materials and methods

Steers with no previous experience of grazing were used in the experiment. All animals were treated with anthelmintics before experiment started. Animals were weighed on five occasions: in February, at the start of the grazing season (May), after two weeks at pasture, in mid-July and at the end of the grazing season (September or October). Weight gain during the indoor period was used as a covariate for the statistical analysis. Sward height was continuously monitored every second week throughout the season in the three grazing regimes that were studied in this project. Pasture samples for laboratory analysis of nutrient content of the herbage were collected at the same time.

The three treatments in the experiment are listed below and shown in figure 1.

1. Conventional grazing – continuous grazing with a decrease in grazing pressure as the season progresses (paddock C, Figure 1).
2. Grazing every second year –grazed conventionally every second year and left ungrazed the year in between (paddock A and B, Figure 1).
3. Late grazing – grazing only during the second half of the season (from late July) in selected paddocks combined with conventional grazing in other paddocks (paddocks D and E, Figure 1).

<table>
<tr><td rowspan="2">Paddock A and B
Two paddocks grazed as conventional every second year and left ungrazed in the intervening year</td><td rowspan="2">Paddock C
Conventional grazing (grazing every year)</td><td>Paddock D
Conventionally grazed until mid-July.</td><td>Paddock E
Late grazing
May-July: 0 steers</td></tr>
<tr><td colspan="2">Late July: Gate between paddock D and E is opened. More animals (non-experimental) added to the group.</td></tr>
</table>

Figure 1. Design of grazing treatments and paddocks in the experiment.

In reality, the semi-natural paddocks used were not the same size, as suggested by figure 1, and were heterogeneous with regard to the amount of trees, bushes and rocks. Grazing pressure was approximately 2 animals hectare^{-1} of grass sward in the paddocks, as averaged over the entire season.

Results and discussion

Animal production

Three experimental years have now successfully been completed. The three grazing regimes and animal weight gains are presented in table 1.

Table 1. Number of animals in the treatment groups, average live weight (kg) at turn-out and weight gain (g animal^{-1} day^{-1}) of steers in different treatment groups during the first three experimental years, least square means (LSM) and standard errors (SE)[1].

Treatment	No. of steers	Live weight (kg)	Weight gain at pasture, g animal^{-1} and d^{-1}							
			First two weeks		Early season		Late season		Season average	
		Mean	LSM	SE	LSM	SE	LSM	SE	LSM	SE
2001[2]										
Conventional grazing	5	321	-945	296	373	85	908	76	642	48
Late grazing	11	357	-1091	203	519	59	734	52	629	33
2002										
Conventional grazing	6	286	-1192	263	436	76	886	68	623	42
Late grazing	11	280	-811	193	448	56	909	50	642	31
Grazing every second year	12	286	-951	185	414	53	838	48	592	30
2003										
Conventional grazing	5	291	-2407	287	310	83	803[a]	74	534[ab]	46
Late grazing	8	302	-2798	232	417	67	528[b]	60	466[a]	37
Grazing every second year	10	305	-2478	203	468	59	772[a]	52	606[b]	33

[1]Means in the same column and year with different superscripts differ ($P < 0.05$)

[2]Effects of grazing a paddock that was ungrazed the previous season could not be evaluated in the first year.

During 2001 and 2002, the weight gain of animals on the treatments 'late grazing' and 'grazing every second year' were not significantly different to those on the conventional grazing regime. However, during 2003 weight gain of the animals on the 'late grazing' treatment was significantly lower than the gain on other treatments during the latter part of the grazing season. The low weight gain after mid-July, in combination with a high weight loss in early season, led to a lower average weight gain over the whole season for this group compared with the animals on the 'grazing every second year' regime. It is likely that the low weight gain in the 'late grazing' group was due to a combination of low energy content in the late season pasture and a low sward height (Table 2).

Table 2. Sward height and energy content of pasture in the three treatment groups. Average over the grazing season during three experimental years (least square means and standard errors).

	Sward height[1] (cm)			Metabolisable energy (MJ kg^{-1} DM)		
	2001	2002	2003	2001	2002	2003
Conventional grazing	3.7	4.8 [a]	4.6 [a]	10.1	9.8 [a]	9.9 [a]
Late grazing	4.7	5.2 [a]	4.4 [a]	9.6	9.3 [ab]	9.2 [ab]
Grazing every second year		5.9 [b]	5.8 [b]		8.7 [b]	8.8 [b]
Standard error	0.32	0.20	0.13	- [2]	0.22	0.31

[1]Measured with a rising plate meter (Holmes, 1974).
[2]2001 no standard error due to samples pooled for analysis over early and late season.
[a,b]Values with different superscripts differ ($P < 0.05$).

A study of animal preference was also included in the experiment during the late season of 2002. The question was to what extent animals would choose to graze the low quality herbage in the 'late grazing' area (paddock E), which was available in high quantities, and to what extent the animals would choose to graze the high quality pasture regrowth that was present in smaller quantities in the continuously grazed area (paddock D). The results from these behaviour studies showed that the animals, to a high degree, preferred to graze where there was a large quantity of herbage, i.e., on the late grazed area. However, the sward height in continuous paddock was fairly low and the difference in energy content between the two areas during the late season was smaller than expected, energy content was 9.1 and 8.6 MJ kg^{-1} DM in the continuous and 'late grazing' area, respectively.

The similar weight gains in the three treatment groups during two of the three years indicate that the alternative grazing regimes were comparable with conventional grazing with regard to animal production results. However results from the last year indicate that during certain years, late grazing can give a combination of a short pasture and herbage with a low energy content during the second part of the grazing season. This in turn can lead to lower animal weight gains. The last two years of the experiment will hopefully give more conclusive results on whether production results on the late season grazing regime is lower than the other treatments.

Biodiversity
Data from the first three years showed that the alternative grazing regimes, 'late grazing' and 'grazing every second year' have had favourable effects on flowering and fruit production of vascular plants in the experimental areas (Wissman, 2003).

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Growth dynamics and pasture yield in a protected mountain area of southern Italy (Pollino Park)

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Abstract

This paper reports the results of a trial carried out during a three year period (1999-2001) on land abandoned for over ten years and used as a pasture, in a representative area (1,150 m asl) of a part of the Pollino District. Every year the maximum daily growth intensity occurred in June (more than 100 kg ha^{-1} d^{-1}) pointing out an elevated production potentiality, also under intensive utilisation represented by a cut every 28 days. The utilisation period was 110 days in the best year, and in any case, the grazing period was longer than two months. The floristic analysis confirmed the presence of a sufficiently high number of species of high pasture value, even after three years of intensive utilisation. In conclusion, the results point out the possibility of effective valorisation by intensively grazing the natural grass covering of abandoned land.

Keywords: Mediterranean mountain pasture, pasture growth, pasture yield, Pollino Park

Introduction

Pastures represent a fundamental feature of landscape and economy of the mountain areas of southern Apennines, particularly of protected areas as natural parks. Therefore, in such areas, it can be suitable to valorise abandoned lands turning them into sheep and/or goat pastures; in fact these animals show a high ability to use the fodder resources, often limited, of southern mountain and hilly environments (Basso *et al.*, 1991; De Falco *et al*., 2002). Nevertheless, the productivity of these formations is strongly reduced by the climatic conditions which determine a very short period favourable to grass growth (De Falco *et al.*, 1992). This research was carried out to evaluate the possibility to valorise and to optimise the management of abandoned lands in protected mountain areas and looking at their possible utilisation as sheep and/or goat pasture.

Materials and methods

The research was carried out during the three-year period 1999-2001 on land abandoned for more than ten years and used as a pasture. The field was situated at Terranova del Pollino (PZ), in a representative area of a large part of the territory of the Pollino National Park, at 1,150 m asl (Figure 1). The latitude puts the Pollino district in a Mediterranean climatic environment (humid and rainy in winter, hot and dry in summer), but at middle and high altitudes (above 1,000 m asl) the climate shows temperate-oceanic features with frequent summer showers and snowy winters. The trial was conducted on a loam soil, with neutral reaction and a medium content of exchangeable potassium and phosphorous anhydride, rich in organic matter and with a slope of 3 %. Every year the study of grass growth was carried out from the beginning of the spring vegetative regrowth to the winter vegetative stop, with repeated cuts every 28 days according to the methodology suggested by Corrall and Fenlon (1978), and with the weekly harvest of the grass from different plots in sequence, with four replications. For each sample the epigeous biomass production and the dry matter were determined by taking samples from an area of 4 m^2. The obtained data were subjected to variance analysis. During the spring-summer vegetative cycle of the third year, at the flowering of the greater part of the species (first ten days of July), floristic surveys were carried out according to the Braun-Blanquet methodology, both in the area subjected to repeated cuts and in the area external to the trial. Precipitations during the experimental period (from May to October) were equal to 307 mm in 1999, 368 in 2000 and 234 in 2001. The rainfall distribution was different in the three years and the last two years especially diverged from the thirty-year average: in fact 2000 was marked by a very high summer rainfall (97 mm), while 2001 was marked by the absence of rainfall starting from the first ten days of June. The average temperatures were 18.3 °C in 1999, 17.5 °C in 2000 and 19.2 °C in 2001.

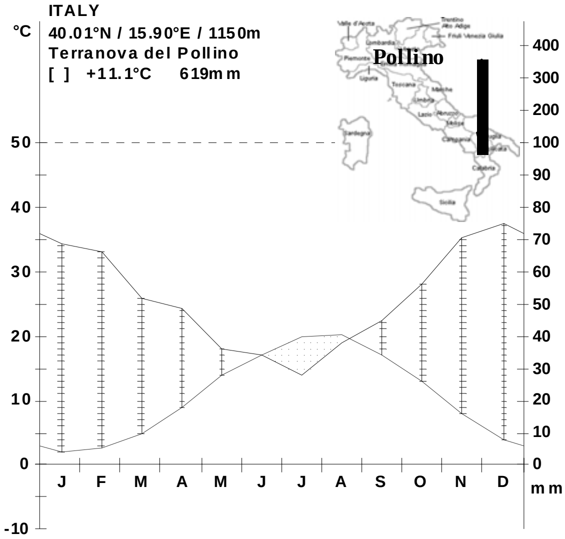

Figure 1. Geographic location and climatic characteristics of the experimental site trial.

Results and discussion

In every year, the grass growth (Figure 2) occurred in the first ten days of May, with very high daily increments between the first and the last decade of June, when the maximum value was reached, without any significant difference among the years (108.7 kg ha^{-1} d^{-1} on average). Afterwards, the daily grass growth rate decreased very rapidly reaching values lower than 10 kg ha^{-1} d^{-1} from the end of July in 1999 and 2001. In the second year, as a consequence of the summer rainfall, the daily growth rate remained higher than this value until the second decade of September. So the years differed in the length of the utilisation period (days with growth rate higher than 10 kg ha^{-1}d^{-1}) and the highest value was registered in the second year (Table 1). The dry matter accumulation (Figure 3) was much higher in the second year, according to the better pluviometric pattern as regards to the other years, reaching the maximum value of 5.58 t ha^{-1} during the first August decade.

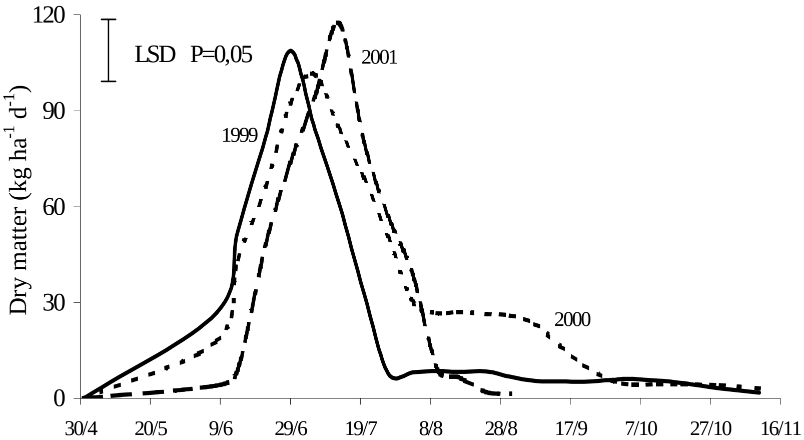

Figure 2. Rate of daily growth of pasture dry matter.

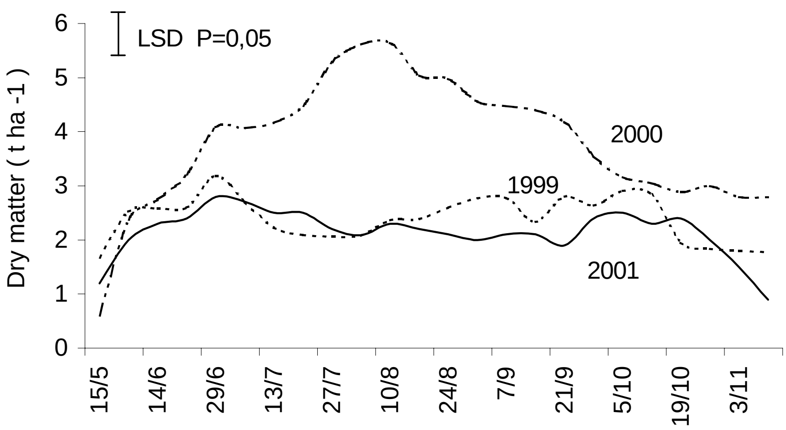

Figure 3. Dry matter accumulation for the experiment period.

Table 1. Days of utilisation.

year	days (n.)
1999	80
2000	110
2001	76
LSD	*6*

Table 2. Floristic composition related to edible species at the end of the three years period (Braun-Blanquet method).

Edible species	palatability[1]	coverage	
		simulated pasture	pasture on site
Anthyllis vulneraria	5		+
Cichorium intybus	5	+	1
Hordeum vulgare	5	2	
Medicago sativa	5		+
Poa trivialis	5	3	2
Trifolium incarnatum	5		+
Trifolium repens	5		2
Vicia gr. cracca	5		+
Achillea millefolium	4	+	+
Avena fatua	4		2
Daucus carota	4	1	1
Hippocrepis ciliata	4	+	+
Lotus corniculatus	4	+	
Medicago lupulina	4	+	+
Phleum hirsutum	4	3	3
Poa nemoralis	4		1
Potentilla erecta	4	+	+
Brachypodium pinnatum	3	2	3
Geranium rotundifolium	3	+	
Poa bulbosa	3		1
Scabiosa crenata	3	1	2
Dactylis hispanica	1		2

(1) Innamorati et al.1989

The floristic composition determined after three trial years on the plots cut every 28 days underlined the presence of a sufficiently high number of pasture species (n = 13); nevertheless this number was lower than that one checked in the area external to the field of the trial and subject to free pasture (n = 19), as is reported in table 2. From the data it is also possible to observe that the palatability of the species was generally high.

Conclusions

The results confirmed the high influence of the thermal-pluviometric pattern on the grass growth and on the length of the possible pasture utilisation. In fact the utilisation days were 110 in the best year and about 20 days less in the other years. In any case they were equivalent to a grazing period longer than two months. Moreover in all years, the maximum daily growth rate reached very high values (more than 100 kg ha^{-1} d^{-1}) pointing out an elevated production potentiality also under intensive utilisation as represented by the cut every 28 days. The floristic analysis confirmed the presence of a sufficiently high number of species of high pasture value, even after three years of intensive utilisation. Finally the results point out the possibility of effective valorisation by intensively grazing the natural grass covering of abandoned land. Further research could study the possibility of increasing the productivity of the pastures by good agronomical practices.

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Utilisation of the grassland potential in the Sudeten for cattle and sheep grazing

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Abstract

The production and utilisation of pastures grazed by cattle and sheep were compared in the Middle Sudeten (650-700 m asl). All-day grazing by cattle and sheep in separate herds was carried in the years 1979-1982 while grazing either simultaneously or consecutively was used between 1986-1990. A rotation system was used with the division of the pasture into 7 paddocks. Stocking rates (1.8 LU ha^{-1}) were adjusted to the lowest seasonal pasture carrying capacity.
Average utilisation of pastures by cattle and sheep in separate herds was similar – over 55 %. Under mixed management simultaneous grazing gave better results (69 %). Poor utilisation of pastures in the beginning of the season (up to 50 %) was recorded in both cycles and resulted in greater invasion by weeds into the pasture sward. Pasture dry matter production ranged between 6.8 and 8.6 t ha^{-1} y^{-1}, which is sufficient to feed 3 LU ha^{-1}.

Keywords: the Sudeten, grasslands, cattle, sheep, systems of grazing

Introduction

Grasslands occupy over 42 % of agricultural lands in Polish part of the Sudeten. The absence of a market for the products of field crops means that these agricultural lands have little alternative use and grassland-based production is steadily increasing in the region. The only way to manage these grasslands is grazing by ruminants – cattle and sheep. The method and extent of grassland utilisation is important not only for the amount and quality of animal fodder but also for the role of grasslands in environmental protection.
Low-cost systems of cattle and sheep grazing were the focus of studies carried out for 30 years in the Sudeten. To avoid additional feeding, stocking rates was adjusted to the lowest carrying capacities of the pasture season (July / August). With such grazing management the problem was poor utilisation of a pasture (ca. 50 %) and increased weediness of the sward. Mixed grazing of different ruminant species is well known worldwide as a practical method of increasing grassland utilisation (Nolan and Connolly, 1977; Zizlavsky *et al*., 1996).
The paper presents a comparison of the extent of production and utilisation of pastures grazed by cattle and sheep separately and where swards were grazed by both cattle and sheep either simultaneously or consecutively.

Materials and methods

Studies were carried out in the Sudeten at an elevation of 650-700 m asl in two cycles. In the first cycle (1979-1982) cattle and sheep grazed in separate herds, in the second (1986-1990) two variants: simultaneous and consecutive systems were used for common grazing. In the simultaneous system the cattle and sheep were kept together, in the consecutive – sheep replaced cattle in particular quarters. All-day grazing without additional feeding was used in both cycles.
Rotational grazing was used in experiments with the pasture divided into 7 paddocks. The pasture was fertilised with 80 kg ha^{-1} y^{-1} K and P. Annual N dose was 120 kg ha^{-1} y^{-1} on the average. Young animals of an initial weight of 200-250 kg (cattle) and 23-30 kg (sheep) were

fed. Animal stock was adjusted to the lowest pasture carrying capacity during July / August. In the beginning of the season it was 1.8 LU ha $^{-1}$. In common grazing the ratio of cattle to sheep stock was 67 / 33 % on the average.

Grazing started in the second half of May and ended in the beginning of September. Grazing lasted 96-109 days. Grazing on a particular quarter lasted 2 days in the first rotation and 3-4 days in the next.

Pasture's utilisation was calculated on the basis of difference in herbage mass at the start of grazing and residual herbage at the and of grazing (on the each of paddock). In order to do this, 4 experimental plots (4 m^2) were selected at representative locations. Before letting animals into the paddock, the pasture on the plots were cut and weighed. For the swards under consecutive grazing management this process were carried out twice (before cattle grazing, and after it – before sheep grazing). After the animals had left the paddock, the residual sward was cut and weighed from 4 plots of 20 m^2.

Data of pasture utilisation and pasture efficiency in particular grazing systems and cycles were treated by analysis of variance.

Results and discussion

Utilisation of pastures by cattle and sheep separately (I cycle) and that under simultaneous and consecutive grazing management (II cycle) is compared in table 1.

Table 1. Pasture utilisation (%).

Rotation	I cycle		II cycle	
	Cattle separately	Sheep separately	Simultaneous grazing	Consecutive grazing
I	45	38	52	42
II	57	50	50	46
III	56	66	61	57
IV	64	70	87	75
V	58	71	89	76
Significance[a]	*	**	***	***
Mean	56	58	68	59
Significance[a]	NS		*	

[a] $P < 0.05$ *, $P < 0.01$ **, $P < 0.001$ ***, $P > 0.05$ NS.

Adjustment of stocking rate to the lowest pasture carrying capacity in July-August was the reason for a low utilisation in the spring (50 %) which increased not earlier than after the third rotation. Utilisation of the sward in the first two rotations of the I cycle was higher in the pasture grazed by cattle (45 and 57 %, respectively) than in that grazed by sheep (38 and 50 %). Fodder resources in the second half of the season were better used by sheep – up to 70 %. Under mixed grazing management better results were obtained when grazed simultaneously both in the beginning (50 % on average) and in the final rotations (up to 90 %). When cattle and sheep grazed simultaneously they had to compete for food, whereas when they were grazed consecutively pasture was wasted.

Mean utilisation of the pasture when cattle and sheep were grazed separately was similar for cattle and sheep (56 and 58 %, respectively). Where cattle and sheep were grazed together simultaneous management resulted in 9 % better utilisation.

Mean yields of dry matter in t ha^{-1} y^{-1} in particular rotations and seasons are shown in table 2. Pasture production was high in the I cycle (8.6 t ha^{-1} y^{-1}) and medium in the II (6.6 t ha^{-1} y^{-1}). These yields allow a carrying capacity of 3 LU ha^{-1}. Higher yields by 2 t ha^{-1} y^{-1} in the I cycle could have been due to more favourable weather conditions. Grazing by cattle and sheep in separate herds and where they were grazed together did not result in differences in pasture dry matter production. The amount of fodder (4.9 t ha^{-1} y^{-1} on average) remaining for sheep in consecutive grazing was high. Production in particular rotations of both cycles confirmed its uneven distribution during the pastoral season.

Table 2. Pasture efficiency (t DM ha^{-1} y^{-1}).

Rotation	I cycle			II cycle	
	Cattle in separate herd	Sheep in separate herd	Mixed grazing	Consecutive grazing-forage for cattle	Consecutive grazing-forage for sheep
I	1.96	1.89	1.52	1.58	1.26
II	2.40	2.16	1.81	1.72	1.34
III	2.07	1.87	1.43	1.49	1.09
IV	1.90	1.75	1.00	1.02	0.60
V	0.78	1.06	0.88	0.75	0.57
Significance[a]	**	**	***	***	***
Annual	8.72	8.47	6.64	6.57	4.88
Significance[a]	NS		NS		

[a] $P < 0.05$ *, $P < 0.01$ **, $P < 0.001$ ***, $P > 0.05$ NS.

All studied grazing systems resulted in increased weediness of the pasture sward. Less palatable plants like *Deschampsia caespitosa*, *Urtica dioica*, *Rumex crispus* and *Rumex obtusifolius* spread and formed stable populations. This process was greater in swards grazed by sheep and where swards were grazed alternatively by cattle and sheep.

Conclusions

The adjustment of stocking rates to pasture production in July / August led to a low utilisation of pasture in the first two rotations which affected its utilisation later in the season and over the season as a whole. Results allow for estimating fodder reserves in particular rotations and in the grazing season.

Pasture production, in spite of its differentiation, allowed for feeding ca. 3 LU ha^{-1} (Dobicki *et al*., 1999). So high animal stocking rates can not, however, be fed in the all-day grazing without harvesting fodder excess in the spring and using it for feeding in periods of low pasture production. This latter approach also prevents weed invasion.

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Effects of brushing out practice on structure and pastoral value of siliceous mountain pastures

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Abstract

A study was carried out to evaluate the effect of brushing out practice on the structure and pastoral value of mountain pastures in the Gorbeia Natural Park (Basque Country). In summer 2002, fourteen sites (eight mechanically brushed out and six unbrushed) were studied. Plant species cover and Pastoral Value were calculated for each site. Brushing out had a significant positive effect on the total cover of herbaceous species, dead organic matter and the pastoral value of grasslands, however, it significantly reduced the cover of *Carex caryophyllea*. The relative cover of the main plant species such as *Agrostis capillaris*, *A. curtisii*, *Brachypodium pinnatum*, *Festuca* gr. *rubra*, *Poa pratensis* and *Trifolium repens* was not significantly affected by this practice. Thus, brushing out can be considered a beneficial practice to improve siliceous mountain pasture due to its positive effect on herbaceous cover and Pastoral Value.

Keywords: brushing out, grassland improvement, species cover, pastoral value

Introduction

Mountain pasture systems are affected by a combination of physical and environmental factors, and herbivorous and human activities. These diverse interactions lead to high complexity ecosystems. These systems cover 30 % of the European Union surface and maintain 10 % of the European Union population. Land abandonment (i.e., livestock grazing reduction) is leading to a progressive disappearance of this type of ecosystem (Bignal and McCracken, 1996; Bignal, 1998; Ostermann, 1998; Webb, 1998; European Environmental Agency, 1999). Reduction or exclusion of grazing from these areas with a long history of grazing can be considered a disturbance (Milchunas *et al.*, 1988; West, 1993).

In the Basque Country, mountain pastures cover 20 % of the territory. As agricultural land abandonment is leading to a progressive reduction of livestock grazing in the mountainous pastures of the Basque Country, these areas undergo an encroachment of shrub layers that reduce pasture value. In order to reduce the increase of shrub layers on pastures, farmers have used different practices such as burning, brushing out or liming (Celaya *et al.,* 1992).

The aim of this study was to assess the effect of brushing on the Pastoral Value of siliceous pastures.

Materials and methods

The Natural Park of Gorbeia located in the centre of the Autonomous Community of the Basque Country covers 21,070 ha. The Gorbeia mountain is in the water divisory of the Cantabric-Mediterranean and divides the park in two climatic areas: the Atlantic influence area that belongs to the county of Bizkaia and the Mediterranean area in the county of Araba. The study was carried out in the Bizkaia area that covers 7970 ha, 48 % of the total area. The mean annual temperature is 12.6 ^{o}C and the mean annual precipitation ranges between 1126 and 1626 mm.

The study was carried out in 14 siliceous pastures (eight mechanically brushed out in Spring 2000 and six unbrushed). The average area of each site was 0.6 ha.

The sampling was done in July 2002 and plant species composition was estimated using a randomly thrown 0.5 x 0.5 m quadrat (12 times per site). In each sample, the plant species present and their cover, percentage of bare soil and dead organic matter were estimated by visual inspection. The forage value of the sites was estimated using the Pastoral Value method (Daget and Poissonet, 1971 and 1972).

Results and discussion

Brushing out had a significant effect on grassland physical structure as total cover of the herbaceous layer, bare soil and dead organic matter increased after the practice (Table 1). The relative cover of the main grasses, namely *Agrostis capillaris*, *A. curtisii*, *Brachypodium pinnatum*, *Festuca* gr. *rubra* and *Poa pratensis*, referred to as the total herbaceous cover, was not significantly affected (Table 1). Only the relative cover of *Carex caryophyllea* was significantly reduced by the treatment. However, the Pastoral Value was significantly improved after the treatment due to the significant increase of the herbaceous species, i.e., increase of their absolute cover, even if the relative cover among them was not affected.

Table 1. Grassland physical characteristics (% ground area within quadrat), main species cover (% total herbaceous cover) and ANOVA results for the brushed and non-brushed sites.

	Brushed	Not brushed	$F_{1,12}$
	Mean ± SE	Mean ± SE	
Herbaceous cover	78.63 ± 4.57	38.10 ± 13.08	10.57**
Bare soil	8.44 ± 2.38	2.50 ± 0.72	4.35*
Dead organic matter	7.45 ± 1.08	2.26 ± 0.90	12.32**
Agrostis capillaris	9.31 ± 4.38	4.54 ± 2.42	0.74
A. curtisii	27.48 ± 7.39	21.63 ± 6.78	0.31
Brachypodium pinnatum	2.85 ± 1.29	0.61 ± 0.56	2.03
Carex caryophyllea	1.41 ± 0.53	4.22 ± 1.21	5.33*
Festuca gr. *rubra*	16.81 ± 3.61	16.37 ± 4.41	0.002
Poa pratensis	2.99 ± 2.38	3.51 ± 1.73	0.03
Pastoral Value	20.78 ± 3.52	8.34 ± 3.33	6.20*

*significant at $P < 0.05$, ** significant at $P < 0.01$.

Conclusions

The positive effect of brushing out on total herbaceous layer cover was enough to improve the grassland Pastoral Value, despite not affecting the relative cover of the main herbaceous species.

Acknowledgements

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Diet selection by free-ranging beef-cattle in the Natural Park of Gorbeia (Basque Country)

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Abstract

Study of the diet of free-grazing livestock is important to understand both profits from animal production and evolution of vegetation communities. Several studies indicate that grazing controls herbage biomass on rangelands, produces a higher proportion of green material and maintains or control shrub proliferation. The objective of the current work was to study diet selection by free-ranging beef cattle in a mountain environment.

The study was carried out in two management units (Steward and Eno, 1998) of the Natural Park of Gorbeia where vegetation ranged from groves and rocky areas to open pastures and those with different degrees of shrub cover. In order to study diet selection, plant composition of vegetation communities was studied by point intercept, animal diet was analysed by faecal microhistological analysis and selection was analysed by applying the Jacobs index.

In general, cows positively selected for graminoids, negatively for dicots and showed no selection for or against shrubs, with variations throughout the grazing period. Graminoids were selected more during spring and summer. As the grazing season evolved, cows changed their selection pattern in favour of lower quality graminoids and shrubby components. Dicots were permanently selected against. The causes and management consequences of this selection pattern, and its relationship with patch selection, will be discussed.

Keywords: beef-cattle, free-ranging, point intercept, microhistology, diet selection

Introduction

The traditional livestock system of beef cattle, dairy sheep, goats and mares in the Basque Country has used mountain pastures with a mixed-grazing system. In recent years this traditional system has changed resulting in an increase in the number of cows and mares, probably because of European Agricultural Policy (milk-quotas and the extensification premium) and to a better compatibility with other economic activities.

During the mountain period the animals' diet selection is constrained by both animal and vegetation characteristics. It is necessary to identify these factors in order to improve habitat management and to better understand animal production. The objective of the current work was to study diet selection by free-ranging beef-cattle in a mountain environment.

Materials and methods

The study was carried out in two management units (Aldamiñape and Egiriñao) of the Atlantic water-shed of the Natural Park of Gorbeia (Basque Country, Northern Spain). Altitudes ranged between 900-1300 m asl and vegetation ranged from tree-covered areas (Gr), rocky scarce pasture (R), to open pastures (Op) with different degrees of shrubby cover, heath composed of open pasture and heather with a cover of less than 50 % (H) and heather-gorse-fern with more than 50 % of shrubs (HGF). The floristic composition of these communities has been described elsewhere (Mandaluniz *et al.*, 2003).

Two beef cattle herds were monitored during spring (May-June), summer (July-August), end of summer (September) and autumn (October-November) in 1997 and 1998. Fresh faecal samples were collected 2 days after daily herd location records due to the delay between ingestion and excretion (Van Soest, 1982).

The animals' diet was analysed by faecal microhistological analysis (Sparks and Malechek, 1968). Due to the complexity of the technique, 6-8 samples per season, grazing area and year were pooled for this determination. In the analysis graminoids were identified, separating the more palatable species from the less palatable ones (Sostaric and Kovacevic, 1974), dicots and shrubs, and the relative abundance of each category was calculated.

In order to study diet selection the relative abundance and vegetation availability of each community (Mandaluniz *et al.*, 2003) were related by the Jacobs selection index (Jacobs, 1974): $J = (U_i - A_i) / \{(U_i + A_i) - [2 * (U_i * A_i) / 100]\}$, where U_i is the percent of the component i observed in the faeces and A_i is the availability of the component i in each area. This index ranges from (–1) to (+1), indicating negative or positive selection, respectively, with zero meaning no selection.

Results and discussion

Mean faecal composition was: 69 ± 10 % graminoids, 10 ± 5 % dicots and 21 ± 12 % shrubs. As can be observed in figure 1, which represented the diet composition of cows in both management units, (Aldamiñape and Egiriñao) in both years of study, the proportion of dicots decreased and proportion of shrubs increased as the grazing season progressed, while the proportion of graminoids was maintained.

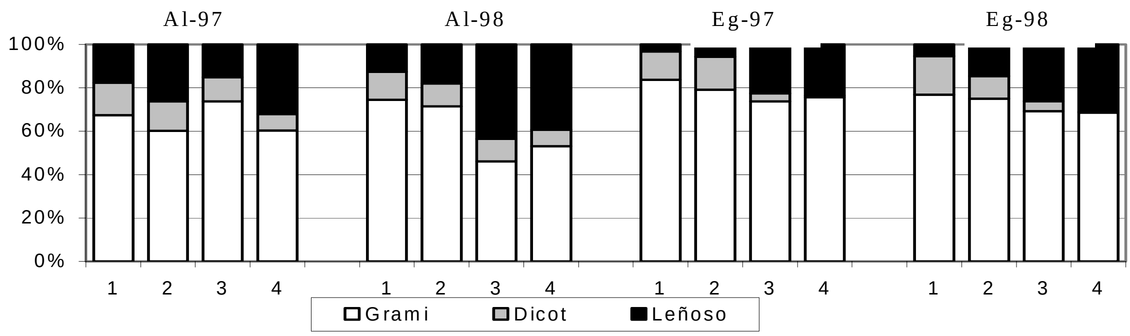

Figure 1. Diet composition of cows in Aldamiñape (Al) and Egiriñao (Eg) along the grazing seasons (1. spring, 2. summer, 3. late summer and 4. autumn) of 1997 and 1998.

As far as diet selection is concerned, cows positively selected graminoids (Figure 2). This selection coincided with a positive selection of Op and H communities with a higher availability of these components (Mandaluniz *et al*., 2003). In contrast with other authors (Holechek *et al*., 1982) dicots were negatively selected by cattle, which could be a consequence of their small vertical size, making it difficult for cattle to graze them. The selection of shrubby components, however, varied during the grazing season.

As the grazing season progressed the presence in faeces of higher quality graminoids was reduced and animals selected more positively lower quality ones and shrubby components, mainly *E. vagans*. This behaviour coincides with a reduction in selection for Op communities and an increased selection for H and HGF communities, which could be a consequence of a reduction of herbage availability (measured as grass height) in the Op community and its maintenance in the shrubby ones, (Mandaluniz *et al*., 2003).

Conclusions

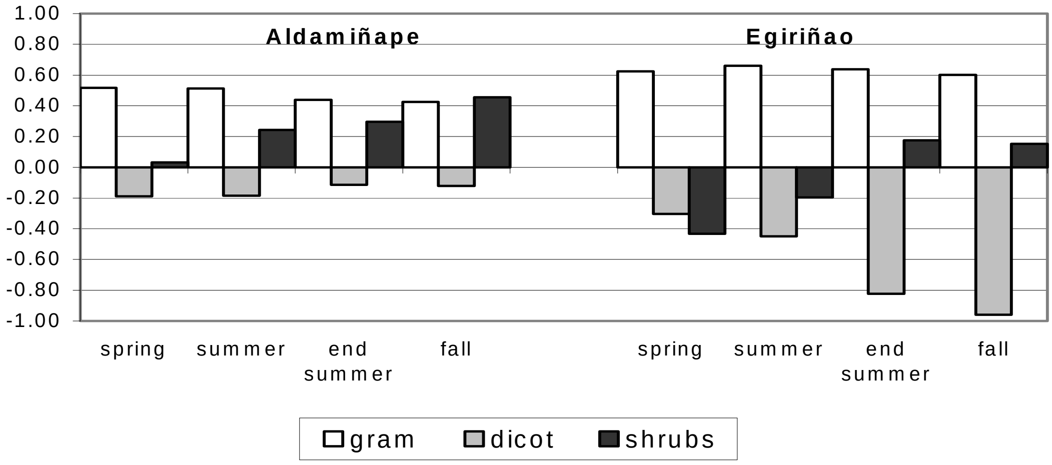

Figure 2. Evolution of diet selection (Jacobs index) along the grazing season in the two management units (Aldamiñape) and Egiriñao)

Although cows are considered as grazers, these results show their ability to distinguish between different types of graminoids and shrubs and the capacity to modify their foraging strategy according to the forage availability during the grazing season. It is very important to take into account the importance of different types of shrubby communities (ignored until now) in order to design a suitable and sustainable grazing management plan for livestock of these protected areas.

From a nutritional point of view, the ingestion of less palatable herbaceous species and shrubby components could influence the digestion kinetics (reduction in the passage rate) and on digestion with consequences for ruminal degradation and the availability of some nutrients, e.g., mineral elements that are more abundant in shrubs (Thomas, 1956).

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Mixed grazing by suckler cows and lambs on cultivated pasture

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Abstract

The influence of mixed-species grazing on herbage and animal production was studied in June-August 2003. Two grazing regimes with two replicates were used: eight Hereford suckler cow-calf pairs alone and eight suckler cow-calf pairs together with 45 male lambs. Each replication grazed on a 4.2 ha area divided into three paddocks for 83 days. The initial forage composition was 42 % timothy, 23 % meadow fescue and 18 % red clover. The lambs greatly influenced the sward structure. Cleansing cutting (topping) was not needed on the mixed-grazed pasture. The body condition of the dams was not affected by the treatment. The calves on pastures where cattle grazed alone had a better daily growth rate than those grazed together with lambs (1.26 vs. 1.09 kg head^{-1}, $P < 0.001$). However, the difference in live weight gains was considered to be of no practical importance. Herbage production was not influenced by the treatment. Mixed grazing yielded 600 kg of lamb meat without any detrimental effect on cattle performance. Although too little attention was paid to social behaviour, mixed grazing seemed to be a practical tool to increase utilisation of pasture in Finnish conditions.

Keywords: calf, cattle, forage, growth rate, live weight, sheep, sward

Introduction

The narrow profit margin of most cattle and sheep enterprises necessitates development of methods to increase the efficiency of forage use. Mixed-species grazing offers opportunities to improve pasture use. Although there has been some controversy about the value of multi-species grazing, long-term experience of mixed cattle and sheep grazing has confirmed the favourable effect on plants and animals. Nolan and Connolly (1989, 1990) found that mixed grazing of cattle and sheep increased outputs and the stock carrying capacity and had a positive effect on the occurrence of parasites. In spite of promising results, mixed grazing trials have not been carried out previously in Finland. The present study on suckler cows grazing with their offspring was undertaken to compare the cows alone with those grazing together with lambs.

Materials and methods

The experiment was carried out at MTT Agrifood Research Finland, Tohmajärvi Research Station (62°14'N, 30°21'E, 110 m above sea level) in summer 2003. The timothy (*Phleum pratense* L. cv. Iki, 65 %)-meadow fescue (*Festuca pratensis* Huds. cv. Antti, 30 %)-red clover (*Trifolium pratense* L. cv. Bjursele, 5 %) pasture was established on sandy loam in 2001. To improve pasture quality, the pasture was overseeded in May 2003 with a mixture of white clover (*Trifolium repens* L., cv. Jögeva 4, 33 %)-Alsike clover (*Trifolium hybridum* L., cv. Frida, 27 %)-meadow grass (*Poa pratensis* L., cv. Balin, 40 %) at the rate 7.5 kg ha^{-1}. The pasture area of 16.65 ha was permanently fenced and divided into two blocks, each with two treatment plots (102.5 m × 410 m). Each treatment plot was divided into three paddocks with portable electric fencing. The annual nitrogen (N) rate was 75 kg N ha^{-1}. N fertiliser was applied twice (15 May and 4-15 July). Half of the pasture area was cut for silage in June assuming that the herbage accumulated faster than the rate at which the animals could graze it. The pastures were grazed five times per season: 3-25 June, 26 June-6 July, 7-28 July, 29 July-19 August and 20-26 August.

Two grazing regimes with two replicates were used: suckler cows with their offspring alone (Treatment 1) and suckler cows with their offspring and with lambs (Treatment 2). Both replications of treatment 1 included eight Hereford suckler cow-calf pairs and both replications of Treatment 2 in addition 45 Finnish Landrace ram lambs. Each replication rotationally grazed on 4.2 ha for 83 days. One bull per group was included for service. The calves were born between 21 March-30 May. At the onset of the grazing season the calves weighed on average 89 kg (sd 21.1). The initial age of the lambs was 81 days (sd 5.3) and live weight (LW) 28.9 kg (sd 3.80). The stocking rates calculated in animal units (AU, a 500-kg cow) were 3.25 and 3.86 AU ha^{-1} in treatments 1 and 2, respectively. During the grazing, parasitological examinations in lambs and cattle were carried out. Faeces sampling was individual, on a monthly basis during weighing. The target final LW for lambs was 45 kg. Lambs were ultrasonically scanned before slaughter and slaughtered in two groups at an interval of one week. The full weights of all animals were taken at the beginning and at the end of the grazing season and every 28 days. The herbage on offer and the sward height were determined immediately before and after grazing each paddock and the feed value before grazing. The botanical composition was assessed twice, at the end of June and August. The chemical composition and feed value of the feeds and the results on parasites will be reported later.

The data were analysed using linear mixed models by the SAS/MIXED procedure. The experimental unit was the treatment plot, i.e., the correlation between animals in one plot was taken into account as Morris (1999) suggested.

Results and discussion

The pasture growth suffered from coldness in June and from drought in July. The mean temperatures during June, July and August were 10.9, 19.5 and 14.1 ^{o}C, respectively (1961-1990 averages 14.0, 15.9 and 13.5 °C, respectively) with a total precipitation of 188 mm (1961-1990 average 207 mm). At the beginning of the experiment, the pastures were composed of 42 % timothy, 23 % meadow fescue and 18 % red clover. During grazing, white clover occurred only in small amounts, but in October, based on visual evaluation, its ground cover was already over 50 % in the mixed-species pasture.

The sward surface height before and after grazing averaged 19 and 9 cm for cattle, respectively, and 15 and 5 cm for cattle and lambs, respectively. At the start of grazing the recommended sward height for cattle in Finland is 15-30 cm and under 10 cm for dense sward under continuous sheep grazing (Hodgson, 1990). The herbage on offer did not differ between the treatments (Table 1). The pre-grazing dry matter (DM) yield was in the range 1025-2455 for cattle and 939-2703 kg ha^{-1} for cattle and lambs. In July, animals in treatments 1 and 2 received in all 1085 and 2185 kg DM hay for supplemental feeding, respectively. The higher stocking rate on the pasture where cattle and lambs grazed together resulted in a lower amount of herbage remaining after grazing. However, the high grazing intensity did not impair the aftergrowth of the pasture.

There were no differences in LW gains of dams during the first 60 grazing days in June and July. In August the dams grazing alone gained more than those grazing with lambs ($P < 0.01$). The total LW increment of dams in treatments 1 and 2 averaged 52.8 and 27.8 kg ($P < 0.05$), respectively. No negative aspects were observed in the development of body condition. The calves grazing alone gained in all 15 kg more LW than those grazing with lambs (daily gain 1.26 vs. 1.09 kg $head^{-1}$, $P < 0.001$). However, the difference was considered of no practical importance. On pasture the lambs gained 15.5 kg LW and achieved their target weight at the age of 164 days (sd 5.4). The final LW averaged 45.5 kg (sd 3.97) and dressing percentage 40 (sd 1.7). The lambs produced a total of 1550 kg of meat, of which 600 kg on pasture.

Table 1. Sward height, herbage production and performance of cows and calves.

	Cattle	Cattle and lambs	SEM[1]	*P* value
Initial sward height (3 June), cm	24.6	26.5	4.3	0.15
Final sward height (26 August), cm	9.6	5.1	0.4	0.08
Herbage on offer (3 June), kg DM ha^{-1}	2455	2703	410	0.45
Herbage on offer (7 July), kg DM ha^{-1}	1052	939	312	0.31
Herbage on offer (29 July), kg DM ha^{-1}	1278	1249	235	0.81
Herbage on offer (20 August), kg DM ha^{-1}	1025	1003	55	0.80
Initial live weight of dams (3 June), kg $head^{-1}$	672	676	31.7	0.94
Final live weight of dams (26 August), kg $head^{-1}$	725	704	31.7	0.64
Initial live weight of calves (3 June), kg $head^{-1}$	91	89	6.2	0.78
Final live weight of calves (26 August), kg $head^{-1}$	196	179	6.2	0.06
Initial body condition scores[2] of dams (3 June)	3.5	3.3	0.15	0.45
Final body condition scores[2] of dams (26 August)	3.5	3.4	0.15	0.77

[1]SEM= standard error of means, [2] Scale 0-5 (0 = thin, 5 = fat, Lowman *et al*. 1976).

The animal species differed in their grazing habits. In accordance with several findings, the lambs consumed forage near dung pats, whereas the cattle rejected such vegetation. Moreover, the lambs grazed several weeds, e.g., detrimental northern dock (*Rumex longifolius* DC.) prevalent in the pasture. Cleansing cutting (topping) was not needed on the mixed-grazed pasture. Ethological observations confirmed that an acclimatisation period would have been necessary before going to pasture, i.e., the animals should have had some days together indoors to get used to each other. During the first grazing day, newly calved dams behaved aggressively towards lambs and thus cattle and lambs were separated with an electric fence for some weeks. An interesting aspect of mixed grazing was the social cohesion that gradually developed between cows and lambs. As the grazing season progressed, cattle and lambs formed a united group. It was conjectured that on pasture situated far away from habitations the dams would protect the lambs from attack by wolves and bears. Little attention was paid to the social behaviour of cattle and lambs grazing together.

Conclusions

Mixed-species grazing did not have a negative influence on herbage production or on cow performance. The influence on the calves was negligible. When suckler cows and lambs grazed together, contrary to mono-species grazing cleansing cutting (topping) was not needed. Mixed grazing with suckler cows and lambs seems to be a practical tool to improve pasture use. Social behaviour must be taken into account in a mixed grazing system.

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The effect of grazing intensity on the structure of the above ground biomass in semi-natural grassland

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Abstract

In 1990 a transformation in Czech agriculture resulted in the abandonment of large grassland areas. The aim of our investigation was to study the effects of different grazing intensity on the structure of the above ground biomass. The experiment was established in 1998 on abandoned grassland. The dominant species before the start of the study were *Agrostis capillaris*, *Alopecurus pratensis*, *Festuca rubra*, *Aegopodium podagraria* and *Galium album*. Treatments applied were: intensive grazing (IG), 1st cut and intensive subsequent grazing (ICG), extensive grazing (EG), 1st cut and extensive subsequent grazing (ECG) and the control unmanaged grassland (UM). Five years of experimentation resulted in a decrease in the dead biomass and an increase in the proportion of grasses, legumes and forbs within the managed plots. In the 0-3 cm layer of the vegetation, we observed similar biomass dry matter and proportion of grasses, legumes and forbs under all grazed treatments, but the proportion of dead biomass was different. The main differences between the treatments were found in the grazed sward above 3 cm.

Keywords: sward structure, intensive grazing, extensive grazing, abandonment

Introduction

At the beginning of 1990's, a transformation in the economy led to a decrease in the number of livestock in the Czech Republic. The total number of cattle decreased from 3,360,000 in 1990 to 1,582,000 in 2000 (Anonymous, 2001). Although some less productive grasslands were reforested, their total area increased from 833,000 ha to 961,000 ha during this period; this is because some arable fields were reseeded with grasses. As a result of these facts, there are incompatible outcomes: larger areas of grassland and an insufficient number of grazers. The aim of this study was to compare different grassland managements, focusing on sward structure in an upland area in the Jizera Mountains.

Materials and methods

The experiment was carried out from 1998 to 2002 in an experimental pasture in the Jizera Mountains, located in the northern part of the Czech Republic. The altitude of the experimental pasture is 420 m, the average annual precipitation is 803 mm and the mean annual temperature is 7.2 °C. The dominant species were common bent grass (*Agrostis capillaris*), meadow foxtail (*Alopecurus pratensis*), red fescue (*Festuca rubra*), goutweed (*Aegopodium podagraria*) and white bedstraw (*Galium album*). The pasture was continuously stocked with young heifers. The grazed experimental plots were 0.35 ha, and the unmanaged plots 0.12 ha, with two replicates for each treatment. Applied treatments were: intensive grazing (IG), 1st cut and intensive subsequent grazing (ICG), extensive grazing (EG), 1st cut and extensive subsequent grazing (ECG) and the control, unmanaged grassland (UM). Average sward heights of 5 cm within IG and ICG treatments and 10 cm within EG and ECG treatments were maintained during the grazing seasons. The above ground biomass was sampled using electric shears in 25 x 50 cm plots. The plots were cut in two layers, 0-3 cm non-grazed stubble and > 3 cm grazed sward. The sampling date was at the beginning of the grazing season in May. The biomass samples were stored in a frozen state and then separated into four plant groups (grasses, legumes, forbs and mosses) and dead biomass.

Result and discussion

Five years of experimentation resulted in a decrease in the proportion of dead biomass and an increase in the proportion of grasses, legumes and forbs within all the managed plots (Figure 1). Changes in sward structure are a result of the feeding strategy at different stocking rates (Bakker, 1989). Although the actual yield (in May) was higher on unmanaged and extensively grazed plots the total annual pasture production was higher within the intensively grazed plots and better reflected the forage growth during the vegetation season (Pavlů *et al.*, 2001). On the unmanaged and extensively managed treatments (EG, ECG), a higher yield of grass component was found. However its proportion was higher within the intensively managed treatments (IG, ICG).

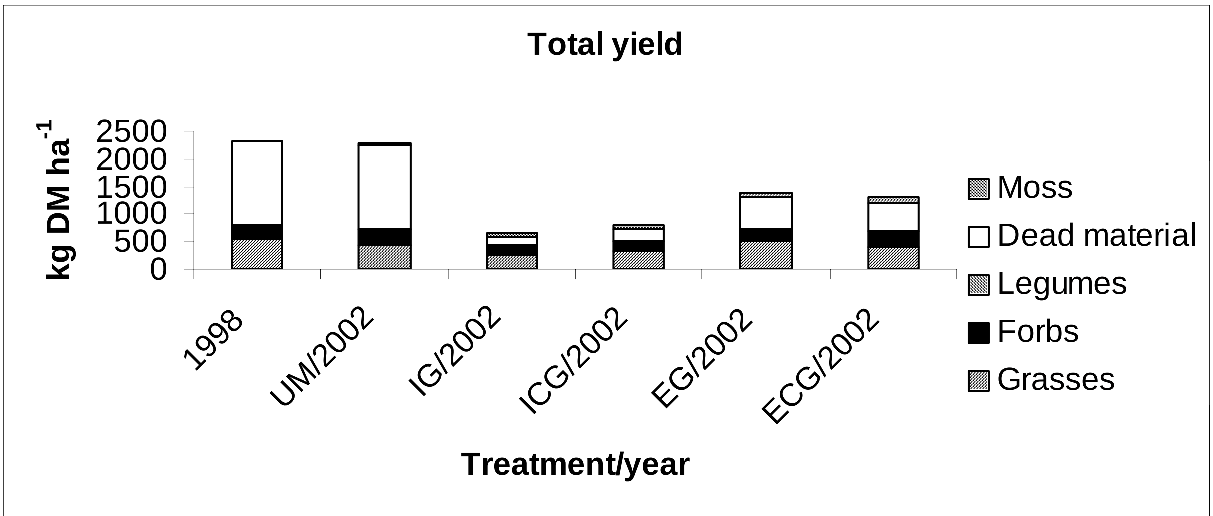

Figure 1. Yield of the different biomass components under different grazing management at the beginning of the grazing season (whole sward).

In the 0-3 cm layer we observed a similar yield of grasses, forbs and mosses within all the treatments, but significant differences in the amount of dead biomass (Figure 2). The proportion and yield of dead material decreased in all managed treatments. It represented 90 % and 60 % of total biomass in the unmanaged and extensively managed treatments respectively, whereas the lowest rate (30 %) was found in the IG treatment. More than 95 % of the total dead biomass was accumulated within the 0-3 cm layer, which is not usually grazed by cattle.

The main differences for all components studied were found within the > 3 cm layer (Figure 3). The yield of grasses was in inverse proportion to the intensity of use. There was a higher proportion of forbs in the ICG and ECG treatments, as compared to those of the grazed only. We observed a relatively higher proportion of legumes (mainly *Trifolium repens*) in the intensively managed treatments, this being a reaction to the frequent defoliation.

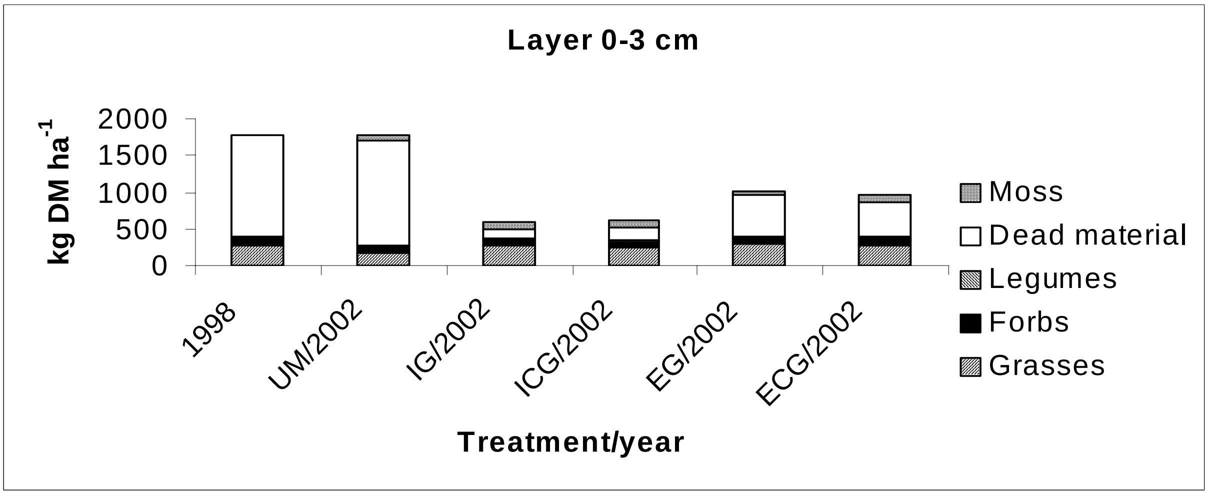

Figure 2. Yield of the different biomass components in layer 0-3 cm under different grazing management at the beginning of the grazing season.

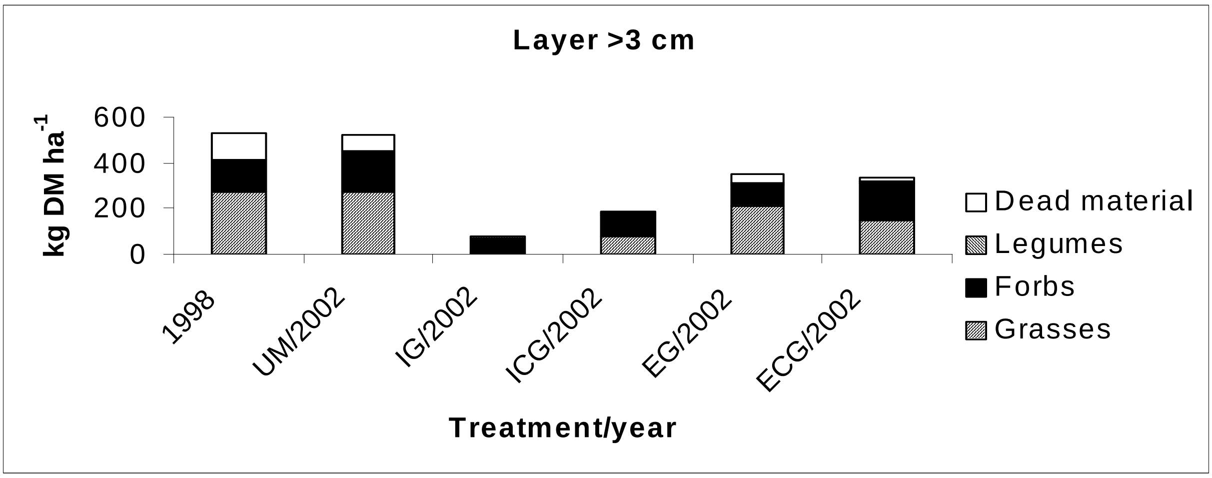

Figure 3. Yield of the different biomass components in layer > 3 cm under different grazing management at the beginning of the grazing season.

Conclusions

The different grazing managements affected the structure of the above ground pasture biomass. In the 0-3 cm layer, we observed an important difference in the dead biomass, as reflected by the biomass turnover caused by grazing intensity. The layer above 3 cm seems to be more sensitive to the different grazing managements.

Acknowledgment

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Defoliation of patches of *Lolium perenne*, *Agrostis capillaris* and *Holcus lanatus*

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Abstract

Grasses in extensively managed pastures can grow in patches that are dominated by a single species. Their rate of spread can be influenced by the intensity of defoliation. We tested the hypothesis that the intensity of defoliation of tillers of *Agrostis capillaris*, *Holcus lanatus* and *Lolium perenne* in patches by free-ranging sheep was similar and did not vary with location within the patch. The 0.75 m square patches were arranged in pairs (*Lolium-Agrostis* and *Lolium-Holcus*) in 4 cm and 8 cm tall swards grazed by sheep. The estimated amount of green leaf length (GLL) removed by grazing was greater at the centre than the edge of patches in the 8 cm sward. GLL removal was similar for all patches in the 4 cm sward. In the 8 cm sward the GLL removed was greatest for *Lolium* when it neighboured *Holcus* and was reduced for *Lolium* when it neighboured *Agrostis*. A greater proportion of GLL was removed from the *Lolium-Holcus* than the *Lolium-Agrostis* pairs. We conclude that there are differences in defoliation intensity between species patches particularly in a tall sward and that the severity of defoliation of tillers in a patch can be influenced by both the species in neighbouring patches and by location within the patch.

Keywords: defoliation intensity, grass patch, feeding station, *Lolium*, *Agrostis*, *Holcus*

Introduction

The species in a community are commonly aggregated into patches that are dominated by a single species (Begon *et al.*, 1996). The species in patches interact at their boundaries and for some species pairs this can result in one species spreading as its neighbour retreats. In grasslands the rate of spread of a species patch depends both on species identity and the intensity with which it is defoliated (Barthram *et al.*, 2002). We tested the hypothesis that the severity of defoliation of tillers in adjacent patches of *Lolium perenne*, *Agrostis capillaris* and *Holcus lanatus* was similar for patches of all three species at each of two mean sward surface heights. We also tested the hypothesis that the defoliation of tillers in a patch was similar at the centre (where inter-specific interactions are unlikely) and the edge of the patch (where inter-specific interactions take place).

Materials and methods

The study was carried out at the Macaulay Institute's Hartwood Research Station in Scotland, UK (3°51'W, 55°49'N). Two replicates of two, 0.5 ha, plots were established in pasture dominated by *L. perenne*. One pair of adjacent *Lolium-Agrostis* and one pair of adjacent *Lolium-Holcus* patches (each 0.75 m square) were sown within each half of each plot. From the following May, one plot in each replicate was managed to maintain a mean sward height of 4 cm and the other a height of 8 cm by weekly changes in the density of yearling Greyface sheep. Measurements began on Monday 13 July when, within each patch of a pair, two tillers near the centre and two within 10 cm of the boundary between the two species were marked with a twist of wire. The tillers were examined daily for the rest of the week. At each examination the green length of each lamina and its grazing status (newly grazed or not) was recorded. This procedure was repeated on a fresh set of tillers on alternate weeks for four measurement weeks. Tiller characteristics were compared using measurements made at the time tillers were marked each Monday, and the amount of leaf removed by grazing from each tiller was estimated by summing the average changes in green leaf length (GLL) on days when it was not defoliated and on days when it was defoliated. 512 tillers were examined and 79 of these were grazed at some time. All data were analysed using the method of residual maximum likelihood, using a nested random effects model allowing for variation in plot halves, species pair, species patch and tiller location within patch (Genstat for Windows v. 6.2, VSN International, Oxford).

Results

Tiller GLL was greater in the 8 cm than the 4 cm sward (154 mm vs. 79 mm, maximum standard error of difference (sed) 16) and greater for the *Lolium* than the not-*Lolium* patches in the 8 cm sward (198 mm vs. 110 mm, sed 12). GLL did not differ significantly ($P > 0.05$) between the two locations within patches, between *Agrostis* and *Holcus* and between tillers which were grazed or not grazed later in the week. When averaged over both sward heights, the net increase in tiller GLL (excluding days when a tiller was defoliated) was similar at both locations within a patch, was slowest for *Agrostis* (2.20 mm d^{-1}) and was similar for *Holcus* (5.03 mm d^{-1}) and *Lolium* (4.67 and 4.11 mm d^{-1} for *Lolium* growing adjacent to *Agrostis* or *Holcus* respectively. The respective values on the analysed, square root, scale were 1.48, 2.24, 2.16 and 2.03, sed 0.15).

None of the sample tillers at the centre of the *Lolium* patches in the *Lolium-Agrostis* pairs in the 8 cm sward were grazed, so the amount of GLL removed by grazing at this location could not be estimated. However, interactions at higher levels show that tiller location was a determinant of the amount of GLL removed by grazing. At the sward height × pair × location level ($P < 0.01$) tillers from the centre locations of the *Lolium-Holcus* pair in the 8 cm sward had more GLL removed than those at the edge (83.4 mm d^{-1} vs. 50.0 mm d^{-1}, sed 17.3), and at the sward × patch × location level ($P < 0.05$) the not-*Lolium* patches had more removed from centre than edge locations (48.9 mm d^{-1} vs. 16.0 mm d^{-1}, sed 16.2).

Table 1. Estimated amount of green leaf length removed by grazing (mm $tiller^{-1}$ d^{-1}).

Sward	Species pair	Patch species		
		Lolium	*Agrostis*	*Holcus*
4 cm	*Lolium-Agrostis*	27.2	11.0	
	Lolium-Holcus	22.8		29.4
8 cm	*Lolium-Agrostis*	37.4	36.4	
	Lolium-Holcus	100.2		30.1

The sed for comparing means within a sward is 22.9.

Averaging over both locations within patches, in the 8 cm sward most GLL was removed from *Lolium* growing adjacent to *Holcus* and this was greater than the amount removed from *Lolium* growing adjacent to *Agrostis* (Table 1). The amount removed by grazing can also be expressed as a percentage of the pre-grazing GLL. Only patch pairs differed ($P < 0.01$), with more being removed from the *Lolium-Holcus* than the *Lolium-Agrostis* pair (41.4 % vs. 23.6 % as back-transformed means; 40.1 vs. 29.1, sed 3.8, on the analysed angular transformed scale).

Discussion

From the grazers point of view it is the absolute amount rather than the percentage of leaf removed that is the important determinant of intake rate. Percentage will be relevant to the grazer only in that it can affect the rate of regrowth and thus the amount available for grazing at the next visit. The amounts removed from the patches in the 4 cm sward were similar. In the 8 cm sward similar amounts of leaf were removed from the similarly sized *Agrostis* and *Holcus*. More was removed from the larger *Lolium*, but only when growing adjacent to *Holcus*. Thus as expected (e.g., Burlison *et al.*, 1991) more leaf was removed from the larger tillers but this response was modified by an effect of some characteristic other than the mean GLL of the adjacent patch. One medium-term consequence of this response will be the development of height heterogeneity in the *Lolium* component of a sward containing patches of the other species.

A greater percentage of leaf was removed from the *Lolium-Holcus* than the *Lolium-Agrostis* pairs. This means that *Lolium* growing in patches adjacent to *Agrostis* will have a greater current production of photosynthetic assimilate (Parsons and Johnson, 1986) than that growing next to *Holcus* and so would be expected to expand leaf more rapidly after defoliation. Our results were in this direction, but not significantly so (P = 0.39). Such a response is expected to give these patches of *Lolium* a competitive advantage (Briske, 1996). The greater percentage removed from *Holcus* than *Agrostis* is unlikely to give *Agrostis* a similar competitive edge as *Agrostis* does not seem to rely as much on a strategy of rapid expansion of leaf after defoliation to survive grazing (its net rate of increase in GLL was low compared to *Holcus* and *Lolium*). The different percentages of leaf removed were paralleled in both swards. This demonstrates that the grazer’s responses to these species were independent of sward height.

The patches were larger than a feeding station (Roguet *et al.*, 1998). More leaf was removed from patch centres than patch edges. The reason for this is not clear but it might be related to the differential grazing responses to different species and the likelihood that the feeding stations at patch edges were likely to contain a mixture of species at the species patch boundary.

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Effects of livestock breed and stocking rate on sustainable grazing systems: 2. grazing behaviour and diet selection

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Abstract

Temperate natural and semi-natural grasslands in Europe are managed so as to remain both economically and ecologically sustainable, i.e., to maintain farm incomes and sustain rural economies, while protecting biodiversity and landscapes. Grazing herbivores affect biodiversity by the creation and maintenance of structural heterogeneity in the sward as a result of their dietary choice. Our aim is to obtain comparative information on the effects of stocking rate and breed of animals (commercial vs. traditional) on the foraging behaviour of grazing livestock and to relate this information to the level of sward biodiversity. Three grazing treatments, moderate stocking with a commercial breed (MC), lenient grazing with a commercial breed (LC) and lenient grazing with a traditional breed (LT), were therefore conducted with cattle grazing at different initial levels of biodiversity (high in France, low in the UK and in Germany), and with sheep grazing on a biodiverse natural grassland in Italy. In all four countries, the first results indicate consistent differences in the bites selected within the moderate and lenient grazing treatments, which can be related to the evolution of sward structure. Conversely, there is no indication yet that breed differences will prove important, the variations observed so far being largely related to body size and possibly to prior grazing experiences of the animals.

Keywords: biodiversity, breed, cattle, grazing, sheep, stocking rate

Introduction

The most appropriate sustainable management for biodiverse grasslands remains a subject of considerable debate. It is however generally accepted that drawing together studies on behavioural ecology of grazing herbivores with knowledge from plant ecophysiology is required to build a general conceptual framework for the management of this important resource. Many specific features of sward structural heterogeneity are induced by decisions made by grazing herbivores about where and when to place bites (Parsons and Dumont, 2003). There are clear differences between animal species in their impact on grazed communities, but the type of animal (breed, sex and age) that should be used is often based on anecdotal evidences or at best on empirical studies with limited applicability (Rook *et al*., 2004), with the result that they may not deliver the biodiversity benefits required (Kleijn *et al*., 2001). Our aim in this EU project (QLK5-2001-00130 FORBIOBEN) is therefore i) to obtain comparative information on the effects of stocking rate and breed of animal (commercial vs. traditional) on the grazing behaviour of cattle and sheep, and ii) to relate this information to sward structure and to the level of sward and animal (mainly insects) biodiversity.

Materials and methods

Three grazing treatments, moderate stocking with a commercial breed (MC), lenient grazing with a commercial breed (LC) and lenient grazing with a traditional breed (LT), were conducted from spring 2002, with young cattle grazing swards of different initial levels of biodiversity (high in France, low in the UK and in Germany), and adult ewes grazing a biodiverse natural grassland in Italy. Each treatment was replicated three times according to a randomized block design. Behavioural observations were made on three occasions during the grazing season: in spring before flowering of major sward components, in summer when sward heterogeneity was at a maximum and in autumn when cumulative effects were at a maximum. Measurements consisted of scan sampling (every 5 minutes from dawn to dusk) of the selected bites of three animals within each group. Bites were broadly defined according to their botanical composition (grass, legumes or forbs), height (limiting the intake rate or not) and vegetation stage (vegetative, reproductive or dry). Between scans, additional measurements (bite rate and step rate) were made to obtain more information on animals' selectivity during periods of active grazing. Data were analysed using the PROC MIXED procedure of SAS to account for observations being made on the same animals over the grazing season (Littell *et al*., 1998). In each country, the model considered for each bite type and for bite to step ratio, the effects of grazing treatment, season, block and the interactions between treatment and season, and treatment and block. Post-hoc comparisons were done with Least Square Means Differences. We report the results from the first year of grazing.

Results and discussion

Results showed a clear effect of stocking rate (MC vs. LC) with animals grazing more from the short (i.e., limiting their intake rate) areas in the plots at the moderate stocking rate. Cattle took more bites in short areas (whatever their botanical composition) in Germany (MC: 56.5 vs. LC: 35.1 % of bites; $P < 0.001$) and in the UK (70.4 vs. 42.3 %; $P < 0.001$). Similarly, sheep grazed more from the short grass patches in Italy (22.8 vs. 6.6 %; $P < 0.001$). In France, heifers at the moderate stocking rate tended to graze less from the tall grass patches (30.7 vs. 41.7 %; $P < 0.10$) and grazed more dry material (12.2 vs. 1.5 %; $P < 0.001$) in the autumn, as compared to those at the lower stocking rate. These differences can be related to the evolution of sward structure under the different stocking rates, since in each country the height in MC was significantly lower than that in LC from mid-summer, and even from late spring in the UK and in France (Scimone *et al*., 2004).

Some seasonal variations have also been observed, with animals grazing more bites containing legumes during the summer in France (21.9 vs. 13.9 and 8.1 % of bites in spring and autumn respectively; $P < 0.001$) and in Italy (6.5 vs. 1.6 and 2.0 %; $P < 0.001$), and during the autumn in the UK (33.7 vs. 21.2 and 21.5 % in spring and summer respectively; $P < 0.001$).

There were no significant and consistent differences between animals from the traditional and from the commercial breed grazed at a low density (LT vs. LC), but there were some variations in three countries. The Devon steers (traditional breed) in England made fewer bites on pure grass (35.6 vs. 46.4 % of bites; $P < 0.001$) and fewer bites containing mostly grasses and legumes (22.6 vs. 26.6 %; $P < 0.05$), but consumed more bites containing forbs (41.8 vs. 27.0 %; $P < 0.001$) than the Charolais × Holstein-Friesian crossbreds. In Germany, the Angus steers (traditional) grazed more from the tall areas in the plots than the Limousin × Friesian crossbreds (75.0 vs. 64.9 %; $P < 0.01$). In Italy, the Karst ewes (traditional), consumed more from the tall grass patches than the Finnish ewes (72.1 vs. 62.6 %; $P < 0.01$), grazed less clover (1.8 vs. 6.5 %; $P < 0.01$), and browsed more (2.9 vs. 1.1 %; $P < 0.05$).

Part of these differences probably arose from differences in body weight with, for example, the traditional breed being smaller (on average 314 vs. 349 kg), and therefore likely to be more selective (Demment and Greenwood, 1988) in the UK (the Devon steers also took less bites per step: 9.6 vs. 12.0; $P < 0.01$), and conversely being heavier (on average

392 vs. 307 kg), and therefore selecting more the tall areas in the plots (Illius and Gordon, 1987) in Germany. Devon steers were also at a later stage of maturity and slightly fatter, which would further reduce their requirements and allow them to be more selective. In Italy, the traditional breed was also taller and thinner than the commercial one, though body weights were similar (on average 52.1 vs. 55.0 kg). Additional effects of different prior grazing experiences cannot be denied at least in England and Germany, where animals were bought before measurements began. In France, where the two breeds had very similar body weight (on average 454 kg for the traditional Salers heifers vs. 478 kg for the Charolais ones), intake capacity (Petit *et al.*, 1995) and prior grazing experiences, no differences were observed in their choices: 70.1 vs. 67.3 % of bites on vegetative grass (NS), 14.4 vs. 13.7 % of bites on legumes (NS) and 11.1 vs. 14.8 % of bites on forbs (NS) for the Salers and Charolais, respectively. In addition, no differences were observed in the animals' selective behaviour, since an average of 9.0 bites per step was taken by animals of both breeds.

Conclusions

In all four countries, these first results indicate consistent differences in the bites selected within the moderate and lenient grazing treatments, which can be related to the evolution of sward structure. Information gathered on the history of the animals will allow us to avoid confounding potential breed effects with rearing effects. The analyses of further data will be facilitated by the fact that animals were produced on the farm from the second year in England, and had similar body weight in Germany. Additional morphological (incisor arcade breadth) or physiological measurements (intake capacity measured indoors) would further help to explain the observed variations, but so far no general and consistent effect of using a traditional instead of a commercial breed was observed.

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Scimone M., Smith R.E.N., Garel J.P. and Sahin N. (2004) Effects of livestock breed and stocking rate on sustainable grazing systems: 4. short-term effects on vegetation. *This Volume*.

Effects of livestock breed and stocking rate on sustainable grazing systems: 3. agronomic potential

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Abstract

The effect of grazing pressure and livestock breed on the agronomic performance of grassland is being investigated in a grazing experiment in four countries throughout Europe. The work forms part of a joint EU funded project aiming at the enhancement of biodiversity by grazing livestock. The sites represent grasslands with a potential to increase biodiversity while maintaining a considerable agronomic output. The experimental design comprises the three treatments: MC: moderate stocking rate of a commercial breed adapted to optimise livestock production, LC: lenient stocking of the commercial breed adapted to optimise biodiversity, and LT: lenient stocking with a traditional breed adapted to optimise biodiversity. At three sites (United Kingdom, France, Germany), growing cattle are used (continuous stocking), at the Italian site the grassland is grazed by sheep. The herbage on offer was significantly higher and the feeding value slightly lower in leniently grazed plots compared to moderately grazed ones. No treatment effect was found with regard to the quality of the ingested herbage, which is explained by a stronger selective grazing in LC and LT plots. The liveweight gain (LWG) per animal was slightly higher, the LWG per ha by 30 % lower in LC and LT plots compared to MC plots. The effect of the livestock breed on the target variables was generally low.

Keywords: grassland biodiversity, grazing, agronomic yield, breed

Introduction

Grazing livestock at a low stocking rate is considered as a promising option to enhance and maintain biodiversity of grassland. However, extensive grazing systems will only be sustainable, if a certain economic output for the farmer is achieved. Thus, grazing management systems with a reduced grazing pressure, which meet the biodiversity target as well as a certain profit to the farmer, need to be developed (Watkinson and Ormerod, 2001). A main feature of extensive grazing is that at least early in the grazing season, the herbage growth exceeds the herbage demand of the grazing animals. As a result, selective grazing is encouraged and the spatial variability of amount and quality of the herbage on offer increases. To what extent this process will affect the performance of the grass sward and the grazing animal needs to be determined, if the development of sustainable management systems is aimed at. The objective of the present paper was to study the effect of reduced grazing pressure on the agricultural output of the grazing system. In addition, the use of either commercial or traditional livestock breeds was compared since there are some indications that traditional breed, due to a different grazing behaviour, might have a different impact on the grass sward structure and the related biodiversity. The research is part of an integrated programme including various topics such as vegetation and sward structure, grazing behaviour, vertebrate and invertebrate diversity, and socio-economic implications (Rook *et al*., 2004). This paper reports on the first year results.

Materials and methods

In spring 2002, a grazing experiment was set up in four European countries (EU 5th FPRTD; project QLK5-2001-00130 FORBIOBEN). The experimental design comprised the following three treatments with three replicates: moderate stocking rate of a commercial breed adapted to optimise livestock production (MC), lenient stocking of the commercial breed adapted to optimise biodiversity (LC) and lenient stocking with a traditional breed adapted to optimise biodiversity (LT). The grassland was grazed by growing cattle, i.e., bullocks (United Kingdom / IGER and Germany / UGOE) and heifers (France / INRA), and by sheep (Italy / SAASD). The grazing system was continuous, except of the SAASD site where the sheep were kept in a rotational grazing system with periods of 10 days. The sites are characterized by mesotrophic grassland with a moderate to high plant species diversity. The herbage on offer was determined in weekly intervals by measuring compressed sward heights (CSH) with a rising-plate-meter with 50 measurements per plot. For calibration, a linear regression function was developed from additional CSH measurements and herbage sampling by cutting at ground level. The feeding value of the herbage on offer was determined in monthly intervals by hand pluck samples using standard chemical analysis including *in vitro* digestibility. The value of the ingested herbage was estimated by means of the faeces nitrogen technique (Schmidt *et al*., 1999). Liveweight changes of the grazing animals were recorded by monthly weighing and the body condition was scored at the beginning and at the end of the grazing season.

Results and discussion

On average of all sites, the stocking rate of the LC and LT treatment was 35 % lower than that of the MC treatment. The herbage on offer was, on average over the grazing season, significantly higher (25 %; $\alpha = 0.05$) on leniently grazed plots (LC, LT) as compared to moderately grazed ones (MC); this effect was found on each site. Results of the feeding value of the hand pluck samples are shown for the sites with growing cattle (Table 1). Neither the neutral detergent fibre content nor the crude protein content were significantly affected by the grazing treatment.

Table 1. Effect of the grazing treatment (MC = moderate stocking rate / commercial breed, LC = lenient stocking / commercial breed, LT = lenient stocking / traditional breed) on the amount and quality of the herbage on offer averaged over the grazing season, NDF = neutral detergent fibre fraction, CP = crude protein. Sites with growing cattle are indicated.

Site	IGER			INRA			UGOE		
	Mass	NDF	CP	Mass	NDF	CP	Mass	NDF	CP
Treatment	g m^{-2}	g kg^{-1}	g kg^{-1}	g m^{-2}	g kg^{-1}	g kg^{-1}	g m^{-2}	g kg^{-1}	g kg^{-1}
MC	328a§	579	164	191a	568	164	244a	501	138
LC	441b	585	162	230ab	578	154	307b	520	126
LT	431b	574	162	256b	586	155	301b	512	124
F-value	< 0.001	n.s.	n.s.	0.05	n.s.	n.s.	0.03	n.s.	n.s.

§ Data within columns followed by the same character are not significantly different, S-N-K test, $\alpha = 0.05$, n.s. = not significant.

While the feeding value of the leniently grazed plots is slightly, albeit not significantly, reduced, there is almost no difference between treatments for the ingested herbage. No significant difference is found between the commercial and traditional breeds with regard to

the amount and quality of the herbage. Obviously, the increased amount of herbage on offer on leniently grazed plots provided more opportunities for selective grazing. Thus, the animals could ingest herbage of a higher quality than the average offered herbage.
The animal performance is expressed as average individual liveweight gain (LWG per head) and LWG per ha. On an area basis the performance of the LC and LT treatment is 30 % lower compared to that of the MC treatment, on average of all sites ($\alpha = 0.05$). For the cattle grazed sites, this effect is significant at two out of three sites (Table 2).

Table 2. Effect of the grazing treatment on the liveweight gain of growing bullocks (IGER, UGOE) and heifers (INRA) head^{-1} d^{-1} (on average of the grazing season) and ha^{-1} season^{-1}.

Site	IGER		INRA		UGOE	
Treatment	g head^{-1} d^{-1}	kg ha^{-1}	g head^{-1} d^{-1}	kg ha^{-1}	g head^{-1} d^{-1}	kg ha^{-1}
MC	906	528b§	1152b	332c	671a	527
LC	1044	330a	1157b	238b	918b	422
LT	1045	288a	908a	187a	906b	432
F-value	n.s.	0.001	0.001	<0.001	0.032	n.s.

§ Data within column followed by the same character are not significantly different, S-N-K test, $\alpha = 0.05$, n.s. = not significant.

The individual performance is higher (17 % on average of all sites; $\alpha = 0.05$) on the leniently grazed plots compared to the moderately grazed plots. This finding is of particular importance for the farming practice. Provided area costs are kept low, extensive grazing systems seem to have a potential to be integrated into economically viable livestock farms. This result will have to be confirmed during the following years of this ongoing research.

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Effects of livestock breed and stocking rate on sustainable grazing systems: 4. short-term effects on vegetation

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Abstract

This work is part of the EU project FORBIOBEN, which analyses the impact of commercial and traditional breeds with different stocking rates on biodiversity at different levels. Three grazing management systems were compared in five countries in a 3 year experiment, (i) moderate grazing / commercial breed, (ii) low grazing / commercial breed, and (iii) low grazing / traditional breed. The effect of grazing systems on specific and structural diversity of vegetation was analysed after one year. The responses mainly depend on the background difference between countries, and result in different patterns. The treatment effect appears to be more evident as a whole with not much difference between levels. A general decrease of specific biodiversity with grazing pressure is found in all cases, except for the most biodiverse site (France). An increase in structural diversity, especially in the least biodiverse site (UK), for the relatively high impact grazing system is also noticed. The local within treatment variability is still high.

Keywords: breed, stocking rate, vegetation, biodiversity

Introduction

The EU project FORBIOBEN (QLK5-CT2001-00130) studies the effect of different grazing systems in five European countries. The main assumption is that the use of local, traditional breeds with low-intensity stocking rate could result in benefits at various levels (animal behaviour, productivity, biodiversity and sustainable economy). This paper, part of a comprehensive project presentation at EGF 2004, has the aim of verifying if the different experimental grazing systems significantly affect vegetation diversity during the first grazing season, and to what extent this happens in the different countries. The analysis reported here refers to experiments in France, Germany, Italy and UK. Although partial, the analysis can already lead to some general conclusions that will be considered in more detail in relation to long-term effects in the following experimental seasons.

Materials and methods

Three grazing systems (treatments) were compared by combining different breeds and stocking rates: (1) moderate grazing / commercial breed (MC), (2) low grazing / commercial breed (LC) and (3) low grazing / traditional breed (LT). The experiments were carried out with cattle in the UK, France and Germany, with sheep in Italy and with goats in Spain. Each treatment had 3 replicate paddocks, with each paddock being continuously grazed over the whole season (April to October on average), with the exception of Italy, where rotation grazing was applied with a 10 day turnover period. Vegetation data were sampled in three periods during 2002. They were: (i) botanical composition as species cover in 10 random quadrats of 1 m^2 in each paddock; (ii) vegetation height from 250 random sampling points in each paddock and (iii) vegetation patches along 50 m transects in each paddock, a ‘patch’ being a sequence of the same vegetation type at the level of the main species groups (grasses / legumes / others), recorded at 10 cm intervals. Data from (i) were used to calculate the species diversity indexes, i.e., the species richness of the number of species (NSP), Shannon entropy (H’), Pielou evenness (J’), Margalef richness (M) and Simpson dominance (D) (Pielou, 1975; Whittaker, 1972). Data from (ii) and (iii) were used to calculate structural diversity indexes, such as sward height (h) and the number of patches along a transect (PAT). One-way analysis of variance was applied on the indexes between treatments at each period, and post-hoc comparisons between the average values were made applying Tukey’s test. Significant correlations were found between H’ and J’ and between NSP and M, therefore J’ and M were neglected in the discussion.

Results and discussion

By the end of the first grazing season, an overall decrease in specific diversity (Table 1) was detected in Germany and UK, and less remarkably in Italy, whereas in France an overall increase occurred, more so as a seasonal peak. This effect is not homogeneously recorded when comparing treatments (in a few cases the difference is significant), which means that the effects of different breeds and stocking rates are not yet obvious. Large background intra-variation (block effect) was observed almost everywhere.

Table 1. Average values of diversity indexes per country, grazing systems and periods through the season 2002 (1: beginning, 2: mid, 3: end of grazing season). Data followed by the same superscript letter is not significantly different between treatments at $P \leq 0.05$.

	France			Germany			Italy			United Kingdom		
Index: Period	MC	LC	LT	MC	LC	LT	MC	LC	LT	MC	LC	LT
NSP:1	24.5	25.3	23.4	17.7	18.8	18.4	16.2^{b}	14.4^{a}	14.9^{ab}	12.3	12.3	13.0
:2	25.4	26.1	25.3	16.0	17.1	17.3	15.1	15.9	14.4	11.4	11.2	11.7
:3	22.7	24.7	23.3	14.6^{a}	16.3^{b}	15.4^{ab}	13.8	14.3	12.8	11.0	10.5	11.4
H’:1	2.35^{b}	2.17^{a}	2.35^{b}	1.98^{b}	1.96^{b}	1.83^{a}	2.15	2.04	2.09	1.37^{ab}	1.31^{a}	1.51^{b}
:2	2.57	2.63	2.56	1.96	1.84	1.83	2.14	2.03	2.01	1.41	1.27	1.46
:3	2.45^{ab}	2.58^{b}	2.43^{a}	1.84^{b}	1.77^{ab}	1.70^{a}	2.07	2.03	1.92	1.16	1.10	1.11
D:1	0.14^{a}	0.18^{b}	0.13^{a}	0.19^{a}	0.20^{ab}	0.23^{b}	0.17	0.18	0.17	0.38^{ab}	0.40^{b}	0.31^{a}
:2	0.11	0.10	0.11	0.19^{a}	0.23^{ab}	0.24^{b}	0.16	0.20	0.19	0.36	0.41	0.33
:3	0.13	0.10	0.13	0.22^{a}	0.24^{ab}	0.26^{b}	0.18	0.19	0.22	0.45	0.47	0.48
h:1	11.3^{a}	11.9^{b}	13.4^{c}	22.9^{b}	21.5^{a}	20.6^{a}	21.7^{ab}	23.0^{b}	21.2^{a}	11.1^{a}	17.6^{c}	16.8^{b}
:2	15.7^{a}	18.4^{b}	18.3^{b}	20.3^{a}	36.6^{b}	36.6^{b}	13.8^{a}	18.3^{b}	19.0^{b}	8.4^{a}	15.2^{c}	13.4^{b}
:3	7.8^{a}	11.0^{b}	11.0^{b}	10.4^{a}	18.3^{c}	16.6^{b}	13.5^{a}	16.6^{b}	18.3^{c}	7.7^{a}	10.9^{b}	10.5^{b}

The seasonal distribution of sward height (Table 1) reflects more so the effect of the grazing system. The difference between treatments is in this case always statistically significant. In each country, the height in MC is much lower than in LC and LT from the 2nd period (mid-summer), and in the UK already from the 1st period. This distribution is similar to the seasonal growth of herbage in France and Germany (curve peak in mid-summer), whereas in Italy and UK the sward height reaches the maximum at the beginning of the season, then decreases. This could indicate a major grazing pressure or the start of grazing when herbage growth was consistent. The seasonal trend of PAT (Figure 1) is very different between countries. In no case is the difference between treatments significant, due to the large intra-variation within blocks.

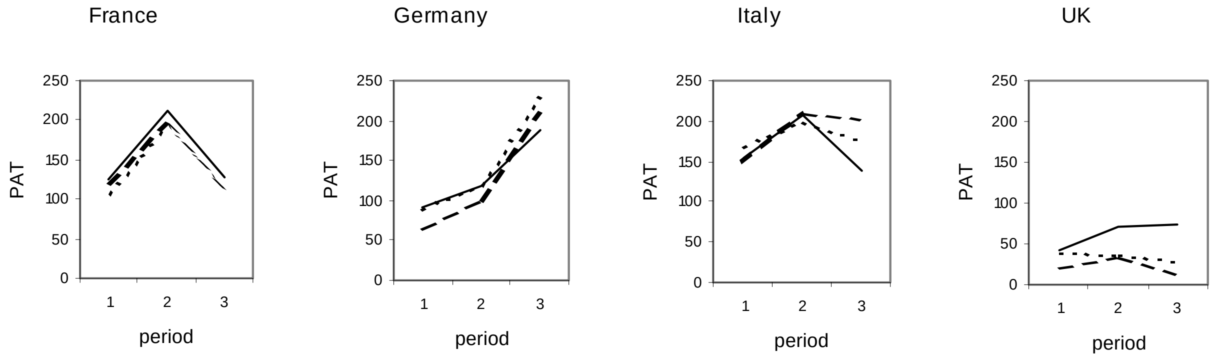

Figure 1. Seasonal trend of number of patches (PAT) per country and treatment (MC: straight line, LC: dashed line, LT: dotted line; 1, beginning, 2, mid, 3, end of grazing season).

In France, it reflects the seasonal growth, with MC tending to have highest values. In Germany, a continuous increase of PAT along the seasons occurs, irrespective of the treatments. In Italy, the distribution is similar to that in France, but in the 3rd period MC sharply decreases when compared to the other treatments. In UK, there is an increase for MC during the season whereas the other treatments tend to slightly decrease.

Conclusions

After the first grazing season, there was a clear change in vegetation diversity in all treatments over time but little evidence of treatment effects. To determine whether this is solely a seasonal effect or a first indication of grazing effects building up will require data from more seasons. The effect results mainly in a general decrease of specific diversity over time, except in France. The effect on structural diversity looks to be more dependent on the different treatments than specific diversity. Especially for vegetation height, and partially for number of patches, the MC grazing system tends to differentiate from LC and LT through time. This effect is not homogeneous, with the vegetation systems being basically different from country to country. The system responses range very differently from the most (France) to the least (UK) biodiverse places. In France the specific diversity is increasing through the season, in contrast to the other countries. In the UK, the grazing system with the potential highest impact (MC) seems to cause an increase in fragmentation and structure diversification. The local intra-variation of treatments should be taken into consideration, as the difference between replicated paddocks is considerable, and probably interacts with the effect of grazing systems, at least in the first season, causing a ‘background noise’.

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Effects of livestock breed and stocking rate on sustainable grazing systems: 5. short-term effects on fauna

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Abstract

Finding an optimal balance of the impact of grazing on animal biodiversity is an important issue in the development of sustainable grazing systems. Here we consider the first year results of grazing experiments conducted in four countries. All sites involved three treatments: 1) moderate stocking rate with a commercial breed, 2) low stocking rate with a commercial breed and 3) low stocking rate with a traditional breed. Animal biodiversity was studied at the species level for birds, hares, butterflies, grasshoppers and at higher taxonomic level for ground-dwelling arthropods. Bird and hare numbers were low and revealed no treatment effects. Butterflies and grasshoppers showed lower species richness and abundance at moderate stocking rate but no difference between breeds appeared. In contrast, the number of ground-dwelling arthropod groups was higher at moderate stocking rate, but treatment effects on abundance could not be detected at the family level yet.

Keywords: biodiversity, grazing, stocking rate, livestock breeds, butterflies, grasshoppers

Introduction

Grazing by large herbivores can dramatically influence the structure and composition of animal communities (Van Wieren, 1998). Unfortunately, in determining grazing impact, research mostly focuses on the comparison of grazed and ungrazed areas, whereas a comparison of different stocking rates would be more meaningful (WallisDeVries and Raemakers, 2001). Moreover, differences between livestock species and breeds have rarely been considered.

This paper reports the initial results from an EU Framework 5 project (QLK5-2001-00130 FORBIOBEN) based on an integrated experimental programme at several sites across western Europe that examines the effects of management intensity (stocking rate) and breed of grazing animal on natural and semi-natural grassland systems. Over this first year, treatment effects are only expected for species that strongly respond to changes in the structure of the vegetation. Breed effects, if present, are expected to develop more slowly and indeed, this is targeted in the continuation of the experiment over several years.

Materials and methods

Treatment lay-out has been described by Rook *et al.* (2004). Three treatments were considered: moderate stocking rate with a commercial breed (MC), lenient stocking rate with a commercial breed (LC) and lenient stocking rate with a traditional breed (LT). Each

treatment was replicated threefold according to a randomized block design. At each site animal biodiversity in each paddock was recorded as follows: birds and hares, 10 bi-weekly counts from fixed points and along three 50 m transects; butterflies, 10 bi-weekly counts along the transects; grasshoppers, 4 counts during summer along the transects using sweep-net sampling; ground-dwelling arthropods, 3 periods of pitfall trapping over two weeks with 4 traps placed along each transect; identification at higher taxonomic level for 28 groups.
Data analysis focused on treatment effects on species richness and individual abundance. Results within plots were pooled over transects prior to analysis. Log-transformation was applied to abundance data. Besides treatments, the ANOVA included a fixed factor country, a random block factor nested within countries and a country × treatment interaction. As the Spanish site was different (Rook *et al.*, 2004), only the results from the British, French, German and Italian sites are reported here.

Results and discussion

Bird and hare numbers were low and revealed no significant treatment effects. Significant treatment effects were found in butterflies and grasshoppers, with lower species richness and abundance of individuals at moderate stocking rate (Figure 1). Effects were similar across countries. Treatment effects on abundance were mainly accounted for by species associated with tall grassland. Breed differences were not significant, but the variation between LC and LT indicates that these might develop over the years. In contrast to butterflies and grasshoppers, the number of ground-dwelling arthropod groups was higher at moderate stocking rate ($P = 0.026$), but only in France and Germany. However, no significant treatment effects on individual abundance were detectable at the family level yet.

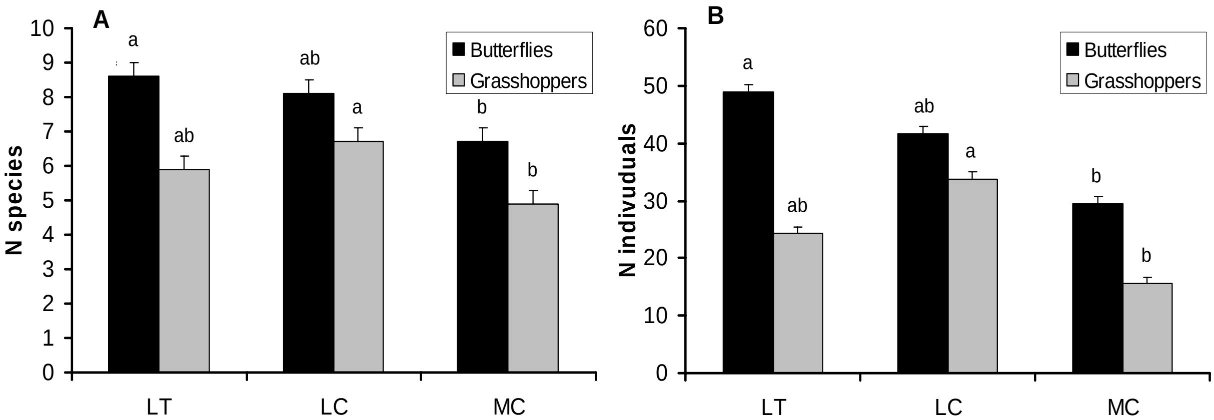

Figure 1. Species richness (A) and abundance (B) of butterflies and grasshoppers over the first grazing season under three replicated grazing treatments (data represent paddock totals from 3 transects averaged over 4 countries, ± s.e.). For abbreviations see text. Treatments not connected by the same letter are significantly different ($P < 0.05$, Tukey HSD).

Conclusions

It can be concluded that butterflies and grasshoppers show a quick response to variation in stocking rate. This effect is expected to develop over the next years for other animal groups. The present results do not indicate important differences between livestock breeds.

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Effects of livestock breed and stocking rate on sustainable grazing systems: 6. socio-economic impacts

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Abstract

If targeted grazing management systems and the use of traditional breeds prove to have a role in improving sward biodiversity, they will also need to achieve viable economic results. Our aim was to evaluate the socio-economic costs and benefits of using different management intensity (stocking rates) and breed of animals, using data from grazing experiments and surveys conducted in the United Kingdom, France, Germany and Italy. All regions experienced negative Net Farm Incomes (NFIs) per hectare when subsidies were excluded from the calculations, highlighting the dependency of these types of production systems on subsidies for their viability. Mostly, the systems using lower stocking rates and traditional breeds produced higher NFIs than the commercial systems, due in part to lower variable costs. A survey of farmers in all four regions revealed their concerns about the reduction in profitability from adopting biodiverse grazing systems. Such systems are impractical in certain locations due to the fragmented nature of land parcels requiring movement of livestock over extensive areas. Concerns were also raised about the poor quality of traditional beef breed carcasses. Most respondents felt that farmers in their regions would be unwilling to adopt traditional breeds, whilst the responses to the adoption of the new grazing systems were more positive.

Keywords: grazing, stocking rate, traditional breeds, socio-economics

Introduction

If targeted grazing management systems and the use of traditional breeds prove to have a role in improving sward biodiversity, they will also need to achieve viable economic results which are socially acceptable. This implies a critical analysis of the inputs, economic feeding policies and quality of the products marketed. Currently most European Union (EU) livestock production systems are unable to compete with world market prices. They are dependent on Common Agricultural Policy (CAP) subsidies for their viability. With threat of modulation reducing direct subsidy payments to farmers and a move from headage to area payments, the production systems in marginal areas may become less financially viable. The CAP Mid-term Review proposes to move a proportion of modulated money from Pillar 1 of the CAP to the Rural Development Regulation Programme (RDR) (Commission of the European Communities, 2003). This is seen as an important tool to encourage farmers to move away from intensive, high volume commodity production. Those farmers operating extensive livestock production systems and using traditional breeds to improve biodiversity, should benefit from such changes (Rook *et al*, 2004a). Our aim in this EU project (QLK5-2001-00130 FORBIOBEN) is to evaluate the socio-economic costs and benefits of such systems and traditional breeds using data from the grazing experiments and surveys conducted in the United Kingdom, France, Germany and Italy (Rook *et al*, 2004b).

Materials and methods

Economic data was collated from the four experimental sites for the 2002 / 2003 season. These sites are operating 3 treatments: moderate stocking with commercial breed (MC), lenient stocking with commercial breed (LC) and lenient stocking with traditional breed (LT). For each treatment data was collected on: livestock weight and price when purchased and sold during the season; variable costs, comprising concentrate, veterinary and medicine and forage costs; and fixed costs including labour, machinery and general overhead expenses. This data was entered into financial farm models which were used to calculate the Net Farm Income (NFI) per hectare for each treatment. All subsidies were excluded from the analysis to enable clear identification of the economic differences resulting from the treatments.
In addition, four farmer questionnaires were completed in each region. The questionnaires described the characteristic of the farmer and farm business and detailed attitudes to the proposed grazing management systems and to the use of traditional breeds. Respondents were selected based on a range of interest in environmentally-sensitive farming and who were operating a grazing system similar to that used in treatment MC.

Results and discussion

The first year's economic results are given in table 1 and reveal that all sites produced negative NFIs, highlighting the importance of subsidies in maintaining these types of farm management systems.

Table 1. Gross Margin (GM) per head and Net Farm Income (NFI) per hectare for the four experimental sites for 2002 / 2003 season.

	MC	LC	LT
UK site (Charolais x Friesian steers and Devon steers)			
GM per head (€ head^{-1})	-79.26	-79.24	14.66
NFI per hectare (€ ha^{-1})	-739.97	-518.26	-260.04
French site (Charolais heifers and Salers heifers)			
GM per head (€ head^{-1})	194.92	179.71	209.66
NFI per hectare (€ ha^{-1})	-349.33	-461.99	-432.04
German site (Simmental steers and German Angus steers)			
GM per head (€ head^{-1})	-113.38	-79.45	-203.57
NFI per hectare (€ ha^{-1})	-1,706.90	-1,035.97	-1,481.06
Italian site (Finnish sheep and Karst sheep)			
GM per head (€ head^{-1})	-66.62	-59.99	-0.87
NFI per hectare (€ ha^{-1})	-141.21	-82.47	-42.21

Treatments using commercial breeds (MC and LC) produced often lower NFIs in comparison with traditional breeds (LT) due to higher negative gross margins per head resulting from additional vet and medicine and feed costs and higher livestock purchase prices. For MC the negative GM per head combined with the higher stocking rates per hectare resulted in low NFIs per hectare. The introduction of subsidy payments based on area rather than headage would suggest that LC and LT have the potential to be more profitable than the more intensive grazing management systems.

Analysis of the farmer questionnaires revealed a wide range of attitudes to the grazing management systems and traditional breeds in the different regions. Farmers from all four regions had concerns about the reduction in profitability from adopting the biodiverse grazing systems. In the UK and German regions there were concerns about the reduced yield and forage quality of the pastures, whilst they recognised that the system would reduce both input and labour costs. In the Italian region the fragmented nature of the land parcels would make such a system impractical, requiring movement of livestock over extensive areas. The main management changes required on the farms in all regions in response to adopting the grazing management systems would be to either rent or buy more grazing land, or convert arable areas to pasture in order to maintain headage numbers. Views about the marketing potential of products from biodiverse grazing systems and traditional breeds were mixed. In the UK, France and Germany, the farmers were concerned about finding outlets for a high number of added value carcasses, although they recognised that a small quantity could be sold through direct selling. The UK and German farmers felt there was less marketing potential for traditional breeds due to their inferior quality compared to commercial breeds, as the high fat content of traditional breeds is unpopular with consumers. The Italian farmers were more positive about the potential of marketing products from traditional breeds due to an increasing consumer demand for such products.

All regions referred to the advantages of the traditional breeds' good characteristics in terms of ease of handling and hardiness. With the exception of the French region, where farmers already use traditional breeds, most respondents felt that farmers in their regions would be unwilling to adopt traditional breeds. This contrasts with the responses to the adoption of the grazing management systems, which were generally, more positive.

Conclusions

The negative NFIs produced for all treatments in the absence of EU subsidies highlights the importance of subsidies in maintaining livestock grazing management systems. The results also show that NFI is higher for low intensity grazing than for intensive grazing. Furthermore, low intensity grazing systems could be favoured by a move from headage to area subsidy payments. A survey of farmers in the project regions show that they would be more in favour of adopting low grazing management systems than changing to traditional breeds.

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Plant species diversity influences on forage production and performance of dairy cattle on pasture

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Abstract

We conducted a grazing study to determine if plant species diversity in pastures affects forage and animal productivity and weed invasion. Replicated pastures (1 ha each) planted to mixtures of two, three, six, or nine temperate forage species were grazed with lactating dairy cattle during two years. Herbage yield and vegetation dynamics were measured along with dry matter intake and milk production of Holstein dairy cows. Herbage yield increased with increasing species richness (4800 kg ha^{-1} for the two-species mixture and 7400 kg ha^{-1} for the nine-species mixture) in 2002 (a drought year). There were no differences among treatments in 2003, probably because of greater rainfall. Milk production averaged 35.6 kg cow^{-1} d^{-1} and grazed dry matter intake averaged 13.7 kg cow^{-1} d^{-1} in 2002 with no significant differences among treatments. The six- and nine-species mixtures had fewer weeds than the two-and three-species mixtures. These results indicate that complex mixtures of forages in pastures benefit herbage production without affecting individual animal performance.

Keywords: biodiversity, forage intake, complex mixtures, milk production

Introduction

Greater plant diversity in grassland plant communities has been linked to increased primary production, greater stability in response to disturbance (Minns *et al*., 2001), and reduced weed pressure (Tracy and Sanderson, 2003). Restoration of grassland plant diversity has been demonstrated to increase forage production on sites spanning a range of climate and geology (Bullock *et al*., 2001). Thus, managing complex mixtures of plants to take advantage of spatial and temporal variability in land and climate may be one ecological approach to increase productivity of grazing lands (Sanderson *et al*., 2004). We tested the hypothesis that complex mixtures of forage species would yield more dry matter and reduce weed competition compared with a simple grass-legume mixture.

Materials and methods

Four levels of plant diversity were established in replicated 1 ha pastures at University Park, Pennsylvania, USA in the autumn of 2001. The treatments were: 1) orchardgrass (*Dactylis glomerata* L.), white clover (*Trifolium repens* L.); 2) orchardgrass, white clover, chicory (*Cichorium intybus* L.); 3) orchardgrass, tall fescue (*Festuca arundinacea* Schreb.), perennial ryegrass (*Lolium perenne* L.), red clover (*Trifolium pratense* L.), birdsfoot trefoil (*Lotus corniculatus* L.) and chicory and 4) six species mix plus white clover, alfalfa (*Medicago sativa* L.) and bluegrass (*Poa pratensis* L.). The experimental design was a randomized complete block with two replicates.
The pastures were subdivided into smaller paddocks and stocked rotationally with lactating Holstein cows during April to August in 2002 and 2003. Four cows grazed each treatment.

Herbage allowance was 25 kg dry matter cow^{-1} d^{-1}. Cows were fed a 13 % crude protein corn-based concentrate (0.25 kg kg^{-1} milk) in two equal feedings after milking. Cows were moved to a fresh paddock after morning and afternoon milking. Herbage intake was estimated by the chromic oxide technique during May, June, July, and August in each year. Lactating cows were not available after August 1 of each year, therefore, pastures were mob grazed with 21 dry cows for one day in mid August (2003) and early September (2002 and 2003) to complete the grazing season. Animal performance was not measured on the dry cows. Pre-grazing and post-grazing herbage mass was measured twice each week during the grazing season with a calibrated rising plate meter. The botanical composition (forage and weed species) of each pasture was measured during each grazing cycle by hand separating clipped samples before and after grazing

Results and discussion

In 2002, forage yield was significantly lower on the orchardgrass, white clover mixture compared with the more complex forage mixtures (Figure 1). In 2003, with much greater rainfall, there were no yield differences among mixtures. The largest increase in forage yield in 2002 occurred with the inclusion of chicory in the three-species mixture, indicating that the yield increases with increasing seeded species richness resulted from adding a highly productive species, an example of the ‘sampling effect’ mechanism for explaining plant species diversity effects (Minns *et al*., 2001).

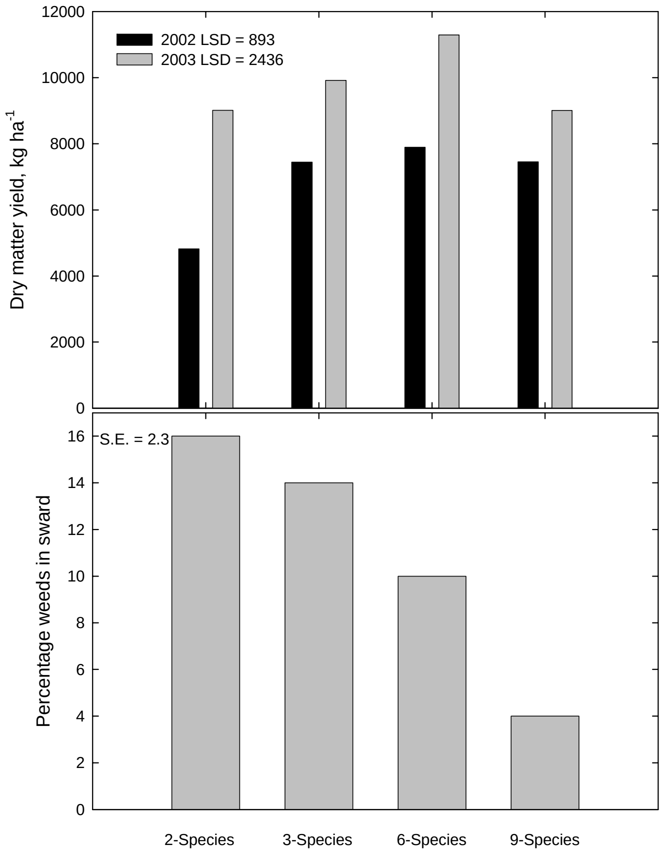

Figure 1. Seasonal herbage yield and weed percentage of pastures seeded with two, three, six, or nine forage species. Weed data are averages for two years.

Milk production averaged 35.6 kg cow^{-1} d^{-1} during April to August 2002 with no differences among treatments. Dry matter (grazed forage) intake averaged 13.7 kg cow^{-1} d^{-1} and did not differ among treatments. The two-species mixture had the highest fiber and lowest digestibility of the four mixtures (Soder *et al*., 2003), and differed in sward structure from other mixtures (Taube *et al*., 2004).

The hot and dry weather of summer of 2002 severely limited herbage growth on the pastures. Monthly average air temperature during the summer of 2003 was 2.5 ^{o}C lower than in 2002. The orchardgrass, white clover mixture yielded 87 % more forage in 2003 compared with 2002, whereas the yield increases for the other mixtures ranged from 21 to 45 % (Figure 1). Thus, it appears that complex forage mixtures may be more stable, in terms of herbage yield, during times of stress or disturbance (e.g., drought).

The percentage of weeds differed among the four sward mixtures (Figure 1). Weed proportions were similar for the two- and three-species mixtures in 2002, whereas the six- and nine-species mixtures had lower weed populations than the simple mixture. These data indicating less weed pressure with complex forage mixtures compared with simple grass-legume mixtures agree with Tracy and Sanderson (2003).

Conclusions

Complex forage mixtures were more productive than simple grass-legume mixtures during drought and also had reduced weed pressure. Individual animal performance was similar among simple and complex mixtures. Increasing plant species diversity on pastures may be a simple way to increase forage productivity, stability, and reduce weed competition.

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The influence of species composition on productivity, forage quality and herbage disappearance of grazed mixed swards

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Abstract

Diet selection of grazing animals is influenced by the sward composition and the vertical sward structure. A grazing study was established to determine if selective grazing behaviour affects the sward structure among different sward layers. Replicated pastures (1 ha each) were planted, including mixtures of two (grass, white clover), and nine temperate forage species (including forage chicory). The vertical structure was measured before and after grazing with special clipboards dividing the samples into six layers and a succeeding separation in different plant groups. Forage samples of the different layers were analysed for nutritive value via calibrated near infra-red reflectance spectroscopy. Calibration samples were analysed for neutral detergent fibre (NDF), *in vitro* true digestibility (IVTD) and crude protein (CP). The measurements were conducted in 4 grazing periods during the grazing season allowing the calculation of herbage disappearance as an indicator for diet selection, as well as the IVTD of the disappeared herbage as an indicator for the consumed quality of herbage. The nine-species mixture out-yielded the two-species mixture. The deep rooting chicory was particularly productive due to the very hot, dry weather conditions in the experiment. Cows tended to graze layer by layer. The results of the stratified samples showed more selection behaviour among the top layers than the bottom layers. Cows preferred legume to grass and young chicory leafs to bolted chicory stems as well. Herbage disappearance and IVTD of disappeared herbage indicated that quantity and quality of consumed forage is not influenced by the proved sward compositions.

Keywords: herbage disappearance, diet selection, forage intake, stratification, sward structure, dairy cows

Introduction

In low input production systems greater plant diversity in grassland plant communities has been linked to increased primary production, greater stability in response to disturbance (Minns *et al*., 2001), and reduced weed pressure (Soder *et al*., 2003). In high input production systems, however, increasing productivity is linked with a reduction in number of plant species (Wachendorf and Taube, 2001). In low input systems restoration of grassland plant diversity has been demonstrated to increase forage production on sites spanning a wide range of climate and geology (Bullock *et al*., 2001). Thus, managing complex mixtures of plants to take advantage of spatial and temporal variability in land and climate may be one ecological approach to increase productivity of grazing lands. We tested the hypothesis that in complex mixtures of forage species offered to dairy cows the amount of herbage disappeared (difference between herbage mass before and after grazing) as an indicator for herbage intake might be increased. In an associated study Sanderson *et al*. (2004) investigated these different swards in terms of potential consequences for animal performance.

Materials and methods

Four levels of plant diversity were established in replicated 1 ha pastures at University Park, Pennsylvania, USA in autumn 2001. The treatments were: 1) orchardgrass (*Dactylis glomerata* L.) and white clover (*Trifolium repens* L.), 2) orchardgrass, white clover, chicory (*Cichorium intybus* L.), 3) orchardgrass, tall fescue (*Festuca arundinacea* Schreb.), perennial ryegrass (*Lolium perenne* L.), red clover (*Trifolium pratense* L.), birdsfoot trefoil (*Lotus corniculatus* L.) and chicory and 4) six species mix plus white clover, alfalfa (*Medicago sativa* L.), and bluegrass (*Poa pratensis* L.). The pastures were sub-divided into smaller paddocks and stocked rotationally with lactating Holstein cows during April to August 2002. Four cows grazed each treatment. Herbage allowance was 25 kg DM cow^{-1} d^{-1}. Cows were fed a 13 % crude protein, corn-based concentrate (0.25 kg kg^{-1} milk) in two equal feedings after milking. Cows were moved to a fresh paddock after morning and afternoon milking. Pre- and post-grazing herbage mass was measured twice each week during the grazing season with a calibrated rising plate meter. For one week in each of the four grazing periods, the structure of swards 1 (two species mixture – 2SM) and 4 (9 species mixture – 9SM) were determined by clipping two samples per replicate. Each replicate consisted of four clips along two transects before and after grazing at each sampling date. We stratified the samples taken in the field into 6 layers (0-5, 5-12, 12-19, 19-26, 26-33 and 33-40 cm above ground level, designated layers 1-6, respectively). Sub-samples of each layer were used to measure herbage mass and forage quality parameters of each species in the mixture. Herbage disappearance was assumed by using the difference between pre- and post-grazing. Fertiliser N was not applied, in order to establish high amounts of legumes in the swards. The analysis of variance, based on a 2 × 4 × 6 factorial design (2 mixtures, 4 periods, 6 sward layers) in a complete block with two replicates, was performed with the MIXED procedure in SAS.

Results and discussion

The mean differences in sward composition due to the complexity of the mixture can be summarized as follows: i) the invasion of weeds and unsown species was much more relevant in the 2SM; ii) the % of legumes was much higher in the 9SM due to relatively high amounts of red clover in the swards, however, alfalfa and birdsfoot trefoil were not competitive in this mixture; iii) chicory was the dominant species in the 9SM in all grazing periods. Focussing on the significance of experimental factors on the contribution of sward components (% of DM yield) for pre-grazing, herbage disappearance and post-grazing, it is evident that herbage disappearance, which is an indicator for selection of herbage, is mainly relevant for chicory, showing significant effects of period of grazing. While chicory was preferred in the first grazing period, the situation changed to the opposite in the latter ones, when chicory became more stemmy and reproductive. In the 2SM however, the % of white clover was always lower in the post-grazing situation when compared with the pre-grazing one. Type of selection, however was different between chicory and legumes. While chicory was actively selected due to the availability of single leafs and stems for the cows, legumes were selected mainly by stratification. That means that cows stratified the sward in the simple mixture from the upper layers downwards without any active selection. So the available biomass of white clover, which is located mainly in layers 3 and 4 (18-32 cm above ground level) disappeared between pre- and post-grazing, while the grass fractions, which are mainly located in layers 1 and 2 were not affected by grazing. The consequences of these differences in the vertical structure of the 2SM and the 9SM indicate a higher production potential (milk / meat) for the 9SM, due to significantly higher values in *in vitro* true digestibility (IVTM) in the pre-grazing situation (Figure 1). With respect to the disappeared IVTM, however, which indicates the quality of consumed forage, no significant differences were observed over the grazing season. These indications are confirmed by Sanderson *et al*. (2004), who did not find any differences in milk production due to the complexity of mixtures.

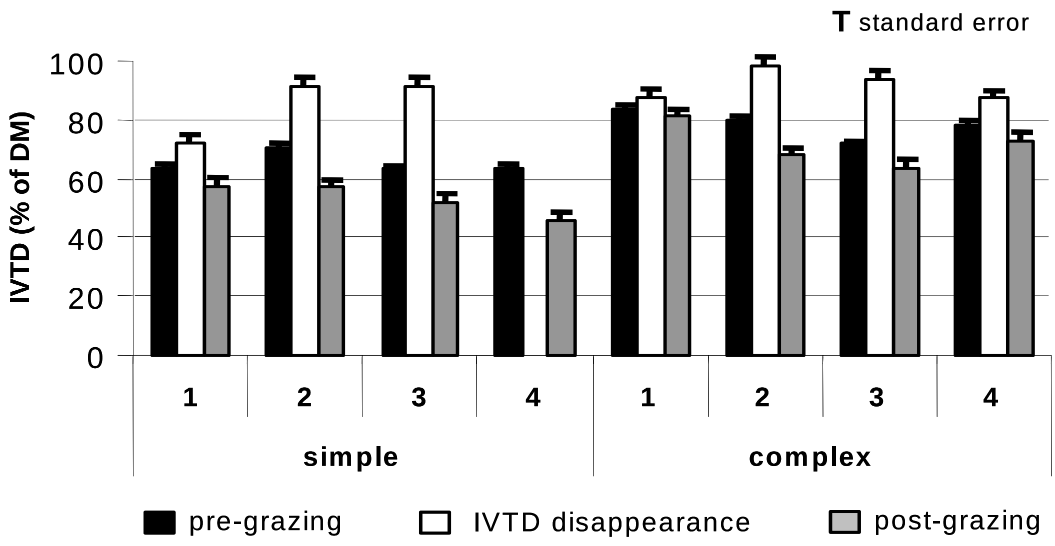

Figure 1. *In vitro* true digestibility (IVTD) proportion of the DM for the four grazing periods and two mixtures before and after grazing. The IVTD of the herbage apparently consumed by the cows (IVTD disappearance) is a function of the total yield and the IVTD proportion before and after grazing.

Conclusions

Complex mixtures obviously allow a higher production potential (pre-grazing situation) than simple mixtures in low input production systems. Differing patterns of sward composition and forage quality in the pre- and post-grazing situation, however, indicate that consequences of different types of selection processes have not yet been fully understood. Further research is needed to understand the consequences of an increasing complexity of mixtures. In our experiment, it was evident that the factor complexity of mixture was influenced by the strong competitiveness of a single species (chicory) in the 9 SM, which was not abundant in the 2SM. However, the data presented indicate, that the vertical structure of the sward is a key parameter to understanding selection processes by grazing ruminants, with respect to different complexity of swards.

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Dry matter yields from different grassland systems on Flemish dairy farms

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Abstract

In Flanders, grassland management is very diverse. Multiple combinations of intensive, extensive, rotational, continuous, day-night or day only grazing occur. Continuous grazing and the intermediate system (rotational grazing on only 4 to 6 parcels) are the most commonly used grassland systems. Recently, some farmers have changed from continuous grazing to rotational grazing systems, in the expectation of achieving higher DM yields. In this work continuous grazing, rotational grazing and an intermediate system for dairy cows were compared.
Grassland management data from 20 dairy farms (166 land parcels) were analysed and DM yields were calculated. No significant differences in DM yields were found between the three cut-grazing systems. The differences between farms and within farms were much higher then those between grazing systems.

Keywords: dry matter yield, continuous grazing, rotational grazing

Introduction

Grassland remains the most important and cheapest source of forage for summer feeding on Flemish dairy farms, comprising more than 50 % of an average dairy farms land use. Some farmers have recently changed their grazing system from continuous grazing to rotational grazing or to an intermediate system in the expectation of achieving higher DM yields. The intermediate system is very popular in Flanders because it combines the positive aspects of continuous grazing (less labour) and rotational grazing (more flexibility). This research investigates the DM yields of three different grazing systems.

Materials and methods

The grassland management of 20 dairy farms (166 land parcels) was recorded on a daily basis during the grazing season of 1999. The selected farms were comparable in intensity (milk production cow^{-1} and ha^{-1}), in the proportion of farmland comprising of grassland and in the N surplus on a per farm level (Table 1).
The farmers collected the following data: date and amount of fertiliser applied (mineral and organic), mowing data, grazing time and stocking density. The DM yield of mown grass was calculated based on the silage volume and density, or on the grass height at mowing time (Behaeghe, 1993). The grass uptake by cows was calculated based on the milk production per cow and the lactation period. The grass uptake was corrected for the time of season according to the French UEL-system (Jarrige, 1988): the uptake of autumn grass is lower then the uptake of spring grass. Three cut-grazing systems (at least 1 cut y^{-1}) were identified: continuous grazing (farms with less then 4 land parcels for grazing cows), rotational grazing (7 or more land parcels) and an intermediate system (4 to 6 land parcels).

Results and discussion

Grazing system had no effect on yield (Table 1). This agrees with Lantinga and Van Bruchem (1998) and Cavallero *et al.* (1993), who also found no difference in DM yield between continuous and rotational grazing systems. The only observed significant difference between the grassland systems was the area of the individual land parcels. This arises because a rotational grazing system needs more land parcels of a smaller area then does a continuous grazing system. There was a larger variation in DM yield within a grassland system than between grassland systems. The lowest and highest DM yields in a continuous grazing system were 7635 and 11,271 kg DM ha^{-1} respectively. In the rotational grazing system, the lowest and highest DM yields were 8664 and 12,392 kg DM ha^{-1} respectively. This illustrates that the applied grassland management within a grazing system had a greater effect than the system itself.

Table 1. Grassland management data and DM yields on Flemish dairy farms with different grazing systems.

		Grazing system		
	Units	Rotational	Intermediate	Continuous
Number of farms		5	9	6
Number of land parcels per farm		> 6	4-6	< 4
Average plot area	ha	1.37	1.95	2.75
N content of mineral fertilisers	kg N ha^{-1}	244	225	177
Effective N content of organic fertilisers	kg N ha^{-1}	72	68	55
Average number of cuts		1.92	1.33	1.15
Average yield per cut	kg DM ha^{-1}	2,220	2,470	2,330
Cut grass, proportion of total yield	%	35	31	26
Total yield	kg DM ha^{-1}	10,660	10,630	10,250
Milk production	l cow^{-1}	8,100	8,410	7,960
Milk production	l ha^{-1}	13,400	14,800	13,800
Proportion of farm comprising of grassland	%	52	53	51
Farm-N-surplus	kg N ha^{-1}	273	355	297

Multiple regression analysis showed that the two most decisive management factors for grassland yield were N fertilisation and the number of cuts:

$Y = 7770 + 452\ X_1 + 7.20\ X_2$
$R^2 = 0.36$ (n = 166)
Standard error of Y = 1110
F-value > 0 with $P < 0.05$

With Y = grass production (kg DM ha^{-1})
X_1 = number of cuts
X_2 = total N-fertilisation (mineral N +effective organic N) (kg ha^{-1})

A higher mowing frequency resulted in extra DM production (+452 kg DM ha^{-1} per cut), especially when the grass was mown in late autumn. Autumn grass is less palatable, subject to high trampling losses and winter damage can occur when too much grass is left ungrazed and carried into the winter. In a situation where cows refuse the autumn grass, it is more profitable to take a cut in October. Many farmers integrate this new practice and take an autumn cut. This explains why the average DM production per cut (Table 1) was not so high. Farmers in Nitrate Vulnerable Zones receive a financial payment if the residual soil nitrate content (0-90 cm) is below 90 kg NO_3-N ha^{-1}. Attaining this target is far easier when autumn grass is cut rather then grazed. In vulnerable zones, an autumn cut is increasingly becoming common practice. Also alternating grazing and mowing can result in higher utilisation of the grass and fewer losses due to refused grass.

The calculated regression also shows that a reduction of the N-fertilisation by 63 kg ha^{-1} can be compensated by an additional cut.

Conclusions

Grassland DM yield did not differ between farms applying continuous grazing, rotational grazing or an intermediate system in a cut-gazing system. The differences in DM yield were greater within a grazing system than between grazing systems. A management system with a higher proportion of cuts provides the possibility to reduce the amount of N fertiliser used without a reduction in DM yield. As a result there is less available to be lost to the environment.

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Effect of time of initial grazing date and subsequent stocking rate on dairy cow performance and pasture production

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Abstract

This study investigated the effects of contrasting spring grazing dates (GD) and subsequent stocking rate (SR) on milk production performance of dairy cows. Forty eight Holstein cows (160 ± 35.2 days in milk) were assigned to one of four (n = 12) grazing treatments. Two swards were created by either grazing in March (early grazing; E) or by delayed first grazing (late grazing; L). Two stocking rates, high (H) and medium (M) were applied. The experiment began on 17 April and finished on 20 June. Grazing area was allocated daily based on the following (i) Daily grazing area for LH treatment was calculated to offer 18 kg DM cow^{-1} d^{-1} (> 50 mm). (ii) Same grazing area cow^{-1} d^{-1} was allocated to the LH and EH treatments (iii) Daily grazing area for EM was calculated to offer the same DM cow^{-1} d^{-1} as the LH treatment at ground level. (iv) Same grazing area was offered to the LM and EM grazing treatments. DHA (> 50 mm) were on average 12.9, 15.7, 18.2 and 21.0 kg DM cow^{-1} for EH, EM, LH and LM, respectively. There was a significant interaction between GD and SR ($P < 0.001$) for milk, fat ($P < 0.01$), protein yield ($P < 0.001$) in both rotations and fat corrected milk yield ($P < 0.001$) in rotation 1. Early grazed swards should be grazed at a medium SR, grazing swards early also allows higher grass utilisation with beneficial effects persisting in subsequent rotations.

Keywords: dairy cows, spring grazing, stocking rate, turnout

Introduction

Grazed grass can be increased in the overall diet of the dairy cow by allowing cows access to grass earlier in the spring period. As well as improving animal performance (Sayers and Mayne, 2001; Dillon *et al.*, 2002), early spring grazing can have beneficial effects on increasing grass utilisation, sward quality and making grazing management easier. Information on the effect of preliminary grazing in spring on subsequent sward productivity and on animal production performance is minimal. The objective of this study was to examine the effect of contrasting spring grazing date and stocking rate on the milk production performance and grazing management of dairy cows.

Materials and methods

Four grazing treatments were studied with two different sward types and two stocking rates. Two different swards were created by either grazing in March (early grazing; E) or by delaying the start to grazing until mid-April (late grazing; L). Two stocking rates were imposed across each sward, high (H) and medium (M).
The experiment took place 17 April to 20 June. Treatment groups (n = 12) were balanced on the basis of the following: parity, stage of lactation (160 ± 35.2 days), milk yield (31.8 ± 4.07), milk fat yield (35.6 ± 5.94), milk protein yield (29.2 ± 1.62), body weight (622.4 ± 48.78) and body condition score (2.3 ± 0.45). The daily grazing area was allocated based on the following grazing management rules. (i) Daily grazing area for LH treatment was calculated to offer 18 kg DM cow^{-1} d^{-1} (> 50 mm). (ii) The same grazing area cow^{-1} d^{-1}

was allocated to the LH and EH treatments. (iii) The daily grazing area for EM was calculated to offer the same DM cow^{-1} d^{-1} as the LH treatment at ground level. (iv) The same grazing area was offered to the LM and EM grazing treatments. Non experimental dairy cows ('extra cows') were used to maintain rotation length the same between treatments.

Herbage mass (> 50 mm) was determined in each grazing paddock by cutting either four or six strips (0.5 × 10 m) with an Agria motorscythe. Before and after harvesting, 10 grass height measurements were recorded in each cut strip in order to determine the sampled height precisely and to calculate the bulk density (kg DM per mm ha^{-1}). The sward height before grazing was estimated (100 measurements ha^{-1}) on each sub-plot using an electronic plate meter. This sward height multiplied by the mean bulk density from the Agria cuts was used to calculate the herbage mass at the paddock level. To estimate herbage mass from ground level, the residual herbage mass after cutting by the Agria mower was measured. Pre and post grazing sward heights were measured each day with a rising plate meter with 30 measurements per treatment taken at random across the grazed strip. The sward height measured was used to calculate the daily herbage removed per cow per day.

Results and discussion

Grazing date ($P < 0.001$) had a significant effect on pre grazing herbage mass (> 50 mm) and herbage mass at ground level in both rotations (Table 1). Herbage mass (> 50 mm) in rotation 1 was 2597 kg DM ha^{-1} for early grazed swards compared to 3814 kg DM ha^{-1} for late grazed swards. In rotation 2, the difference in herbage mass (> 50 mm) declined, early grazed swards recorded herbage mass (> 50 mm) of 2095 compared to 2611 kg DM ha^{-1} for late grazed swards. Pre grazing sward height was significantly affected by grazing date ($P < 0.001$) and stocking rate ($P < 0.05$) in rotation 1. Early grazed swards had a pre grazing height of 12.4 cm compared to 16.7 cm for late grazed swards. In rotation 2, earlier grazed swards had lower sward height (11.7 vs. 12.9 cm) for later grazed swards.

Grazing date significantly affected ($P < 0.001$) post grazing sward height, early grazed swards had a post grazing height of 4.7 and 5.0 cm compared to 7.1 and 6.2 cm for the later grazed swards in rotation 1 and 2, respectively. In both rotations grazing date ($P < 0.01$) and stocking rate ($P < 0.001$) had significant effects on the amount of herbage removed. Cows grazing the early swards removed (14.3 vs. 17.2 kg DM cow^{-1} d^{-1} in rotation 1) and (14.8 vs. 16.0 kg DM cow^{-1} d^{-1} in rotation 2) compared to cows grazing the late grazed swards. Cows grazing at the medium stocking rate removed (16.8 vs. 14.7 kg DM cow^{-1} d^{-1} in rotation 1) and (16.2 vs. 14.6 kg DM cow^{-1} d^{-1} in rotation 2) compared to cows grazing at the high stocking rate.

Milk production performance was significantly affected by the interaction between grazing date and stocking rate. The difference in milk production between EH and EM treatments was 3.1 kg milk cow^{-1} d^{-1}, while the difference between LH and LM treatments was 0.9 kg milk cow^{-1} d^{-1}. The cumulative effect of the first grazing rotation increased in the second rotation. The milk yield difference between EH and EM increased to 4.9 kg milk cow^{-1} d^{-1}, while the difference between LH and LM remained similar at 1.0 kg milk cow^{-1}d^{-1} in the second rotation. The effect of stocking rate approached significance for milk fat content ($P < 0.06$) in rotation 1. Cows grazing at the high stocking rate recorded milk fat content of 38.1 compared to 37.1 g kg^{-1} d^{-1} for medium stocked cows. There was no other significant effect on milk composition in either rotation.

This interaction shows that for early turnout the cows grazing the medium stocking rate treatment performed the best, while for late turnout there was no difference between stocking rates, similar effects were found for fat, protein and FCM yield.

If early grazing is practised, less grass can be allowed to the herd but more grazing area will have to be allocated, to compensate for the lower herbage mass. While if late turnout is practised higher grazing stocking rates can be imposed without significantly affecting dairy cow performance, with this strategy milk yield per hectare will be increased by grazing higher herbage mass swards.

Table 1. Effect of grazing date (GD) and stocking rate (SR) on milk yield, milk composition, bodyweight and body condition score of grazing dairy cows. E and L are early and late grazing, respectively. H and M are high and medium stocking rate, respectively. Rse is Row standard error.

	EH	EM	LH	LM	Rse	GD	SR	Inter-action
Rotation 1								
Daily grass growth (kg DM day^{-1})	66	68	70	58	6.3	Ns	Ns	+
DM production (kg ha^{-1})	2904	3001	3051	2584	274	Ns	Ns	+
Pre grazing herbage mass > 50 mm	2567	2627	4026	3602	373	***	Ns	Ns
Pre grazing herbage mass > ground level	5954	6105	7004	6856	649	**	Ns	Ns
Pre grazing sward height	12.7	12.2	17.6	15.9	0.98	***	*	Ns
Post grazing sward height (cm)	4.5	4.9	7.0	7.2	0.38	***	Ns	Ns
DHA (kg DM cow^{-1} d^{-1}) > 50 mm	12.2	15.3	19.7	22.5	1.39	***	***	Ns
DHA (kg DM cow^{-1} d^{-1}) > ground level	28.6	35.9	34.6	43.1	2.8	***	***	Ns
Grass removed (kg DM cow^{-1} d^{-1})	13.0	15.6	16.5	17.9	1.13	***	***	Ns
Milk yield (kg day^{-1})	21.1^{a}	24.2^{bc}	23.9^{c}	24.8^{b}	0.237	***	***	***
Milk fat content (g kg^{-1})	38.5^{a}	37.1^{ab}	37.7^{ab}	37.0^{b}	0.382	Ns	+	Ns
Milk protein content (g kg^{-1})	28.4^{a}	28.6^{ab}	29.1^{b}	28.6^{ab}	0.161	Ns	Ns	Ns
Rotation 2								
Daily grass growth (kg DM day^{-1})	66	65	60	58	6.1	*	Ns	Ns
DM production (kg ha^{-1})	2075	2029	1877	1829	190	*	Ns	Ns
Pre grazing herbage mass > 50 mm	2074	2117	2608	2613	248.7	***	Ns	Ns
Pre grazing herbage mass > ground level	6108	6220	6605	6767	535.1	*	Ns	Ns
Pre grazing sward height	11.8	11.5	12.9	12.9	0.83	**	Ns	Ns
Post grazing sward height (cm)	4.8	5.2	6.1	6.4	0.42	***	+	Ns
DHA (kg DM cow^{-1} d^{-1}) > 50mm	13.4	16.0	17.6	20.4	1.63	***	***	Ns
DHA (kg DM cow^{-1} d^{-1}) > ground level	40.6	48.6	45.6	53.8	3.61	***	***	Ns
Grass removed (kg DM cow^{-1} d^{-1})	13.9	15.6	15.3	16.8	1.04	**	***	Ns
Milk yield (kg day^{-1})	17.4^{a}	22.3^{b}	20.3^{c}	21.3^{bc}	0.521	Ns	***	***
Milk fat content (g kg^{-1})	38.3	37.1	38.0	37.0	0.486	Ns	Ns	Ns
Milk protein content (g kg^{-1})	29.5	29.2	29.3	29.4	0.244	Ns	Ns	Ns

Means in each row followed by same letter are not significantly different at $P < 0.05$.

Conclusions

The results suggest early grazed swards should be grazed at a medium stocking rate, there was no effect of stocking rate on milk production from late grazed swards. Early grazed swards allow higher grass utilisation and increased milk production performance with beneficial effects persisting in subsequent rotations.

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A comparison of three grass based systems of spring milk production incorporating low fixed costs

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Abstract

A 2 year experiment investigated the effect of systems of milk production with lower fixed cost structures on the performance of spring calving dairy cows. All systems had similar mean calving dates. Systems A and B had similar stocking rates (2.7 cows ha^{-1}), system C had a stocking rate of 1.7 cows ha^{-1}. The animals in system A were housed in a conventional slatted housing unit with access to easy feed silage. System B's housing system consisted of roofless cubicles with access to easy feed silage. System C had no housing facility. The animals grazed over the winter and were confined to a sacrifice paddock having access to grass silage from a silage trailer. Lactation length was 295, 260 and 230 days for system A, B and C, respectively. The mean lactation yields (kg) over the two years were: 6391, 6018, 5735 (milk), mean milk composition (g kg^{-1}) was: 39.5, 39.6, and 40.5 (fat), 33.0, 33.4 and 33.6 (protein) and 45.8, 46.1 and 46.1 (lactose) for system A, B and C, respectively. System C required 37 % more land area than systems A and B, the extra land was used during the winter grazing period.

Keywords: low cost, winter housing, dairy cows

Introduction

When assessing the viability of dairy farms one of the many criteria of classification should be the quality of farm facilities. Farms with poor facilities are unlikely to remain viable farm entities in the future. Potentially viable farms with poor facilities are more likely to be in a situation to improve farm facilities and become viable. One of the main reasons dairy farmers are ceasing milk production is the poor state of facilities on their farms. Most dairy farmers are not in a position to finance high capital cost structures. Nowadays, dairy cow housing is expensive, alternatives to high cost housing facilities require investigation. If facilities with lower fixed costs are to be applicable to the Irish milk production system, they must developed as part of the milk production system. The objective of this study was to compare two systems of milk production with very low fixed cost structures with the Moorepark blueprint for spring milk production (Dillon *et al*., 1995) over a two year period.

Materials and methods

Sixty Holstein Friesian cows at the end of their first lactation were balanced for previous lactation milk yield, expected calving date, live weight and body condition score and blocked into three groups. Each cow was then randomly assigned to one of three winter housing systems on December 1 1998. System A had a stocking rate of 2.7 cows ha^{-1}, annual nitrogen input of 320 kg N ha^{-1} and concentrate input of 500 kg cow^{-1}. The animals were housed in a slatted cubicle house with access to grass silage. When the animals calved they were allowed to grass full time. In late lactation, the animals were housed when pasture cover reduced below recommended levels and were milked until each animal had completed on average 290 days in lactation.

System B had the same stocking rate, nitrogen application rate, grazing management and silage conservation strategy as system A. The animals on this system were housed in roofless

cubicles. They had full time access to easy feed silage. Slurry storage was within an earthen bank slurry tank. The animals remained in a roofless cubicle area during their dry period. The animals were milked until pasture cover allowed day and night grazing, when grass supply decreased below this level the animals were dried off together, and put into the roofless cubicle area. It was envisaged that the animals would milk for approximately 260-270 days, which was the number of day and night grazings achieved during the grazing season.
System C had a stocking rate of 1.7 cows ha^{-1}. The nitrogen application rate, grazing management and silage conservation strategy were different to the other two systems. The animals in system C had no housing facility. As out of season grazing was a major component of this system, the provision of sufficient pasture cover within the system to enable winter grazing dictated the animals drying off date. A 230-240 day lactation was planned for the animals within this system. The animals were wintered in a sacrifice paddock (7 % of the total land area which equated to 4.6 ha). Grass silage was fed from a mobile silage trailer. Animals were allowed access to grass at 09.00 in the morning until 16.00 hours when weather conditions allowed. Whenever weather conditions deteriorated the animals remained in the sacrifice paddock.

Table 1. The effect of system of milk production over two years

		A	B	C	SE	Sig
Year 1	Milk yield (kg)	6370	5882	5746	100.2	**
	SCM[1] (kg)	5803	5409	5319	89.9	**
	Milk fat (g kg^{-1})	38.8	39.1	39.7	0.64	NS
	Milk protein (g kg^{-1})	32.4	32.9	32.7	0.30	NS
	Milk lactose (g kg^{-1})	45.4	45.7	45.9	0.22	NS
	Lactation length (days)	300	265	230		
Year 2	Milk Yield (kg)	6396	6164	5683	109.6	**
	SCM[1] (kg)	6013	5796	5445	106.7	*
	Milk fat (g kg^{-1})	40.1	39.9	41.1	0.65	NS
	Milk protein (g kg^{-1})	33.5	33.8	34.5	0.31	NS
	Milk lactose (g kg^{-1})	46.1	46.6	46.3	0.19	NS
	Lactation length (days)	289	255	230		

[1]SCM – Solids corrected milk yield, SE – standard error, NS – not significant at $P < 0.05$.

Results and discussion

The effect of milk production system on total lactation milk yield and composition is shown in table 1. There was a significant difference in milk yield and SCM between the systems in both years. System A had significantly higher ($P < 0.01$) milk yield, fat yield ($P < 0.05$), protein yield ($P < 0.01$) and lactose yield ($P < 0.01$) in year 1. In year 2, system A and B had significantly ($P < 0.01$) higher milk yield and SCM ($P < 0.05$), fat yield ($P < 0.05$), protein yield ($P < 0.05$) and lactose yield ($P < 0.01$) than system C. There was no significant effect of milk production system on milk fat, protein or lactose concentration in any year of the study. Mean annual lactation length was 295, 260 and 230 days for systems A, B and C, respectively. Milk production system had no significant effect on bodyweight in year 1. System A's cows had significantly higher body condition score pre-calving ($P < 0.05$), at calving ($P < 0.01$) and 10 weeks post-calving. In year 2, system C had significantly ($P < 0.05$) higher bodyweight 10 weeks post-calving. System C's cows had also significantly ($P < 0.05$) higher body condition score 4 weeks pre-calving and 10 weeks post-calving.
In year 1 the winter feeding measurement began on December 1. Systems A, B and C were offered 1.1, 1.0 and 0.8 t silage DM cow^{-1} in total during the winter period. In year 2 this was increased to 1.4, 1.5 and 0.9 t silage DM cow^{-1} for systems A, B and C, respectively. System C's cows had access to grass by day for the entire winter period excluding 42 days in year 1 and 7 days in year 2 which decreased their winter forage requirement. System C had 37 %

more land area available than systems A and B. This extra land was used for grazing during the winter period. In year 1, the total concentrate DM offered was 490, 463 and 404 kg cow^{-1} for systems A, B and C, respectively. In year 2, the total concentrate DM offered was 422, 377 and 178 kg cow^{-1} for systems A, B and C, respectively.

Conclusions

With the use of low fixed cost structures lower milk output per cow must be accepted due to shorter lactation lengths. However economically low fixed cost structures are viable options for farmers with poor farm facilities. This study shows that such systems similar to system B are viable alternatives.

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High grazing pressure in early-spring increases herbage intake of grazing dairy cows in late-spring

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Abstract

The aim of this experiment was to quantify animal intake response in late-spring as a consequence of previous grazing management in early-spring. In March and April, perennial ryegrass swards were either 1) rotationally grazed by dairy cows to a post-grazing height of 7 cm (Control: C), or 2) continuously grazed by heifers to a constant sward height of 4-5 cm (Leafy: L). After 28 days of regrowth, C and L swards were compared either at low and high herbage allowance (12 vs. 20 kg DM cow^{-1} d^{-1} above 5 cm, respectively). Twelve Holstein cows in mid-lactation (24 kg FCM, 185 DIM) were assigned half to one herbage allowance and grazed the Control and Leafy swards successively over three 10-day periods from the end of May. Sward leafiness was higher in L, and cows received higher green leaf allowance on L compared to C (+6 kg DM d^{-1}). Herbage intake was 13.0, 15.7, 13.9 and 15.6 kg OM and 4 % FCM was 16.5, 19.0, 18.8 and 20.3 kg for C12, L12, C20 and L20, respectively. Intake and milk yield were significantly higher in L than in C, irrespective of herbage allowance. It is concluded than herbage intake and milk production of grazing dairy cows can be increased in late-spring by previous severe grazing in early-spring.

Keywords: dairy cow, herbage allowance, grazing management, intake

Introduction

Increasing individual performance of grazing dairy cows by grazing management can be achieved by increasing the daily herbage allowance and / or improving the pre-grazing sward structure. The effect of sward structure, defined mainly by its herbage mass, sward height, density and leaf / stem ratio, is much less documented than the effect of herbage allowance on daily intake under a rotational grazing system. The aim of the present experiment is to quantify the effect of grazing severity in early spring on subsequent sward structure and herbage intake in late spring.

Materials and methods

Four treatments were compared in a 2 × 2 factorial design with 2 perennial ryegrass sward states (Control: C and Leafy: L) and 2 herbage allowances (Low and High, 12 and 20 kg DM cow^{-1} d^{-1} > 5 cm, respectively). Prior to the experiment, in March and April, Control swards were rotationally grazed by dairy cows to a post-grazing sward height of approximately 7 cm (lax grazing). At the same time, Leafy swards were continuously grazed by heifers in order to maintain a constant sward height of 4-5 cm (severe grazing). The date of the last pre-experimental grazing day was similar for both Control and Leafy swards. It was fixed at 28 days before the planned intake measurement period of each experimental period in order to have a constant age of regrowth for each treatment during each period. The experiment was carried out with 12 Holstein cows during 3 consecutive periods of 10 days according to a hierarchical switchback design. Six cows were assigned to each herbage allowance level and grazed the Control and Leafy swards successively (C-L-C or L-C-L sequences). Mean pre-experimental characteristics of the cows were: 4 % fat-corrected milk, 23.5 kg; DIM, 185 days; live weight, 590 kg.

Pre-grazing herbage mass (> 5 cm and at ground level), pre- and post-grazing extended tiller and sheath height, morphological and chemical composition of offered grass were determined twice per period in each treatment. Individual herbage intake was measured over 5 consecutive days at the end of each period from faecal output by dilution of chromic oxide and from OM digestibility of selected grass using faecal indicators (Parga *et al.*, 2002).

Results

Pre-grazing sward structure was very different between types of swards. Leafy swards showed lower herbage mass (2.2 vs 3.7 t DM ha^{-1} > 5 cm, $P < 0.001$), lower extended tiller height (288 vs 407 mm, $P < 0.001$), lower extended sheath height (103 vs 178 mm, $P < 0.01$) and higher lamina proportion in the total DM (75 vs 62 % > 5 cm, $P < 0.01$; 45 vs 37 % at ground level, $P < 0.01$) compared to Control swards. Herbage mass below 5 cm (2.7 t DM ha^{-1}) and green leaf mass (2.2 t DM ha^{-1}) did not differ between treatments. Leafy swards showed similar crude protein content (172 g kg^{-1} DM), lower NDF content (497 vs 541 g kg^{-1} DM, $P < 0.01$) and higher OM digestibility (792 vs 751 g kg^{-1}, $P < 0.01$) than Control swards.

Daily offered area ranged between 37 and 104 m^2 cow^{-1} d^{-1} according to treatments in order to achieve planned herbage allowances (Table 1). Total herbage allowance to ground level and green leaf allowance were much larger on Leafy than on Control swards (+ 6.7 and 5.6 kg DM cow^{-1} d^{-1}, respectively).

There was no effect of herbage allowance and no interaction between herbage allowance and sward structure on both herbage intake and milk yield (Table 1). The OM digestibility of selected grass tended to be higher on High than on Low herbage allowance (+1 percentage unit, $P < 0.10$). Cows grazing the Leafy swards showed a higher herbage intake (15.6 vs 13.4 kg OM, $P < 0.01$) and higher milk yield (19.6 vs 17.6 kg 4 % FCM, $P < 0.001$) than the cows grazing the Control swards.

Post-grazing tiller height was lower on Low than on High herbage allowance ($P < 0.001$) and on Leafy than on Control swards ($P < 0.05$) (Table 1). Post-grazing lamina height was also lower on Low than on High herbage allowance ($P < 0.001$), but higher on Leafy than on Control swards (+20 mm, $P < 0.001$).

Table 1. Effect of sward type (SW) and herbage allowance (HA) on daily offered area, herbage allowance, post-grazing sward height, herbage OM intake (HOMI), OM digestibility of the selected grass (OMD) and 4 % fat-corrected milk yield (4 % FCM) in grazing dairy cows.

Herbage allowance:	Low		High		RSD	Significance		
Sward type:	Control	Leafy	Control	Leafy		HA	SW	HA × SW
Daily grazed area (m^2)	37	61	61	104	11.3	**	**	ns
Herbage allowance (kg DM)								
> 5 cm	13.2	12.6	21.9	21.1	0.07	***	ns	ns
At ground level	23.8	29.4	37.5	45.3	2.70	***	**	ns
Green leaf	8.5	13.5	14.1	20.4	1.93	**	**	ns
Post-grazing ETH (mm)	109	93	154	138	8.9	***	*	ns
Post-grazing ELH (mm)	16	31	37	61	4.5	***	***	ns
HOMI (kg)	13.0	15.7	13.9	15.6	1.71	ns	**	ns
OMD (g kg^{-1})	805	816	817	824	6.8	0.10	**	ns
4 % FCM (kg)	16.5	19.0	18.8	20.3	1.32	ns	***	ns

RSD: residual standard deviation of the model. Effect of HA was tested using the effect of cow as the residual error term; ***: $P < 0.001$; **: $P < 0.01$; *: $P < 0.05$; ns: non significant; ETH: extended tiller height; ELH: extended lamina height (tiller minus sheath height).

Discussion

The large difference in sward structure between Leafy and Control swards is probably a result of the post-grazing sward height at the beginning of the regrowth period. The sward pseudostem in the Control treatment were less grazed prior to the experiment, explaining the higher sheath height and fibre content of grass in late spring. The positive correlation between the leaf / stem ratio and the chemical composition of grass observed in this experiment shows that, on a daily basis, any sward structure advantage on intake may be partly related to a higher feeding value of grass.

Animal response to sward structure in late-spring was high (2.2 kg DM), whatever the herbage allowance. Particularly, the high intake level on leafy swards at low allowance level was unexpected. Such results were already observed by Hoogendoorn *et al.* (1992) and Parga *et al.* (2002). As most sward structure characteristics were affected by early-spring grazing management, the respective effects of herbage mass, sward height and leaf / stem ratio on herbage intake can not be determined. High intake and milk response to severe early-spring management is probably a cumulative effect of lower herbage mass (Parga *et al.*, 2002) and higher green leaf proportion (Hoogendoorn *et al.*, 1992), which results in higher green leaf allowance. Intake response to sward type was probably maximized in this experiment because the management of herbage allowance above 5 cm to ground level allows a high daily offered area and higher herbage allowance at ground level for low-mass swards. From a practical point of view, it means than high individual performance in low-mass and leafy swards may only be achieved by reducing the stocking rate. Similar or lower milk yield is effectively observed on low-mass and leafy swards when maintaining the same stocking rate as in high-mass swards (O'Donovan and Delaby, 2004).

Herbage intake and milk yield were more related to post-grazing lamina height than to post-grazing tiller height as observed by Parga *et al.* (2002). This shows that sward height *per se* during the grazing-down process under rotational grazing management will not limit intake when the grazed horizon has a high proportion of lamina.

The intake response to herbage allowance was lower than expected (Delagarde *et al.*, 2001) but the numerical increase in milk yield with herbage allowance was close to previous studies.

Conclusions

This experiment shows clearly that severe grazing in early-spring can condition the sward in late spring to obtain high dairy cow grass intakes and milk production with a lower stocking rate imposed. The results also highlight that herbage intake in a strip-grazing system is better predicted from daily green leaf allowance than from total herbage allowance or green leaf mass. Post-grazing lamina height is a better estimate of intake than post-grazing tiller height.

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The herbage intake model for grazing dairy cows in the EU Grazemore project

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Abstract

A predictive model of herbage intake was developed as part of the EU funded Grazemore decision support system to describe performance of grazing dairy cows. Initially, the potential intake (i.e., *ad libitum* intake) is calculated in a sub-model based on the INRA Fill Unit system, taking account of intake capacity of the cows, ingestibility of grass and substitution rate between grass, roughages and concentrate supplements. Secondly, at grazing, the relative intake is calculated in a sub-model taking account of sward characteristics and grazing management that can potentially limit intake compared to indoor feeding. The intake capacity model takes account of the potential peak milk yield, live weight, body condition score, stage of lactation, stage of gestation, body reserves and protein status. At grazing, correcting factors include herbage allowance and pre-grazing herbage mass in a rotational grazing system, sward surface height in a continuous grazing system, and daily access time to the pasture in both grazing systems. Within the Grazemore DSS, sward inputs are provided by the herbage growth model component. Internal and external validation with independent data show that the model is robust over wide range of grazing management practices and suitable for decision support.

Keywords: grazing, dairy cow, intake, milk yield, modelling

Introduction

Decision support tools for grazing management in dairy systems need to predict herbage intake from easy-to-obtain input variables (Mayne *et al.*, 2004). The models developed to predict voluntary dry matter intake by cattle are numerous (Faverdin, 1992), but knowledge and precise prediction of intake at grazing is much more difficult to achieve. This paper presents a new predictive model of intake and milk yield of grazing dairy cows.

Principles of the herbage intake model: The model is based on the Fill Unit system described in INRA (1989), consisting of predicting the intake capacity of cows and the feed ingestibility separately. The intake capacity is a function of animal characteristics and the forage fill value depends on species, grazing cycle number and chemical composition. Concentrates fill value is a function of substitution rate depending on energy balance of the cows. The model first calculates the potential intake (i.e., voluntary intake indoors). In a second step, the model estimates the relative intake at grazing by correcting the fill value of grazed grass by the limiting grazing management factors.

Potential intake sub-model: A new model of intake capacity was developed. In it, it is assumed that the potential milk yield, driven by genetic merit and physiological state of the cows, stimulates intake capacity. The theoretical potential milk curve results from the dynamics of mammary cells (differentiation / death) during the lactation, and is adapted from the model of Neal and Thornley (1983). This potential milk yield represents the energy requirement of the mammary gland, adjusted by protein supply when the protein availability is limiting. The model of intake capacity also takes account of the effects of live weight, body condition score, age, stage of lactation, stage of gestation, and mobilization of body reserves at the beginning of lactation. The use of the body reserves, related to the homeorhesis after calving, tends to delay the increase in intake capacity. Actual milk yield is predicted from the nutritional status of the cow. The law of response of milk yield is a function of the difference between energy demand and actual energy intake, modulated by protein intake level.

Grazing intake sub-model: The INRA fill unit system and the new model of intake capacity allows the prediction of daily voluntary herbage DM intake (HDMI) of dairy cows fed with fresh grass indoors *ad libitum*, whatever the level of concentrate or forage supplementation. For adaptation to grazing, it is assumed that fill value of grazed grass is increased, i.e., ,ingestibility is decreased, by limiting grazing conditions, mainly herbage allowance, sward structure and daily access time to pasture. Under rotational grazing management, the model calculates the average daily HDMI for one paddock and for the whole of the residence time in the paddock. Corrective factors of grazed grass fill value for herbage allowance and herbage mass (only for rotational grazing), sward surface height (only for continuous grazing) and daily access time to pasture (for both grazing systems) were determined as logarithmic response curves by a quantitative review of literature. Effects of herbage allowance and herbage mass are taken into account whatever the height at which they are calculated (from 0 to 5 cm above ground level), by means of equations of conversion. Finally, a specific algorithm using all equations calculates herbage intake and actual milk yield at the herd level, knowing either the individual cow characteristics or the average herd characteristics. Within the Grazemore DSS, herbage mass and chemical composition are provided by the herbage growth model (Barrett *et al.*, 2004).

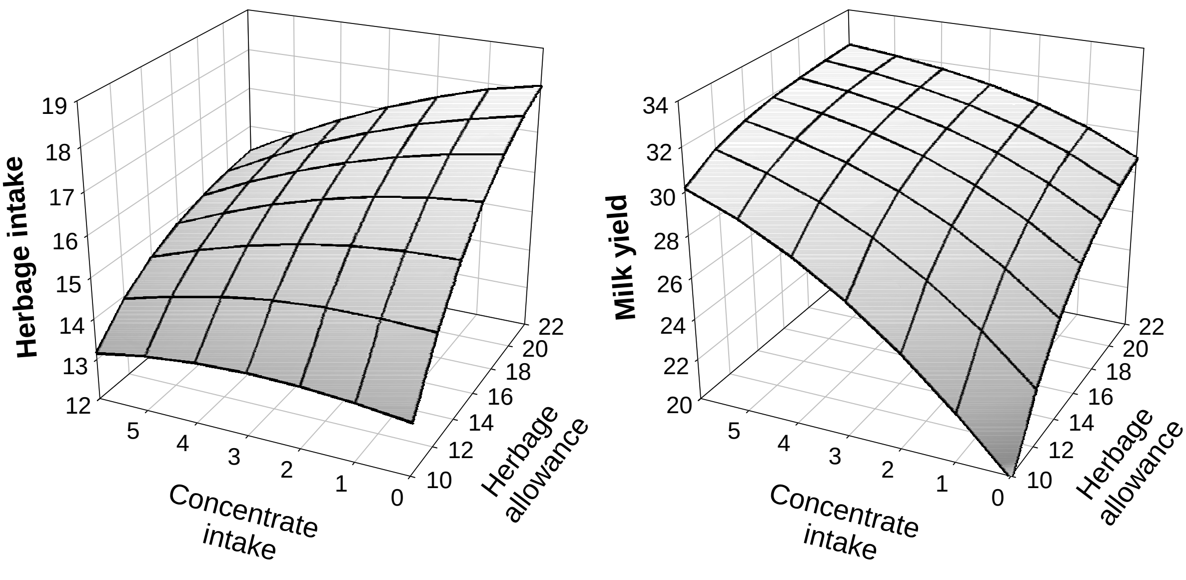

Figure 1. Simulated effects of concentrate supplementation (kg DM) and daily herbage allowance (kg DM > 5 cm) on daily herbage intake (kg DM) and milk yield (kg) by a grazing dairy cow in mid-lactation.

Validation of the model: An internal validation was carried out in order to test the robustness of the model for many grazing situations. An example of a simulation for a standard cow (40 kg milk at peak, 20 weeks of lactation, 600 kg live weight) in a good-quality sward (2000 kg DM ha^{-1} > 5 cm, 80 % OMD, 180 g CP kg^{-1} DM) is given in figure 1.
An external validation was also performed from experimental measurements of herbage intake in the different countries involved in the Grazemore project (Table 1). Data coming from 21 experiments were averaged per paddock and per herd (n = 208). The range of main

variables in this database was as follows: actual herbage intake, 8-22 kg DM; actual milk yield, 11-42 kg; forage supplementation, 0-9 kg DM; concentrate supplementation, 0-10 kg DM; herbage allowance, 13-65 kg DM > 2cm; potential peak milk, 22-50 kg; live weight, 460-680 kg. On average, the model performs well in predicting the differences in herbage intake and milk yield between countries, experiments and treatments. The mean prediction error (MPE) calculated from the mean-square prediction error (MSPE, Rook *et al.*, 1990) is 18 % for intake and 13 % for milk yield. Precision of the prediction is higher considering only herds with more than 20 cows (MPE < 10 % for intake), probably due to a better estimation of actual intake.

Table 1. External validation of the Grazemore herbage intake model for grazing dairy cows at the herd / paddock level with independent data from five research centres in Europe.

Research centre	Number Herds	Supplements intake (kg DM)	Herbage intake (kg DM)			Milk yield (kg)		
			Observed	Bias		Observed	Bias	
			Mean	Mean	s.d.	Mean	mean	s.d.
INRA (France)	118	0.9	16.3	-0.9	1.73	20.8	2.3	2.00
ARINI (N.Ireland)	38	3.5	12.8	2.2	2.62	26.6	1.6	2.57
IVVO (Netherlands)	26	9.4	9.5	0.5	2.73	28.0	1.0	2.63
IGER (England)	18	2.0	14.1	-0.6	3.25	21.7	2.0	1.58
CIAM (Spain)	8	3.5	17.1	-3.2	3.67	23.1	1.0	4.81
Total database	208	2.6	14.7	-0.2	2.65	22.9	2.0	2.34

Conclusions

This herbage intake model is based on present knowledge with regard to voluntary intake of dairy cows and to extensive literature review for adaptation to grazing. It enables the prediction of herbage intake of a group of cows under rotational or continuous grazing, from few input variables, all easy-to-obtain at a farm scale. Internal and external validation of the model showed its robustness, i.e., its ability to translate in a realistic way a broad range of grazing management practices. Actual precision of the prediction shows that the model is suitable for dairy cow feeding management at grazing.

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Development of a European herbage growth model (The EU Grazemore project)

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Abstract

The Grazemore Herbage Growth Model (HGM) is one of three integral components of an EU funded project, which is a decision support system (DSS) to aid and improve grassland management on dairy farms across the Atlantic Arc region of Northwest Europe. The HGM is a mathematical model predicting seasonal herbage production from N fertiliser inputs and forecasted meteorological data. It is based on a previously constructed model, LINGRA (Schapendonk *et al.*, 1998), but has been developed to meet the specifications of the Grazemore project. The HGM differs from the original LINGRA as it takes account of reproductive growth, herbage growth response to applied N fertiliser, while estimates of white clover proportion and herbage quality are also made. The model has been validated using herbage production data from locations across Northwest Europe and is considered suitable for a predictive application.

Keywords: simulation, grazing, production, dairy, management

Introduction

Grassland budgeting is a fundamental component of effective pasture management in a grass-based dairy production system. Budgeting is complicated by the fact that the rate of grass supply is highly variable and difficult to forecast. Models can be useful for predicting biological processes and in this paper a dynamic, mechanistic model is presented that has been produced to function throughout Northwest Europe in predicting grass growth rates and the associated herbage quality. It is used as an integral component in a pasture decision support system (Mayne *et al*., 2004; Hetta *et al*., 2004) in combination with a herbage intake model (Delagard *et al*., 2004).

Materials and methods

The performance of three existing grass growth models were tested (Barrett *et al*., submitted) and the LINGRA model (Schapendonk *et al*., 1998) was selected to form the basis of the Grazemore herbage growth model. Meteorological and nitrogen inputs drive the model. It is a sink/source model, as described by Schapendonk *et al*. (1998), and as such, daily growth is based on the interaction between the mechanistically determined components of source supply and sink demand. Source is determined from the basic light utilisation model for crop growth described by Monteith (1977). Sink strength is related to temperature-dependent leaf area increase, calculated from tiller number and leaf formation and elongation rates, adapting Davies (1977) and Peacock (1975), respectively. A sub-model to account for reproductive growth was added to improve both the theoretical basis of the model, but also its precision (Barrett *et al*., submitted). Other developments to the original model included taking account of nitrogen input rates, by adjusting potential growth using nitrogen response curves produced from the extensive Grassland Research Institute study (Morrison *et al*., 1980). Empirical estimates are also made of the organic matter digestibility (OMD), crude protein (CP) content and the amount of white clover in a mixed grass and white clover sward. The model was independently validated against growth data collected from two European locations. Firstly, from two sites at the Agricultural Research Institute of Northern Ireland (ARINI) throughout the 2003 growing season, from perennial ryegrass plots cut at 21 day intervals and designed over three series, so that one series of plots was cut weekly, similar to the design described by Corrall (1988). Growth was recorded weekly from the beginning of March to the end of October (n = 34). Secondly, the model was compared against growth determined at Wageningen, the Netherlands, in 1983 from data collected for the FAO European grass growth monitoring project (Corrall, 1988) (n = 35).

Results and discussion

The precision of the model was tested using mean square prediction error (MSPE) analysis (Rook *et al*., 1990) (Table 1). MSPE is composed of the sum of three components, namely: bias, line and random variation. At ARINI, the bias and line components of the MSPE were low, 0.068 and 0.009, respectively, while random variation was high. The low bias component indicates that predicted rates are not consistently higher or lower than the observed, while the low line component indicates that the difference of the slope of the regression is low and a good prediction slope was found. Therefore, the main source of variation is in the random component (0.923) and hence due to random causes. For the Wageningen dataset, the bias component was comparatively higher (0.19), and indicates the trend of the model to consistently over- or under-predict at certain times. As was the case, the model over-predicted growth in the latter part of the season at Wageningen. This trend can be seen from the profiles of seasonal production (Figure 1).

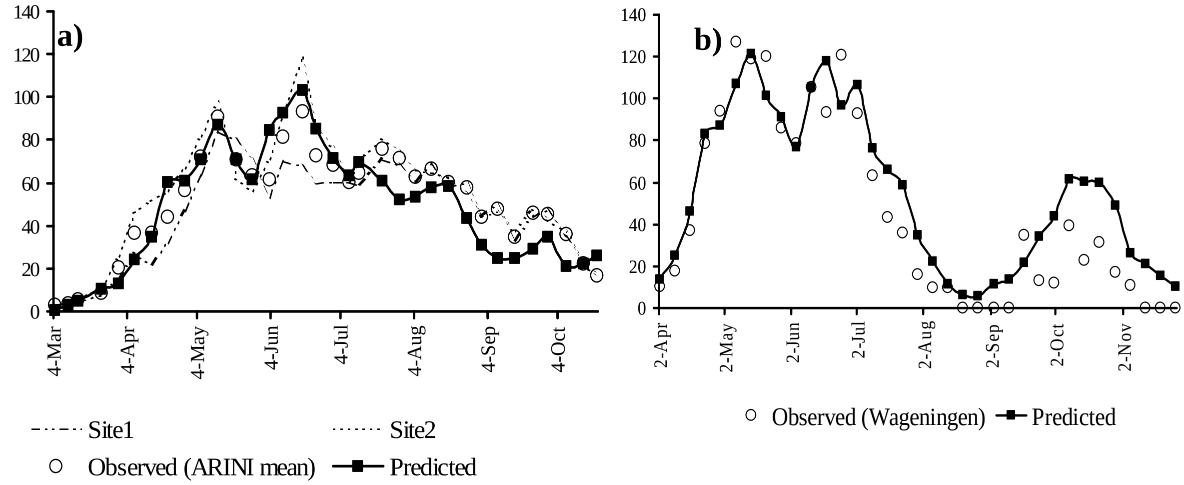

Figure 1. The seasonal profile of the growth rates (kg DM ha^{-1} d^{-1}) from a) both sites at ARINI, the observed ARINI mean and the model predicted, and b) the observed at Wageningen and the model predicted.

A regression of predicted growth rates (from the model) against the observed ARINI growth rates gave a good closeness of fit (R^2 = 0.85). Incidental but notable, is the variation in growth rates between the two sites (Figure 1a), particularly in the first half of the season, where, by comparison, R^2 = 0.75 if the growth rates of the two ARINI sites were compared, highlighting the complexity of predicting the growing process. For the Wageningen dataset, although model predictions were good in the early and middle parts of the season, as mentioned, the model tended to over-predict growth from mid-September onwards. This led to R^2 being lower than those observed at ARINI, while MSPE and MPE values were higher, indicating a closer prediction for the ARINI site than the Wageningen site. However, at both sites, if certain time periods within the season were isolated and analysed, goodness of fits of the model for these periods could have been substantially improved. As it was, taking the season as a whole, the model performed well and with sufficient accuracy to be used in a decision support application.

Table 1. Prediction precision of the herbage growth model against the actual growth rates observed at ARINI (n = 34) and Wageningen (n = 35).

	Growth rates (kg DM ha^{-1} d^{-1})						Proportion of MSPE		
	Actual	Predicted	Bias	R^2	MSPE	MPE	Bias	Line	Rando
ARINI	50.1	47.5	-2.6	0.85	99.0	0.20	0.068	0.009	0.923
Wageningen	44.0	54.0	10.0	0.76	522.5	0.52	0.190	0.002	0.807

MSPE – Mean Square Prediction Error, MPE – Mean Prediction Error.

Conclusions

The herbage growth model was constructed from an existing model and further developed to improve performance and to meet the required specification for the Grazemore project. From the validation, the model was found to effectively predict grass growth at two different locations in Europe, even though growth rates were quite variable between two sites at one location. Precision was considered to be sufficiently accurate for the intended application of the model being used in a decision support system.

Acknowledgements

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Herbage intake of dairy cows on grass/white clover pasture: effect of herbage allowance

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Abstract

An experiment was carried out to examine the effect of different herbage allowances of grass/white clover pasture on herbage intake and milk yield of Norwegian Red Cattle. Target herbage allowances were 12 (L), 18, (M) and 24 (H) kg DM cow^{-1}. The treatments were repeated three times (12 days in June, July and August) in a 3 × 3 Latin square design using three groups of seven cows. In addition to the pasture grass, each group received 3 kg concentrate on average per cow. The average compressed sward height before grazing was 21 cm. Herbage intake (n-alkane method) increased with increasing herbage allowance (10.1, 11.1 and 13.8 kg DM d^{-1} for L, M and H, respectively). Although herbage intake increased with increasing herbage allowance, energy corrected milk yield (21.6 kg d^{-1}) was not significantly affected. Overall, herbage intake was lower than expected, seen in the view that white clover is often reported to promote high intake rates.

Keywords: *Trifolium repens*, white clover, herbage allowance, intake, dairy cow, pasture

Introduction

In Norway, and many other countries, the profitability of milk production is declining, and financial viability can only be maintained by reducing costs. This has lead to increased interest in white clover based systems, which have a potential to reduce costs for N fertiliser and concentrates compared to the grass based systems that are currently dominating on Norwegian farms. However, we still have a limited knowledge on how such systems should be managed in order to maximize the economic output. A central question in any system is the optimal level of concentrate in the feed, which in turn is highly dependent on the level of herbage intake. A number of studies have shown the importance of herbage allowance in determining daily herbage intake (Peyraud and Gonzalez-Rodrigues, 2000). However, comparable data for white clover based systems is lacking. The aim of the present study was to investigate the effect of herbage allowance on herbage intake in dairy cows grazing white clover based pasture at a moderate level of feed supplementation.

Materials and methods

The experiment was carried out on grass / white clover (*Trifolium repens* L.) swards where > 75 % of the grass fraction consisted of perennial ryegrass (*Lolium perenne* L.). Low (L), Medium (M) and High (H) daily herbage allowance (HA) were compared, corresponding to target allowances of 12, 18 and 24 kg DM cow^{-1} at 3 cm above ground level, respectively. Twenty-one spring-calving dairy cows (Norwegian Red Cattle) were used in a 3 × 3 Latin-square design with three consecutive periods of 12 days (27 May-7 June, 24 June-5 July and 29 July-9 August, respectively). The cows were allocated to groups of seven according to their pre-experimental characteristics (days in milk 78 days, milk 24.9 kg, liveweight 482 kg). In each period, a paddock was made available that had been allowed to re-grow for at least three weeks since the previous defoliation. The paddocks were divided longitudinally so that the three treatment groups were adjacent. A strip-grazing system was used, a new strip being allocated each morning by moving front- and back fences. The contrasting herbage allowances were obtained by varying the size of the grazing area.

Individual herbage dry matter (DM) intake was determined using the n-alkane method (Dove and Mayes, 1991). For internal marking, Captec Alkane Capsules MCM (Nufarm Health and Sciences Ltd.) was used. Faeces were sampled twice a day in the field, and in the milking-room on the last five days in each period, for the determination of alkane content. Sward height was determined using a rising-plate meter (Mould, 1992) (150 pre- and post-grazing readings per day). Herbage mass was determined by cutting strips ($0.2 \times 1\text{-}2\ m^2$) at 3 cm above ground using an electrical scissor (36 pre- and post-grazing samples per day). The NIRs-technique was used for chemical analysis. Additional samples were taken for analysis of alkane content and *in vitro* digestibility. Alkane content in herbage and faeces was determined at the laboratory of Macaulay Institute, Aberdeen (Scotland). Herbage DM intake (HI) was calculated on basis of the C_{31} and C_{32}-alkanes in faeces, herbage and concentrates, a daily release of 400 mg d^{-1} of the dosed alkanes and a faecal recovery of 0.826 and 0.861 for C_{31} and C_{32} respectively as reported by Dillon (1993).

Results and discussion

The swards offered to the cows were characterized by a high herbage mass (2795 kg ha^{-1}) and a high compressed sward height (211 mm) compared to current recommendations in Norway of a pre-grazing sward height of 150-200 mm (Johansen and Höglind, 2003). The mean clover content was 35 % of the total herbage mass above 3 cm. The mean chemical composition was 914 g organic matter, 161 g crude protein, 452 g NDF and 165 g water soluble carbohydrates per kg DM, with an *in Vitro* DM digestibility coefficient of 0.75. To achieve expected HA, cows were offered 40, 56 and 75 m^2 cow^{-1} d^{-1} for L, M, and H, respectively. Achieved HA were close to the target: 11.2, 18.1 and 23.6 kg DM cow^{-1} d^{-1} for L, M, and H, respectively. Residual sward heights were 575, 758 and 875 mm for L, M, and H, respectively. The digestibility was highest in the first and lowest in the third period. The lower digestibility in the third period can be attributed to high temperature conditions, leading to fast lignification of cell walls.

HI increased with HA by 0.30 kg DM per kg DM offered, on average (Table 1), which is in good agreement with reported values for pure grass swards at similar variation in HA, eg., 0.25 kg OM kg^{-1} DM reported by Peyraud and Gonzalez-Rodrigues (2000) and 0.29 kg OM kg^{-1} reported by Meijs and Hoekstra (1984). The increase was larger from M to H than from L to M, which deviates from the diminishing return at HA > 20 kg reported elsewhere (Peyraud and González-Rodríges, 2000). However, the standard error was high, making any generalisation about the shape of the curve difficult to make from this single experiment. The intake level at H was similar to the 13.9 kg observed in an earlier trial with the same race and at the same level of concentrate supplementation (Omdal *et al*., 2002). In the cited experiment, the HA was well above 30 kg DM d^{-1} and the sward was dominated by perennial ryegrass.

Although HI increased from L and M to H, the energy corrected milk yield was not significantly affected (Table 1). A comparison of the net energy requirement for maintenance and milk production for the different groups with their net energy intake, calculated according to the Norwegian feed unit system, indicates that cows in L and M were underfed by 16 and 12 % respectively (Table 1). If this is true, it follows that the milk yields in these treatments must have been sustained partly through the mobilisation of body reserves. However, it must be taken into consideration that various sources of errors could have caused an underestimation of the herbage intake (Dove and Mayes, 1991).

Table 1. Effect of herbage allowance on intake, milk production and energy balance.

	Herbage allowance			Significance
	Low	Medium	High	level
Herbage intake (kg d^{-1})	10.1	11.1	13.8	$P < 0.001$
Concentrate intake (kg d^{-1})	3.0	3.3	3.2	NS
Milk yield (kg d^{-1})	21.6	22.4	22.8	NS
Milk composition (g kg^{-1})				
Fat	397	397	370	NS
Protein	318	321	326	NS
Energy corrected milk yield (kg d^{-1})	21.0	22.0	21.7	NS
Net energy intake / Net energy requirement (%) [1]	84	88	106	n.a.

[1] Energy calculations were based on treatment means; no statistical analysis.

Conclusions

Overall, herbage intake was lower than expected, seen in the view that that white clover is often reported to promote high intake rates. More studies will follow upon this one in order to establish why the intake rates were not higher, and to provide data for herbage intake models.

Acknowledgements

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Comparison of the effect of night-time grazing versus silage feeding on milk production and animal welfare

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Abstract

The effect of night-time grazing (P1) versus zero grazing (P0, non-pasture feeding) on animal performance and welfare was compared during the grazing season 2003. Thirty-four Holstein-Friesian cows were used in a randomized block design. Both groups were given indoors grass silage *ad libitum* plus 9 kg commercial concentrates. In addition, the P1 group was allowed to graze 12 h d^{-1} (1730 h – 0530 h) with an herbage allowance of 13.5 kg dry matter (DM) cow^{-1} $night^{-1}$. Grazing resulted in a substitution rate for silage of 0.82 and increased the metabolizable energy (ME) intake by 13 % for the P1 group. Like the ME intake, the milk yield and live weight gain were higher for the P1 group. The difference in milk yield was greater in August (+16 %) than in June (+7 %). There were no differences between the treatments in terms of locomotion score, stereotypic behaviour or muscle condition expressed as the time taken to go from standing to lying position. The ACTH challenge test for cortisol showed no difference between the treatments, but the number of cows which were under the basal cortisol assay level was higher for P1, possibly indicating lower stress.

Key words: milk production, grazing, dairy cow, animal welfare, behaviour

Introduction

During the last decade the proportion of large herds has increased in Finland. Often these farms give up grazing due to lack of available pasture area near the farm despite the low feeding cost of pasture. The economic advantages of grazing during the short Nordic growing season has been challenged by modern silage harvesting and feeding technology. However, under Finnish animal welfare legislation, all farms will have to provide livestock a chance to graze or at least provide access to an exercise area by 2006. One solution to combine efficient, economic production with animal welfare could be part-time grazing, e.g., day grazing or night grazing, which would decrease the need for pasture area. Night grazing was chosen for the trial due to the longer grazing hours between milkings, the favourable temperatures and the adequate illumination during the night-time at high latitudes.

Materials and methods

The effects of night-time grazing versus zero grazing on dairy cow performance and welfare were studied at MTT North Savo Research Station, Finland, during the grazing season 2003. Pastures were fertilised with 220 kg N ha^{-1}. Both silages and pastures consisted of timothy (*Phleum pratense* L.) and meadow fescue (*Festuca pratensis* Huds.). The grazing period for P1 was between 26 May 2003 and 3 Sept 2003. The experiment was conducted as a randomized block design using 8 primiparous and 26 multiparous Holstein-Friesian cows with an average pre-experimental milk yield of 33.0 kg cow^{-1} day^{-1}. Both groups were fed grass silage *ad libitum* plus 9 kg commercial concentrates in indoor tie-stalls. In addition, the P1 group was allowed to graze between evening milking and morning milking

(1730 h-0530 h, 12 h d^{-1}) with an herbage allowance of 13.5 kg DM cow^{-1} night^{-1}. Instead of grazing, the P0 group was allowed into an exercise area for 2 h d^{-1}. The feed intake indoors and the milk production were measured daily. The pasture intake was estimated from pre- and post-grazing herbage mass during three measurement periods lasting 7 days. The chemical composition of the feeds and the milk composition were determined by near-infrared assay. The locomotion score was measured by three trained persons once a week (1-5 scale; 1 = locomotion without any difficulties, 5 = extreme difficulties; Manson and Leaver, 1988). Muscle condition was estimated by the time taken to go from standing to lying position observed during a 12 h daytime period indoors (Herlin, 1994). Physiological parameters describing the stress status of animals were the cortisol concentration of plasma and an ACTH challenge test in which cortisol was measured with a 3-step time series (1.5 h interval) after ACTH administration. Possible stereotyped behaviour was observed before the grazing season, twice during the experiment and three weeks after the grazing season. Each observation period lasted 24 h. Indoor observation was done by video recording and outdoor observation by direct observation at 15-min intervals. The results of the indoor observations for May and July are presented.

Results and discussion

The fermentation quality of the formic acid-conserved grass silage was good (pH 3.87). The average substitution rate for silage (kg DM grass silage / kg DM grazed grass) was 0.82, increasing the ME intake by 13 % for the P1 cows compared to the P0 cows (Table 1). The differences in intake between the treatments were smaller in June than in August. Like the feed intake, the milk yield was higher for the P1 cows and again the differences were greater in August than in June. The milk fat content was higher for the cows in the P0 group than in the P1 group. The observed marginal response of 0.15 kg milk (MJ additional ME^{-1}) between the treatments was slightly higher than typical responses in concentrate supplementation. It is also noteworthy that the live weight gain was greater in August for P1 cows despite the increased milk yield.

Table 1. Effect of feeding system on grass energy content, feed intake and animal performance in June, July and August. P0 = zero grazing, P1 = night grazing, SE = standard error of mean.

	June		July		August			P values	
	P0	P1	P0	P1	P0	P1	SE	Diet	Diet*Month
ME (MJ kg^{-1} DM)									
Grass silage	11.0	11.0	10.2	10.2	10.4	10.4		-	-
Grazed grass		12.0		11.4		11.6		-	-
Feed intake(kg DM)									
Grass silage	10.8	4.7	9.8	4.2	9.3	6.0	0.32	< 0.001	< 0.001
Concentrates	7.8	7.7	7.8	7.8	7.8	7.8		-	-
Grazed grass		6.7		6.9		6.7		-	-
Total	18.7	19.2	17.6	19.0	17.2	20.5	0.32	< 0.001	< 0.001
ME intake (MJ)	214	227	194	216	192	234	3.4	< 0.001	< 0.001
LW (kg)	568	565	578	580	579	593	8.9	0.73	< 0.005
Milk (kg d^{-1})	29.6	32.5	25.7	30.1	23.8	28.3	0.82	< 0.001	< 0.001
Milk fat (g kg^{-1})	39.7	37.5	40.4	36.7	41.3	39.4	0.84	< 0.02	< 0.08
Milk protein (g kg^{-1})	31.5	32.6	31.4	32.1	32.9	33.9	0.53	0.17	0.45

ME = Metabolizable energy; LW = Live weight.

Cows in the P0 group took on average 24.1 s and cows in the P1 group 22.5 s to go from standing to lying (P > 0.1), indicating no significant differences in muscle condition between treatments. Two cows from the P0 and one cow from the P1 group were rejected from the data because of lameness. Grazing did not markedly improve the locomotion of cows (Figure 1). In general, there were few individuals with locomotion difficulties. There was some decrease in the number of score 3 observations in the P1 group. Otherwise the distributions were nearly equal and the differences were present before the grazing season began. No differences were observed between treatments in oral stereotyped behaviour.

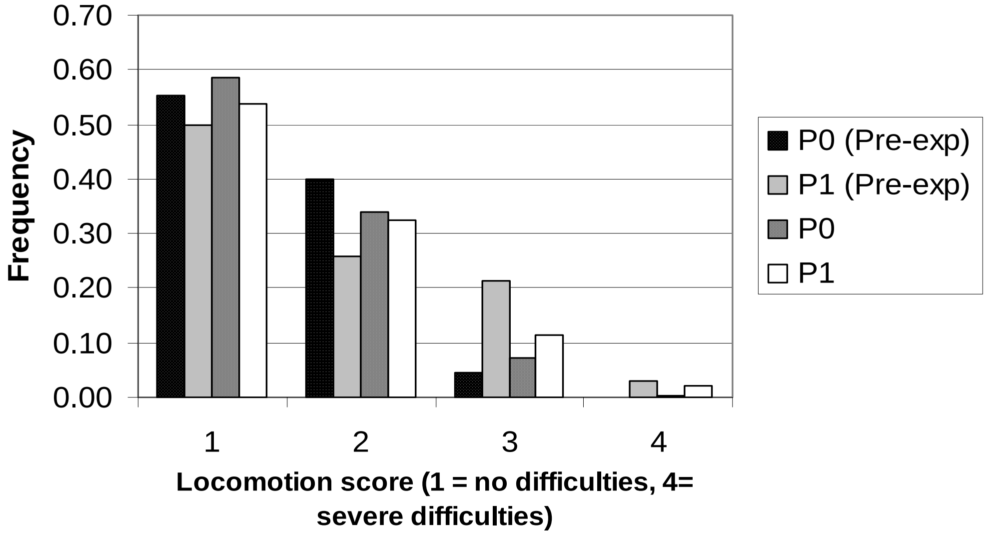

Figure 1. Effect of feeding system on the distribution of locomotion scores both before the experiment (Pre exp.) and during the experiment. P0 = zero grazing; P1 = night grazing.

The serum cortisol base level did not differ between the P1 and P0 cows (25 ± 9 and 31 ± 15 nmol l^{-1} respectively, $P > 0.1$). However, base level values below the minimum cortisol assay concentration (13.8 nmol l^{-1}) were obtained from five and 12 cows in the P1 and P0 groups respectively ($P < 0.05$, Chi-Square). Therefore, the result that the cortisol base level did not differ between the groups may not be totally accurate and the cortisol base level of the P1 cows may have actually been lower than that of the P0 cows. After ACTH administration, there were no differences in the serum cortisol levels between the groups (P1: 288 ± 72, 299 ± 98 and 260 ± 67 nmol l^{-1}, P0: 255 ± 61, 280 ± 72 and 256 ± 90 nmol l^{-1} 1.5, 3.0 and 5.0 h after ACTH administration, respectively; $P > 0.1$ for all time points). The number of cows with low cortisol level before ACTH administration indicates less stress for P1 cows, but the difference was not large.

Conclusions

The total feed intake and milk production were clearly improved by allowing the cows to graze during the night compared to zero grazing, but the effects on measured animal welfare parameters were less obvious.

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Effect of time spent on pasture and protein content of the concentrate on milk yields and body reserves

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Abstract

The objective of this study is to assess the influence of the crude protein (CP) content of concentrate (130 vs. 190 g CP kg^{-1}) on milk yield and body reserves in a production system where ewes can spend a limited number of hours on pasture. A total of 48 multiparous Latxa dairy sheep were blocked into 4 groups on the basis of milk yield, days in milk, body weight and condition score. Ewes were assigned to one of the following experimental treatments: 7 hours high protein; 7 hours low protein; 4 hours high protein and 4 hours low protein. The ewes that spent 7 hours on pasture had higher average milk yields (1490 vs. 1348 ml d^{-1}; $P < 0.001$) and protein content (53.4 vs. 51.0 g kg^{-1}; $P < 0.05$) but lower milk fat content (60.4 vs. 63.4 g kg^{-1}; $P < 0.01$) and higher body weight (60.6 vs. 58.8 kg; $P < 0.001$). High protein supplemental concentrates had a limited (+3.6 %) but significant effect on milk yield (1444 vs. 1394 ml d^{-1}; $P < 0.05$) but not on milk quality or body reserves.

Keywords: dairy sheep, rationed grazing, crude protein, milk yield, milk quality

Introduction

In the Basque country, the milk production system is based on a high pasture utilisation by means of a rationed grazing where ewes spend a limited number of hours on pasture (Oregui *et al.*, 1997) achieving important pasture intakes (Perojo *et al.*, 2003). Nevertheless, pasture intake is not enough to satisfy ewe's production necessities requiring additional indoor feeding (forage and concentrate). As a consequence there is an interaction between all the components of the ration.

Well managed pastures may contain important CP levels which can be degraded rapidly and to a great extent. For lactating ruminants this may result in an Effective Rumen Degradable Protein (ERDP): Fermentable Metabolizable Energy (FME) ratio exceeding microbial requirements and resulting in poor nitrogen use efficiencies.

One method of improving animal performance and the efficiency of nitrogen utilisation to reach a more integrated production system is the use of supplements that optimise the rumen ERDP:FME ratio. Therefore, the objective of the current experiment was to investigate the response of lactating ewes under a rationed grazing system during the spring to variations in the CP content in a supplementary concentrate.

Materials and methods

The experiment was conducted over 6 weeks during the spring of 2003. A total of 48 multiparous Latxa dairy ewes were blocked into 4 groups of 12 on the basis of milk yield, days in milk (DIM) and body weight (BW). Initial mean values for milk yield, BW and DIM were 1818 ± 227 ml, 58.3 ± 7.4 kg and 44 ± 11. Groups were randomly assigned to one of the following experimental treatments: i) supplement containing 130 g CP kg^{-1} (LP) or ii) supplement containing 190 g CP kg^{-1} (HP). Half of the daily allowance (526 g DM) of the supplements, which was formulated to be isoenergetic, was offered during each milking. Ewes were on pasture either 4 hours (4H) resulting in (4HHP) and (4HLP), or 7 hours resulting in (7HHP) and (7HLP). Each group had access to a different paddock of the same field after the morning milking. When not on pasture groups were housed separately in a free stall barn. After the afternoon milking ewes were fed 255 g DM of alfalfa hay.

Sward height was estimated twice a week using a swardstick and maintained between 6 and 8 cm by moving the electrical front fence. Samples of herbage were collected by hand-plucking from each plot every two weeks. Herbage *in vivo* OM digestibility was estimated using the equations proposed by Menke and Steingass (1988) by means of the gas production technique. Milk yields were recorded three times a week. The concentration of fat and protein were determined from one successive morning and afternoon milk sample taken each week. Standard milk yield (SMY) was calculated as described by Bocquier *et al.* (1993). BW was measured weekly. The effect of time spent on pasture and CP content of the supplementary concentrate on milk yield, milk composition and BW was subjected to an analysis of variance by the general linear models (GLM) procedure with SAS software. The milk yield and BW at the beginning of the experience were used as covariates.

Results and discussion

As expected, the mean CP of pasture was high (252.6 ± 25.4 g kg^{-1} DM) with a maximum of 294.2 g at the beginning of the experiment and a minimum of 213.9 g at the end. Therefore, pasture quality was high leading to a mean digestible organic matter of 658.1 g kg^{-1} DM. Milk yields and overall performance are presented in table 1.

Table 1. Milk yields and overall performance of ewes receiving concentrates with 130 or 190 g CP kg^{-1} and spending either 4H or 7H on pasture.

	Time		Protein			Significance		
	4H	7H	LP	HP	se	time	protein	interaction
Milk yield (ml d^{-1})	1348	1490	1394	1444	177.9	***	*	**
SMY (ml d^{-1})	1166	1281	1188	1258	211.5	***	**	ϒ
Fat								
g kg^{-1}	63.4	60.4	61.5	62.4	6.99	**	ns	ns
g d^{-1}	82.3	87.3	82.0	87.6	16.19	*	**	*
Protein								
g kg^{-1}	51.0	53.4	52.3	52.1	4.30	***	ns	**
g d^{-1}	66.6	77.2	70.2	73.5	13.52	***	*	ns
Lactose								
g kg^{-1}	49.0	50.0	49.5	49.4	1.70	***	ns	ns
g d^{-1}	65.0	73.0	67.4	70.7	13.1	***	*	ϒ
Body weight (kg)	58.8	60.6	59.7	59.7	2.20	***	ns	ns

ϒ: $P < 0.1$; *: $P < 0.05$; **: $P < 0.01$; ***: $P < 0.001$, se: standard error of mean.
SMY: milk production standardised to 5.0 MJ l^{-1} according to Bocquier *et al.* (1993).

More time spent on pasture significantly ($P < 0.001$) increased milk yield (+10.5 %), SMY (+9.8 %), milk protein content (+4.7 %), total milk protein yield (+15.9 %), milk lactose content (+2.0 %), total milk lactose yield (+12.3 %) and BW (+3.1 %). However, it significantly ($P < 0.01$) decreased milk fat content (-5.0 %) although it significantly ($P < 0.05$) increased total milk fat yield (+6.1 %). The concentrate predicted to supply high levels of CP significantly increased milk yield and SMY with the associated increases in total milk fat yield, total milk protein yield and total lactose yield. On the other hand, it did not significantly affect milk quality measured in terms of fat content, milk protein content or milk lactose content. However, a significant protein supplement by time spent on pasture interaction was recorded in terms of milk yield, total milk fat yield and milk protein content, and a tendency was recorded for SMY and total milk lactose yield. In terms of milk yield, SMY, total milk fat yield and total lactose yield there were not significant differences between 4HHP and 4HLP (1341 vs. 1353 ml d^{-1}; 1154 vs. 1177 ml d^{-1}; 83.0 vs. 81.6 g d^{-1}; 65.3 vs. 64.7 g d^{-1}) but significant differences were recorded between 7HHP and 7HLP (1536 vs. 1437 ml d^{-1}; 1340 vs. 1222 ml d^{-1}; 92.2 vs. 82.4 g d^{-1}; 76.0 vs. 70.1 g d^{-1}; $P < 0.01$). However, in terms of milk protein content a tendency was found between 4HHP and 4HLP (51.6 vs. 50.4 g kg^{-1}; $P < 0.1$) but on the other hand 7HLP produced significant more milk protein content than 7HHP (54.1 vs. 52.6 g kg^{-1}; $P < 0.05$).

Under this rationed grazing system, the increased pasture intake achieved by ewes spending 7H compared with those spending 4H (Perojo *et al.*, 2003), although little in quantity, could allow the formers to have a higher provision of precursors for gluconeogenesis in the liver. This fact could explain the recorded increases in the milk lactose concentration and milk lactose yield leading to the higher milk yield since milk lactose is the single most important osmotic constituent in milk. Furthermore, the higher body weight of the 7H group could reflect a more positive energetic balance which could explain the lower fat content (Avondo *et al.*, 2002) and the higher milk protein content (Bocquier *et al.,* 2002).

The observed interaction between time spent on pasture and the CP content of the concentrate suggests that the effect of the CP content is modulated by the grazing management. Considering that the CP could affect ingestion (Journet *et al.,* 1983), this effect could be more expressed in the 7H group, which according to recent experiences (Perojo *et al.,* 2003) only graze 32 min h^{-1}, rather than in the 4H group which is characterised by a more intensive grazing pattern achieving very high grazing times per hour spent on pasture (47 min h^{-1}).

Conclusions

Under this rationed grazing system in spring, the inclusion of high CP supplementary concentrates result in very poor differences in terms of milk yield or milk composition. Furthermore, this effect can be modulated by the time spent on pasture.

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Consequences of drought on grazing management in Switzerland

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Abstract

Swiss climate is favourable for herbage production. Grass-growth rates of 60 kg DM ha^{-1} are usual during summer in the lowlands. DM yield and sward-height measurements were made in 2002 and 2003 on 16 pastures located between 430 and 1050 m asl and intensively grazed with dairy cattle. For comparison, we classified them into five groups. During summer 2003, highland pastures in the Alps and on soils with ground water supply in the lowlands were little influenced by the drought. For those in the Jura mountains, in the hill region and on soils with low available water capacity in the lowlands, drought reduced the grass-growth to less than 20 kg DM ha^{-1} day^{-1}.

Keywords: DM yield, grass-growth, sward-density, pastures, grazing, water deficit

Introduction

Average daily herbage production is maintained at 60 kg DM ha^{-1} d^{-1} from June to late August in the Swiss lowlands (Thomet and Blättler, 1998). Stocking rates of 3 to 5 LU ha^{-1} are usually practised during summer. Due to the huge diversity of soils and meteorological conditions, pasture production may vary considerably from one region to another. Grazing management for dairy cows arouses more and more interest and thus needs regional advice. Therefore measurements of herbage growth have been made on different sites. This paper present results from two years and discuss in particular the 2003 drought.

Materials and methods

Sixteen pastures situated in south-west Switzerland were classified into five groups according to altitude, thermic level, water supply and vegetation type (Table 1). They could not be distinguished by soil type because of the huge variability of their properties. Each pasture contained more than 60 % grasses in the botanical composition. Legumes proportion varied between 15 and 34 % for leys in the lowlands and between 4 and 15 % for semi-natural and permanent pastures in the highlands. Groups A and B represent sown meadows situated on the lowland plain with 1000 mm annual rainfall but differ in their water supply. Group C includes semi-natural meadows in the hill region with 1200 mm annual rainfall. Groups D and E represent permanent pastures in mountain regions with 1400 mm annual rainfall, D in the Jura (rather dry soils), E in the Alps (rather wet soils). Table 1 shows meteorological data from 2002 and 2003 for each region. Precipitation recorded from January to September was 45 % lower in 2003 than in 2002 for group C and 27 to 30 % lower for the four other groups. On each pastures two 6.5 m^2 plots were mowed alternately every 14 days from early April to the beginning November. Cuts and measurements occurred on four-week old re-growths. 200 kg N ha^{-1} y^{-1} was applied as ammonium-nitrate (8×25 kg N ha^{-1} cut^{-1}). Fifteen sward height measurements per plot were done before and after the cuts. We used a plate pasture meter (Jenquip, NZ) with a plate pressure of 3.2 kg m^{-2}. DM yield was determined for each cut. Growth rates were calculated every two weeks using the method of Corrall and Fenlon (1978). Sward-density was calculated by dividing yield by the difference between the heights before and after the cut (harvested height).

Table 1. Classification of the sixteen pastures in five groups.

Group	n*	Region	Altitude (m a.s.l.)	Thermic level	Water supply	Vegetation type	Precipitations (mm) from January to September	
							2002	2003
A	4	lowlands	440 to 560	very mild	low	ley (< 5 years)	633	465
B	2	lowlands	430 to 440	mild	high	ley (< 5 years)	633	465
C	4	hill regions	700 to 750	cool	medium	ley (> 5 years)	940	521
D	3	highlands (Jura)	870 to 1050	fresh	low	permanent grassland	823	594
E	3	highlands (Alps)	900 to 1000	fresh	high	permanent grassland	994	695

* number of pastures per group

Results and discussion

Pastures on soils with high water table (B) and in Alpine highland (E) maintained a high annual yield over the two years: 11.7 to 12.4 t DM ha^{-1} y^{-1}, respectively 9.6 to 10.1 t DM ha^{-1} y^{-1} (Table 2). Groups characterised by low and medium water supply in table 1 (A, C and D) were more influenced by drought. In 2003, the yield reduction reached 28 % for A, 19 % for C and 24 % for D. In 2002, considered as a 'normal' year, pastures from groups A and C yielded as much as group E. Permanent meadows with low available water capacity in the Jura (group D) had the lowest yields.

The ratio between DM yield and harvested sward height was smaller for period C1-3 than C4-6 with two exceptions: B in 2002, A in 2003 (Table 2). The increase in sward density during the season is related to higher dry matter content of forage in summer. When plants wilt the sward-height is reduced. This was also observed for groups B, D and E with higher sward density in summer 2003 than in summer 2002. In cases A and C, pastures were so dry in 2003 that other factors influenced the sward density. One was the low amount of collected herbage. The variation in sward density was close to 50 % in both cases. The high yield measured in groups B and E seemed to be correlated with higher sward density.

Figure 1 reveals the diversity of conditions in the investigated area. Groups B and E represent pastures with good grass-growth and weak inter-annual variations. Groups A, C and D include pastures with lower water stress tolerance. From mid-June (week 24) to end August (week 35), grass-growth averaged 52 and 47 kg DM ha^{-1} d^{-1} for B and E respectively. During the same period in summer 2003, growth-rates in groups A, C and D reached only 12, 21 and 19 kg DM ha^{-1} d^{-1}. This represents stocking-rates of 1 to 2 LU ha^{-1} which are low for dairy production. In September 2003 (weeks 36 to 40), high growth-rates were recorded for these three groups. This second growth peak was not measured on pastures from groups B and E.

Table 2. Annual DM yield and average sward density of five pastures groups for two years (C1-3 = cuts 1 to 3; C4-6 = cuts 4 to 6).

Group	Yield in kg DM ha^{-1} year^{-1} (cv*)		Sward-density in kg DM ha^{-1} cm^{-1} (cv*)			
	2002	2003	2002		2003	
			C1-3	C4-6	C1-3	C4-6
A	10141 (23%)	7302 (24%)	188 (24%)	210 (21%)	230 (34%)	184 (50%)
B	11683 (16%)	12391 (15%)	236 (28%)	226 (27%)	226 (23%)	274 (18%)
C	10081 (18%)	8147 (20%)	192 (31%)	262 (23%)	214 (30%)	230 (47%)
D	6792 (17%)	5177 (26%)	200 (45%)	218 (20%)	192 (29%)	248 (29%)
E	10125 (18%)	9585 (13%)	230 (34%)	268 (29%)	244 (16%)	314 (16%)

* coefficient of variation

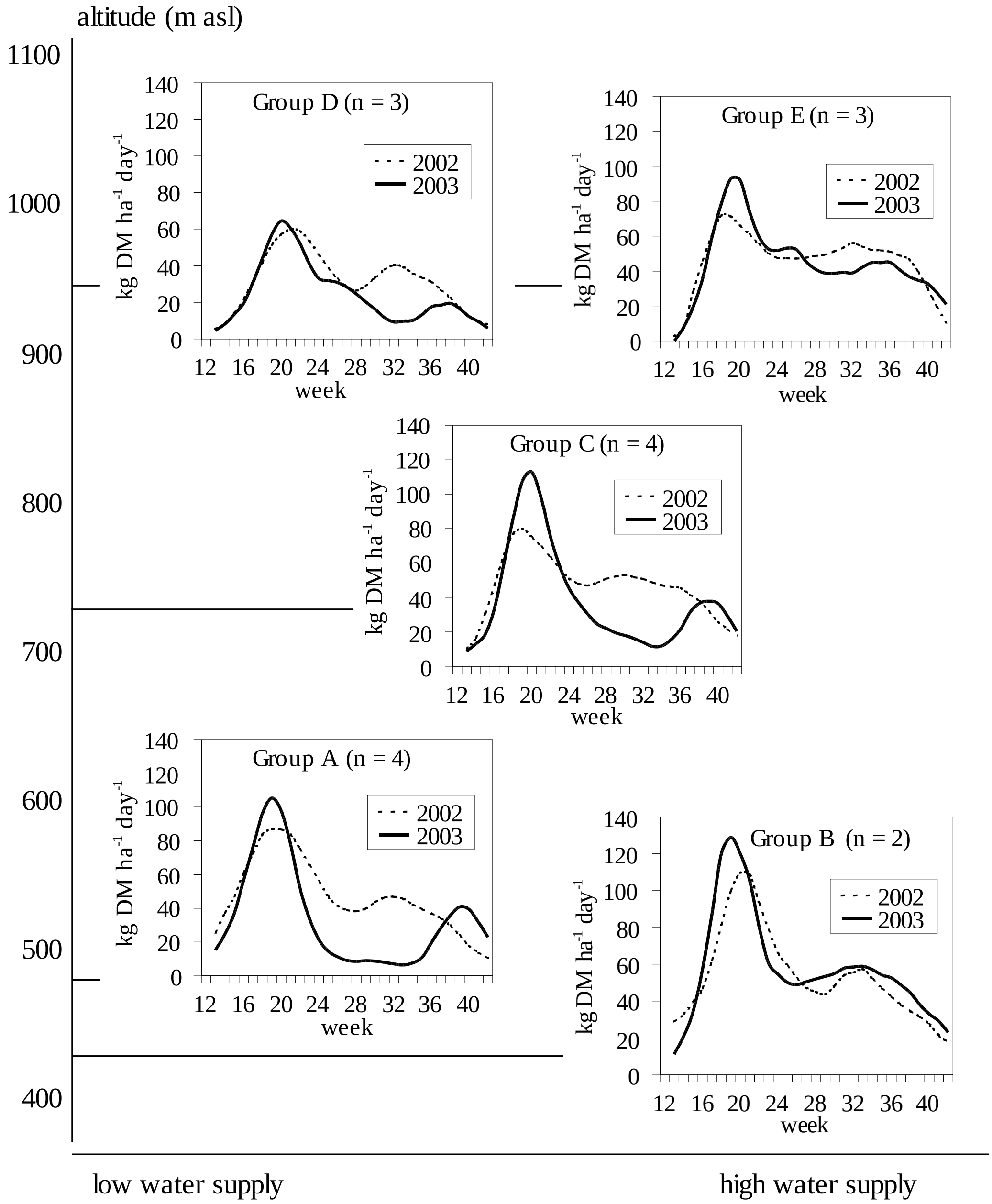

Figure 1. 2002 and 2003 daily grass-growth of five groups of pastures classified according to water supply and altitude (n = number of pastures).

Conclusions

Pastures with good water supply maintain high grass growth during dry years and allow stocking rates of 3 to 4 LU ha^{-1}. In the Jura or on dry soils, the calculated stocking rates in summer can vary from 1 to 3 LU ha^{-1} depending on the year. Areas required for full grazing-management have to be regionalized. Farm grass cover assessment based on grass height measurement has to be improved. These trials revealed high variation in sward density.

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Work organisation and time requirements of different grazing systems for dairy cattle

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Abstract

The three most common grazing systems for dairy cattle (rotational grazing, strip grazing and continuous grazing) were investigated with regard to their impact on work organization. The results revealed that working time requirements were considerably influenced by the housing system, the herding distance, the fencing system and the pasture watering system. Farms with a loose housing system, short herding distances and permanent watering facilities proved to be most advantageous. Under most favourable circumstances (fully parcelled land, continuous grazing), there are no herding activities at all. Working time requirements for grazing without additional feeding in the stable vary between 1 and 5 manpower minutes (MPmin) per cow per day according to herd size.

Keywords: pasture, working time requirements, grazing systems, dairy cow

Introduction

When putting dairy cattle out to pasture there are various grazing systems to choose from, depending on the location of the farm and the field layout (rotational grazing, strip grazing or continuous grazing). The different grazing systems are often combined, or are supplemented by providing complementary feed in the stable or in a rack.

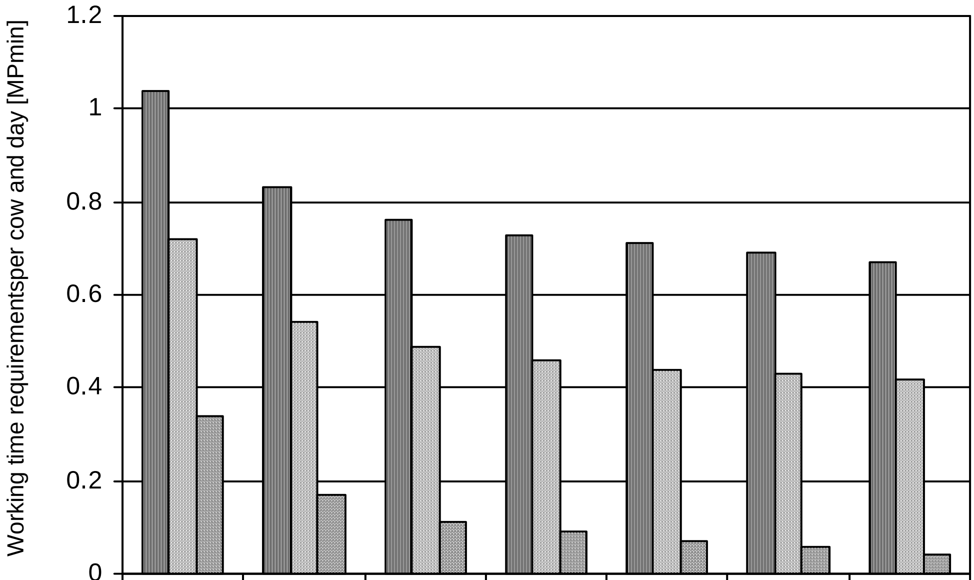
Work process in grazing

The work process in grazing comprises the following daily and non-daily work steps: 'work in the stable', 'pasture work', 'husbandry' and 'pasture management'.

The working time requirements of individual work steps are affected by qualitative factors (e.g., housing type) as well as by various quantitative factors (e.g., herding distance, herd size). In addition to the working time requirements of production-related activities, increasing account must also be taken of pasture management. Grass growth needs constant monitoring, particularly with continuous grazing, and the farm manager needs to review his decisions on an almost daily basis. Conversely, the time requirement for strip grazing is increased slightly by daily fencing. However, management input is relatively low, as decisions (e.g., moving the fence) are predetermined by the system.

Daily tasks mainly consist of herding activities. In tied housing, moreover, the animals must be released and tethered. The tethering device chosen is considered to be the key factor affecting the working time requirement. On the pasture, the other daily tasks include fence inspection and watering work. Watering work in particular can be greatly reduced by the use of permanent watering facilities (Figure 1).

Non-daily tasks include the fencing and management of each pasture. Fencing is very dependent on field size and shape as well as on the grazing system. Mobile fences offer advantages over all the other fencing systems, but sometimes have to be erected and taken down again several times a year. In spring, the work to be carried out before the animals are driven out to pasture comprises rolling and / or harrowing. In summer, following the individual grazing cycles, there is mulching or secondary mowing of the areas. Here the advantage of mulching is that both the residual herbage and the dung piles are evenly chopped and spread.



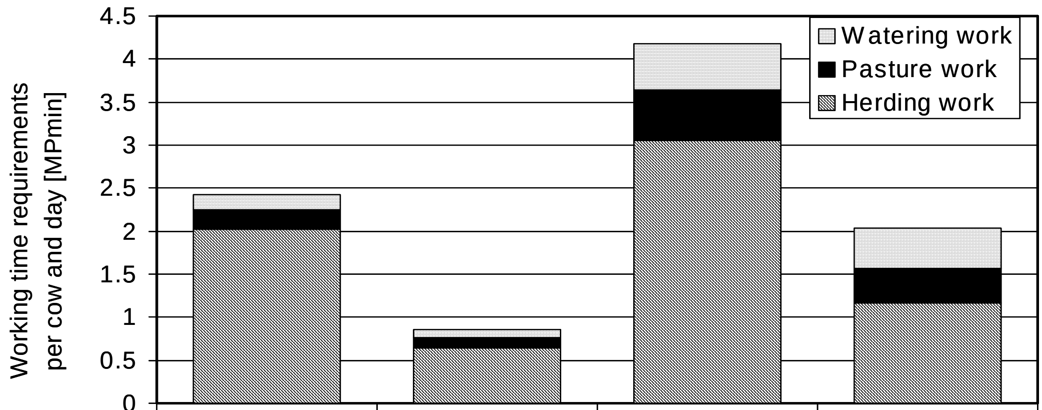
Number of cattle [n]	10	20	30	40	50	60	80
Mobile on pasture	1.04	0.83	0.76	0.73	0.71	0.69	0.67
Drinking tanker	0.72	0.54	0.49	0.46	0.44	0.43	0.42
Permanent facility	0.34	0.17	0.11	0.09	0.07	0.06	0.04

Figure 1. Permanent watering facilities reduce the daily working time requirement. Even here, however, watering inspection should not be neglected (Schick, 2001a).

Model calculation system

A model calculation system was set up to calculate the total time requirement for various grazing systems (Schick, 2001b). This also provides labour organisation information on combining different grazing systems and the relative advantages of the individual systems (Figure 2).

It is clear that the total daily working time requirement for grazing systems is made up of the necessary stable and herding work, daily fencing, and daily watering and inspection work. For example, the time requirement for a herd of 20 cows in tied housing, with a herding distance of 50 m and the ‘continuous grazing with permanent watering‘ system is around 2.4 Mpmin cow^{-1} day^{-1} (approx. 50 MPmin for the whole herd). In loose housing with 40 cows and the same conditions, the time requirement is still only 0.9 MPmin cow^{-1} day^{-1} (approx. 34 MPmin for the herd). With a herding distance of 500 m and the ‘strip grazing with drinking tanker’ system, the working time requirement increases by more than 70 % for tethered housing and 40 % for loose housing. The daily working time requirement for grazing 20 cows in tied housing then amounts to 84 MPmin, and 81 MPmin for a herd of 40 cows in loose housing. This shows the great influence of the variable factors, herding work being the most important. The relative advantages of loose housing and short herding distances quickly become apparent, as there is no need to release or tether the animals. If the cows in tied housing are tethered with articulated collars, the time requirement for grazing can be reduced by approximately 5 %.



	20 cow tied housing	40 cow loose housing	20 cow tied housing	40 cow loose housing
Watering work	0.17	0.09	0.54	0.46
Pasture work	0.23	0.13	0.59	0.41
Herding work	2.02	0.64	3.05	1.16

50 m herding distance Continuous grazing Stationary drinking system	500 m herding distance Strip grazing Drinking tanker

Figure 2. A comparison of various grazing systems illustrates the disproportionate influence of herding distance.

Conclusions

The model calculation system used provides an aid to the assessment of the work organisation effects of different grazing systems on the basis of work observations with direct time measurements. This makes job planning easier and at the same time improves work organisation on individual farms.

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The nitrogen efficiency of dairy production is determined by the production intensity of the system

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Abstract

Preliminary results from a collection of 17 case studies of commercial or prototype dairy farms throughout Europe indicated that the N-efficiency of the farm was negatively related to factors associated to farming intensity, such as fertiliser use and net purchased feed. This seamed to be largely related to a lower N-efficiency of the soil-plant sector which was not compensated by a higher N-efficiency of the animal sector, in spite of the fact that feed purchase allows a more flexible composition of the feed, which could more easily be adapted to the requirements of the animals.

Keywords: nitrogen surplus, nitrogen cycle, system study, milk production

Introduction

There has been a tendency within European agriculture towards an intensification of dairy farming. Intensive systems with large use of purchased feed can easily optimize rations to animal needs and thus increase the efficiency of N-assimilation in the digestive tracts. Such systems sustain higher milk yield per animal, which in turn should result in lower maintenance requirements. Thus, more intensive farms might be more efficient per unit of milk produce. On the other hand, the efficiency of biological processes generally decreases with production intensity. In addition, focus on the efficiency of single processes rather than on the efficiency of the whole production system is likely to transfer losses from one process to another. For these reasons it is important that the N-efficiency of dairy systems is observed and analysed at the farm level. Some results from the comparison of farm N-efficiency from case-studies in seven European countries are presented here. The results may have political implications for the selection of management strategies and these may be affected by environmental and economic requirements.

Materials and methods

Nitrogen balance data were used from 17 surveys published in Europe, ranging from Italy to Norway. Surveys covered organic and conventional farming systems. Most of them were based on averages of several commercial farms, while others were intensive studies of prototype farms (Table 1). Farm systems where more than 50 % of the feed was purchased were not considered. Annual net farm N-imports (*Input*, kg N ha^{-1} as chemical fertiliser, feed, biological fixation, atmospheric deposition etc.) or net N-produce (*Produce*, kg N ha^{-1} in milk and livestock) were calculated. There was no case of net sale of plant products. The intensity of milk production varied from around 3000 to 13,000 l milk ha^{-1} y^{-1} and the median was about 5000 l milk ha^{-1} y^{-1}. The lowest intensities were found in the Alpine regions and in some, but not all, organic farms. The highest intensities were in Northern Europe. The net milk + livestock produce, expressed in kg N ha^{-1} y^{-1} varied from around 20 to 80, the median value was 32. The ratio of the milk N-produce to the livestock N-produce varied from almost 2 to around 7, with the median around 4.7. The N-input through net purchased feed varied from less than 10 to almost 80 kg $ha^{-1}y^{-1}$, except for a farming system in the Netherlands where it was above 180 kg N $ha^{-1}y^{-1}$. Two N-indicators were used: the total N-surplus of the farm (S_{farm} = *Input – Produce*, kg N ha^{-1}), and the specific N-surplus per unit of N in the produce (SS_{farm} = *(Input – Produce) / Produce*, the suffix indicates that losses related to feed production outside the farm are not included).

Table 1. Mangement form (O: organic, I: integrated, C: conventional), country, period and number of farms included in the system studies considered. Source: No. 1, 2, 4: Taube and Pötsch (2001); No. 3: Steinshamn *et al.* (2003); No. 5, 7, 10: Scheringer and Isselstein (2001), No. 6: Kaffka and Koepf (1989); No. 8, 14: van Gool (2001); No. 9, 15: Halberg *et al*. (1995); No. 11: Cuttle (2002); No. 12: Thuen *et al.* (2003); No. 13, 16: Aarts *et al.* (2000), No. 17: Grignani (1996). For complete references see Bleken *et al.* 2003.

No	*Description*	*No*	*Description*
1	O, A, 40 farms, 1998	10	C, D, 39 farms (including 'best 25 %'), 1995/95- 1997/98
2	I, A, 51 farms, 1998	11	O, UK, Prototype 'Ty Gwyn', 1995 -1998
3	O, N, Prototype 'Frydenhaug', 1999/00-2001/02	12	C, N, Prototype 'Sørås', 1998/99-2000/01
4	C, A, 66 farms, 1998	13	C, NL, Prototype 'De Marke', 1993/94-1995/96
5	O, D, 6 farms, 1995/96-1997/98	14	C, N, ca. 20 farms each year, 1991-1999 ('25% worst')
6	O, D, 'Talhof" farm, biodynamic since 1929, 1972-1982	15	C, DK, 16 farms, May 1989-April 1991
7	C, D, 10 farms ('best 25 %'), 1995/96-1997/98	16	C, NL, Estimate, farms around 'De Marke', mid 1990s
8	C, N, ca. 20 farms each year, 1991-1999 ('25 % best')	17	C, I, 23 farms, 1993
9	O, DK, 14 farms, May 1989-April 1991		

Results and discussion

A regression of N-produce against the total N-input into the farm shows that about 13 % of the additional N-supply was found in the animal produce (Figure 1A). If the efficiency of animal manure recycled within the farm remains constant, imports of other N-supplies (mainly chemical fertiliser) should fall as feed import increases. This was not the case: there was a strong linear relationship between the net feed purchase ($F_{off\text{-}farm}$, kg N ha^{-1}) and the sum of other N-inputs (about 1.9 kg N ha^{-1} additional N-input per kg N ha^{-1} $F_{off\text{-}farm}$) (Figure 1B). Animal produce per unit of land area increased with imported feed, but since only a small amount of the N-input was found in the produce, the N-surplus per land area (S_{farm}) increased strongly with increasing use of $F_{off\text{-}farm}$ (nearly 2.5 kg more surplus per additional kg N as $F_{off\text{-}farm}$, Figure 1C). There were no clear distinctions between organic and conventional farms, but the former tended to have smaller N-input per unit of land area and thus lower surplus.

The specific surplus per unit of N in the produce (SS_{farm}) was about equally dependent on the surplus per farm area (S_{farm}), the non-feed imports, and on the total N-input to the farm ($R^2 = 0.60$, 0.59 and 0.55 respectively), but also on the net imports of feed products ($F_{off\text{-}farm}$, $R^2 =$ 0 .44) (all slopes were statistically significant, data not shown). Usually, milk production is expected to be more N-efficient than meat production. However, there was no relationship between either S_{farm} or SS_{farm} and the ratio N-livestock / N-milk.

The use of purchased feed can in theory reduce the surplus at the farm level, since some of the losses connected to feed production are allocated outside the farm. Another alternative could be that purchased feed, used to intensify milk production, causes a greater production of manure than can be effectively utilised by the local plant production, and thereby lower the N-efficiency of the plant component. We tested this hypothesis by considering the relationship between the ratio of imported to farm-produced feed ($F_{off\text{-}farm}$ / F_{farm}) and the specific N-surplus per unit of N in the milk and livestock produce (SS_{farm}). Since only a few studies had information about the actual plant production on the farm, this was estimated for most of them using a constant ratio N-feed / N-in animal produce of 4.6 (nation-wide average based on Bleken and Bakken 1997) to calculate F_{farm} + $F_{off\text{-}farm}$. The result indicated that, SS_{farm} increased as $F_{off\text{-}farm}$ increased from nil to nearly the same amount as F_{farm} (Figure 1D).

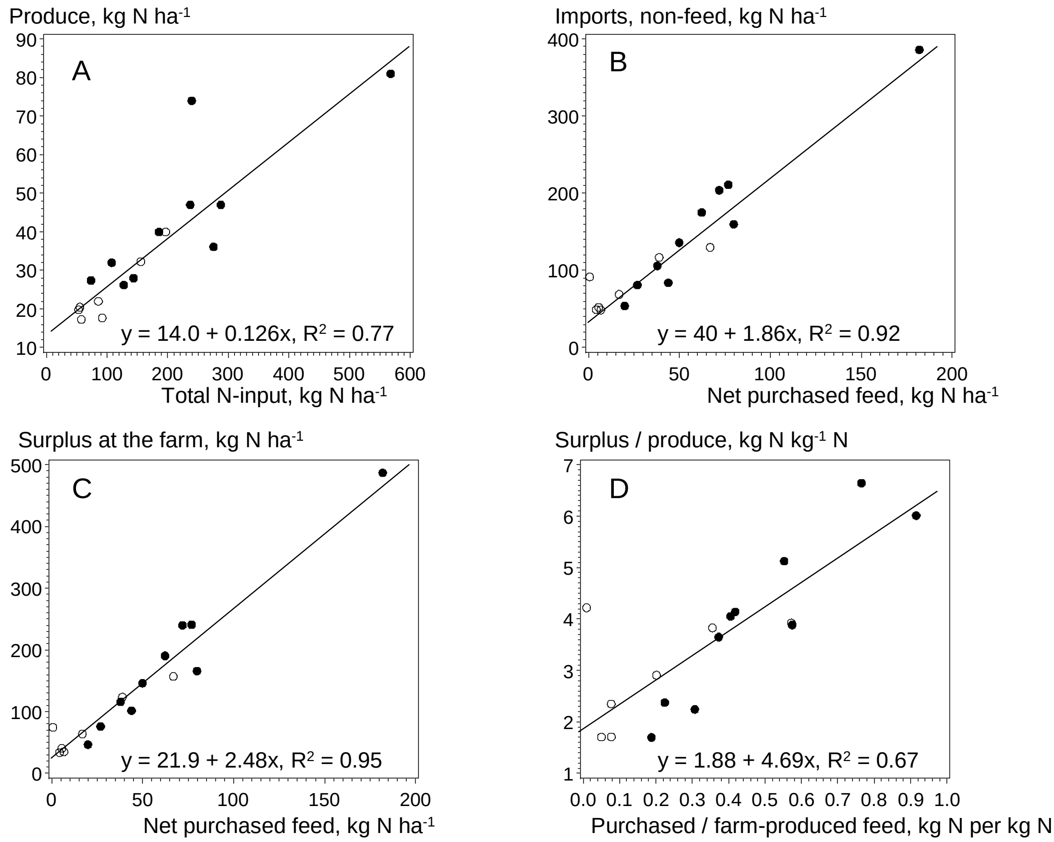

Figure 1. A) Annual N in milk and livestock net produce versus total N-input into the farm. B) N in other inputs versus N-input as net purchased feed. C) N-surplus per farm area versus N input as net purchased feed. D) N-surplus per unit of N in produce, versus the ratio of purchased to farm-produced feed. Open circles = organic or integrated farms. Closed circles = conventional farms.

These results indicate that, when land is available, a more extensive farming based on roughages is the most effective way to improve the N-efficiency. The results also indicate that, under present practice, high imports of feed, compared to the local plant productivity, reduce the N-efficiency of the farm.

Acknowledgment

We would like to acknowledge the role of published surveys in this study and to thank their authors.

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The effect of forage quality on N intake and N excretion under rotational grazing

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Abstract

Under rotational grazing we quantified the effects of forage intake on N excretion. The amount of offered dry matter (DM) on the pasture and its N concentration affected N excretion, more so with urine than with faeces. Furthermore, faeces N content was found to be a proper estimator of forage N content and hence of forage quality.

Keywords: forage quality, forage intake, N excretion, environmental impact

Introduction

The N passage from forage to the animal and to excreta has been investigated under controlled conditions in numerous indoor experiments. Grazing trials investigating N circulation are rare, as experimental parameters are difficult to control and variation of the obtained data exceeds those achieved under indoor conditions. We investigated how much forage and N ruminants take in along a gradient of forage mass and quality on a pasture and how much of the ingested N is excreted in faeces and urine. The gradient allowed a continuous adaptation of the rumen microorganisms to progressive structural changes of the forage and its ingredients.

Materials and methods

On Rengen grassland research station (Germany) in the Eifel mountains at about 500 m asl, a grazing experiment with non-lactating suckler cows (*Limousin*) was conducted from May to July 2003. We let 2 groups of 4 cows each graze along lines of 8 successive plots (42 × 23 m), group 1 along line A and B, group 2 along line C and D, further named replicates A to D. The amount of offered forage increased with time (4 day intervals between 2 plots) and the quality decreased simultaneously from ‘young’ to ‘old’. When cows finished plot 8 in replicates A and C they immediately started grazing plot 1 in replicates B and D, respectively. Plots were divided into two subplots each. In subplot 1 (three quarters of the plot area) forage samples were taken before grazing started. After 72 hours, animals were moved to subplot 2 (one fourth of the plot area) and residual biomass in subplot 1 was measured to calculate DM intake (IT). After 24 hours, animals were moved to the next plot, the number of faeces patches were counted and one random faeces sample was collected in the abandoned subplot 2. Faeces samples were weighed, freeze-dried and analysed for N content. Forage samples were oven dried, and N content was determined. Urinary N excretion was calculated from the intake of N (IT_N) minus N excretion in faeces and N retention in the animal carcass.

Results and discussion

During the very early grazing (plot 1-4 in replicate A), IT_N increased considerably (Figure 1) with IT (not shown) although forage N content decreased (Figure 2). A similar time course was found during replicate B. This was not the case during replicate C, where IT_N declined because forage N content decreased more strongly than IT increased.

For faeces N and forage N a similar curve progression was found in replicate A (Figure 2). Turning the animals thereafter directly to replicate B, faeces N content of the same animals again followed the pattern of forage N after a 'delay' of about 8 days. The same phenomenon

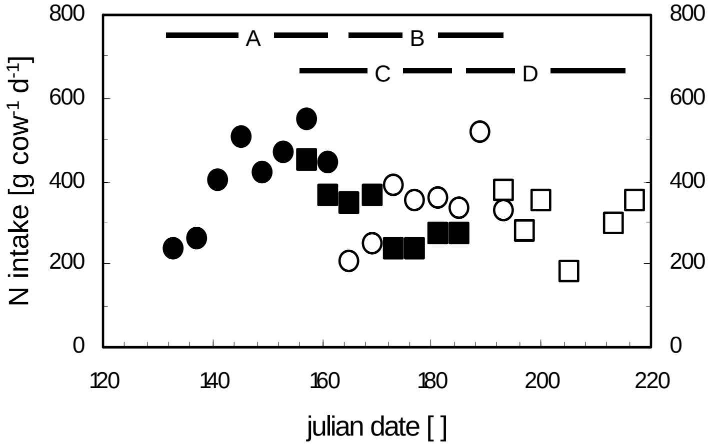

Figure 1. Time courses of N intake on a pasture grazed with 2 groups of non-lactating suckler cows in 4 replicates (A, B and C, D).

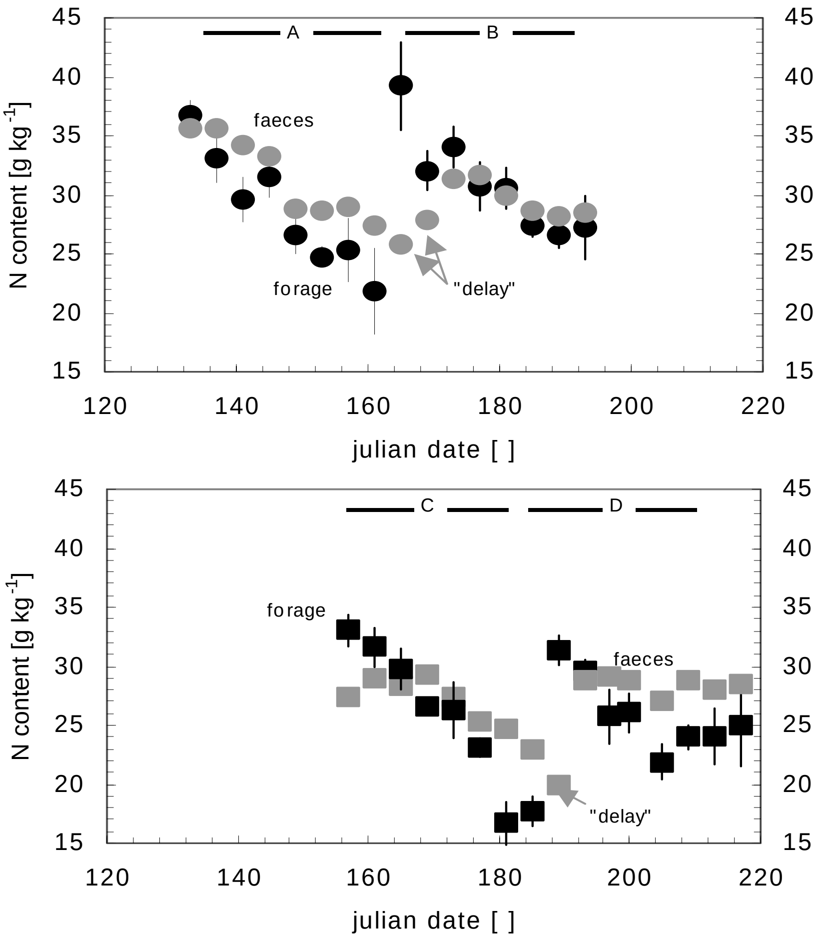

Figure 2. Time courses of forage N (black) and faeces N (grey) content on a pasture grazed with 2 groups of non-lactating suckler cows in 4 replicates (A, B and C, D).

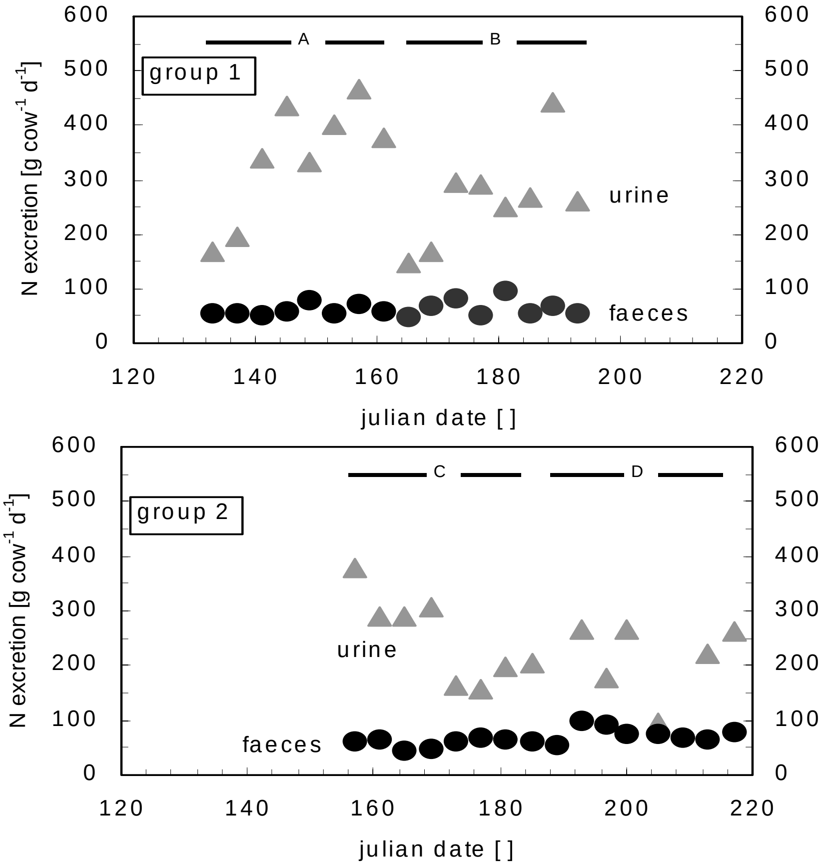

Figure 3. Time course of total faeces (black) and urine (grey) N excretion on a pasture grazed with 2 groups of non-lactating suckler cows in 4 replicates (A, B and C,D).

was observed when turning group 2 from replicate C to replicate D. It depicts from figure 2 that faeces N content may generally serve as an indicator of forage N grazed on grassland plots that differ in quality and quantity of DM. However, we cannot estimate the true N content of actually ingested forage from cut samples due to selective grazing. Faeces N content decreased less rapidly than did forage N when cows were forced to consume rough swards, which reveals increasing selection of leafy and N-rich plant material. It is known from experiments with dairy cows, that excess N is mainly excreted with urine (Haynes and Williams, 1993) and with milk urea (Kohn *et al.*, 2002). Figure 3 confirms, that total faeces N excretion expressed as [g cow^{-1} d^{-1}] remained nearly constant. Even with an abrupt rise in forage N content from A to B (Figure 2) total faeces N excretion varied only slightly. Further, total urine N excretion increased considerably with IT_N during replicates A and B, and declined with C when IT_N decreased.

Conclusions

Increasing forage N content and IT_N provokes excessive urinary N excretion which for the most part is exposed to leaching and hence is environmentally risky. In N cycling simulation models, constants for faeces N excretion can be assumed whereas urinary N release requires adequate formulation in relation to $IT_{N.}$

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Nitrogen utilisation and methanogenesis of sheep fed ryegrass silage supplemented with ensiled legumes and tannins

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Abstract

The objective of this study was to assess whether a partial replacement (500 g kg^{-1} DM) of ryegrass (*Lolium perenne*) silage by ensiled red clover (*Trifolium pratense*) or alfalfa (*Medicago sativa)* with or without the addition of tannins (41 g *Acacia mearnsii* extract kg^{-1} dietary DM) was able to improve nitrogen utilisation and to reduce methane release in sheep. Six growing lambs were allocated to the six treatments in a 6 × 6 Latin square with six experimental periods. Nitrogen turnover was determined in a balance trial and open circuit respiratory chambers were used to quantify methane emission. The partial replacement of the grass by legumes had no effect on the amounts of nitrogen excreted through faeces or urine and did not improve nitrogen retention. The daily methane emission was also unaffected. Tannins reduced ($P < 0.05$) ruminal ammonia concentration and urinary nitrogen excretion and, thus, the nitrogen emission potential, and improved body nitrogen retention. Tannins suppressed ($P < 0.05$) daily methane release by 7 % on average. Interactions between basal diet and tannins were mostly insignificant. The results suggest that tannins could be useful in suppressing methane and nitrogen emission while, under the conditions investigated, the dietary inclusion of legumes was not advantageous in this respect.

Keywords: grass, legumes, methane release, nitrogen utilisation, sheep, tannins

Introduction

There is a large amount of interest in the use of grasslands (particularly where grass and legumes are associated) and in the identification of natural feed additives in organic farming systems. One major goal is to improve the metabolic protein supply of the animals without the need of exogenous mineral nitrogen (N). Ideally, organic production systems should attempt to limit environmentally harmful emissions such as methane and N. However, there is little information available on the effects of grass-legume or grass-alone diets on methane release. McCaughey *et al.* (1999) and Murray *et al.* (2001), applying relatively crude measurement techniques on pasture, found higher methane emissions from ruminants grazing grass-legume swards compared to those grazing pure grass swards. In addition, grasses and legumes are often rich in rumen-degradable protein, which may result in a low efficiency of N utilisation and high energy costs of N excretion. Reducing methane emission and ruminal protein degradation in grass-legume based diets should therefore also reduce metabolic energy losses as well as alleviating environmental problems associated with methane and N losses. Tannins are prevalent in many plants and may reduce ruminal protein degradation and increase duodenal protein flow when given at the ideal dose. Recently, it has been suggested that tannins could also reduce ruminal methane production (Hess *et al.*, 2003), but, given at higher doses, they may also limit animal performance (Barry, 1985). The objective of the present study was to assess *in vivo* the effects of adding legume silages and / or tannins to a diet of grass silage on N utilisation, methane release and energy retention of sheep.

Materials and methods

Six castrated, but still growing, Swiss White Hill breed lambs with an initial body weight (BW) of 25.4 kg (±2.1 kg) were allocated to a total of six treatments and six experimental periods in a 6 × 6 Latin square with a 3 × 2-factorial arrangement ($n = 6$). Basal diets, as one of the main factors, consisted of three silage combinations: (i) only ryegrass (*Lolium perenne*; cultivar: Lacerta), (ii) ryegrass and red clover (*Trifolium pratense*; Leisi) in a ratio of 1:1 on a dry matter basis, and (iii) ryegrass and alfalfa (*Medicago sativa*; Sanditi / Dormal) in a ratio of 1:1. Silages were obtained from pure swards. All three diets were evaluated with or without the addition of 41 g kg^{-1} of dietary DM of a crude tannin extract (725 g condensed tannins kg^{-1}) obtained from the bark of Black Wattle (*Acacia mearnsii*; Weillbull Black, 'Mimosa tannins™'; TANACA S.A., Brazil). The experimental periods lasted for 21 days each, with the last 8 days being reserved for measurements. In these measurement periods, lambs were kept in metabolic crates, and refusals, faeces and urine (immediately acidified) were completely collected. From day 18 to day 21, the lambs were placed in respiratory chambers, and gaseous exchange including methane release was recorded for two consecutive 22.5 h runs. Lambs were fed once daily (09.00 h) with 75 g DM $kg^{-0.75}$ BW of silage thus accounting for changes in BW. Feed, refusals and faeces were lyophilised and analysed for contents of DM, ash, C, N and gross energy, and urine was analysed for N content. Balances of N and energy were calculated with standard equations. Data was subjected to analysis of variance considering the main factors, the interaction and animal.

Results and discussion

All silages had a high DM and N content (Table 1). Ryegrass and red clover silage had a higher ($P < 0.05$) organic matter digestibility than alfalfa silage (0.75 and 0.74 vs. 0.71). This was mainly the result of corresponding differences in fibre digestibility. The supplementation of legume silages to ryegrass silage did not improve N utilisation for body protein synthesis (Figure 1A) or energy retention, and resulted in a slight increase in methane emission (significant when expressed per unit of organic matter digested; Figure 1B). Methanogenesis was, however, enhanced to a far smaller extent than found by McCaughey *et al.* (1999) and Murray *et al.* (2001), but in their studies associated differences in DM intake (not recorded in the study of Murray *et al.*, 2001) could have been the major source of variation. *In vitro*, the addition of the legume *Arachis pintoi* to a low-N Brachiaria grass increased methane emission to the 4-fold level (Hess *et al*., 2003). However, in that study the additional N supplied allowed fermentation to dramatically increase, while in the present study the grass silage already provided very high N amounts.

Table 1. Nutrient composition of the experimental silages.

	Ryegrass		Red clover		Alfalfa	
	mean	sd	mean	sd	mean	sd
Dry matter (g kg^{-1})	819	13	790	9	692	15
Nitrogen (g kg^{-1} DM)	39	1	36	1	34	3
NDF (g kg^{-1} DM)	459	7	361	7	423	17

There were no significant interactions of legume and tannin addition, illustrating that effects were widely additive. *Acacia mearnsii* tannins reduced ($P < 0.05$) apparent organic matter digestibility and increased ($P < 0.001$) the proportion of N excreted with the faeces. As simultaneously less N was excreted in the urine ($P < 0.001$), thus N utilisation was enhanced (Figure 1A). This was associated with a reduced energy expenditure (heat energy loss; $P < 0.05$) and a higher body energy retention ($P < 0.001$). Supplementing with tannins reduced ($P < 0.05$) methane release, both absolutely and per unit of organic matter digested (Figure 1B).

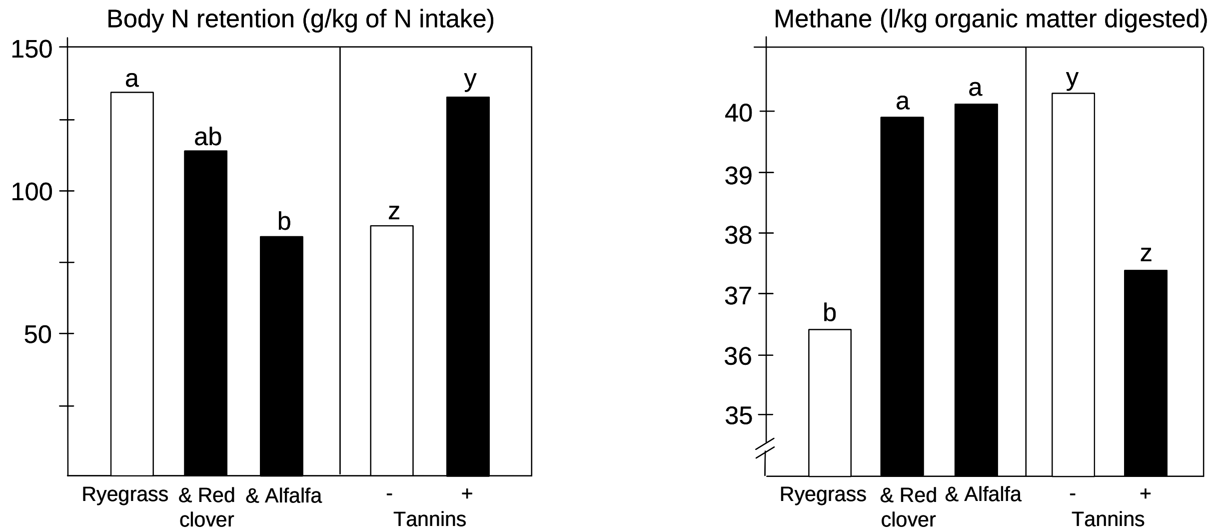

Figure 1. Effect of supplementing legume silages (over both tannin groups) and tannins (over all basal diets) on body N utilisation (left) and methanogenesis (right) in sheep.

The present study suggests that tannins could be used not only to enhance N utilisation, but also to reduce methane emission by ruminants. This confirms *in vitro* results of Hayler *et al*. (1998) and findings on the use of a legume with moderate tannin content (*Lotus corniculatus*; Woodward *et al.*, 2001).

Conclusions

The N content of the ryegrass silage was as high as that of the legume silages. This probably prevented larger effects on N turnover in the lambs. More information is needed as to whether legume addition might improve N utilisation in cases of a lower basal protein supply and whether the N from legumes remains non-utilised. Tannin supplementation, on the other hand, could improve N utilisation particularly in diets which provide excessive amounts of easily-degradable dietary crude protein, as was the case in the present investigation. A favourable side-effect of tannin supplementation seems to be a noticeable suppression of methanogenesis.

Acknowledgements

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Long-term relationships between phosphorus fertilisation, soil phosphorus status and the productivity of a permanent meadow

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Abstract

From the ecological viewpoint the accumulation of phosphorus (P) in grassland soils is undesirable. We studied the long-term effects of five levels of P fertilisation (0 to 23.2 kg P ha^{-1} y^{-1}) on the yield and botanical composition of a low input permanent meadow, on the P content of the harvested herbage and on the P availability in the soil. The experiment ran from 1992 to 2002 in a Cambisol of low P content. The 10-year balance between P off-take and P input was negative in all treatments except the one receiving 23.2 kg P ha^{-1} y^{-1}. After 10 years, the amount of immediately plant available P in the 0 to 10 cm soil layer was only about 2.5 mg P kg^{-1} soil when 0 or 5.8 kg P ha^{-1} y^{-1} was applied. Correspondingly, the yield and the plant P content were 25 % and 1 g P kg^{-1}, respectively, lower in the treatment receiving no P compared to the highest P treatment. The botanical composition in 2002 differed only slightly among the P treatments although the proportion of legumes was 3 % at zero P and 9 % in the highest P treatment.

Keywords: permanent meadow, phosphorus fertilisation, yield, botanical composition

Introduction

Phosphorus (P) fertilisation of permanent meadows should be sufficient to support yield and quality of the harvested herbage, but should not lead to accumulation of P in the surface soil so as to limit P losses to surface water. Changes in the botanical composition and in the P availability in the soil will interact with the amount of P applied to influence yield and P content of the herbage. Meadows therefore show variable responses to P fertilisation (Paynter and Dampney, 1991). Our objective was to assess the relationships between P fertilisation, P availability in the soil, yield and botanical composition of a low input permanent meadow.

Materials and methods

The experiment ran from 1992 to 2002 in a Cambisol (pH = 6.2 (H_2O), clay 22 %, silt 34 %, humus 4.4 %, effective soil depth 50-70 cm) of the Swiss plateau (altitude 500 m, average rainfall 1100 mm y^{-1}). The plots were mowed 3 times a year and fertilised with nitrogen and potassium at a rate of 45 and 83 kg ha^{-1} y^{-1} respectively. Five P treatments were established by applying superphosphate at rates of 0, 5.8, 11.6, 17.4 or 23.2 kg P ha^{-1} y^{-1} (hereafter referred to as P0, P1, P2, P3 and P4, respectively) in a randomized complete block design with 4 replicates. The P content of the harvested parts of the plants was determined yearly, after mixing samples from the three harvests. The botanical composition was determined in 1992 and 2003 according to the method of Daget and Poissonet (1969). The plant available P in the soil was estimated by the isotope exchange kinetic method (Frossard and Sinaj, 1997) for the years 1993 and 2002.

Results

The amount of applied nitrogen and potassium, as well as the amount of P applied in the P3 treatment, were calculated for a target dry matter (DM) yield of 6.5 t ha^{-1} y^{-1}. This was low compared to the yield at the beginning of the experiment, which reached 10 t DM ha^{-1} y^{-1}. The yield correspondingly decreased in all treatments (Figure 1). In 2002, the yield of the P3 treatment was 2.2 and 1.6 t DM ha^{-1} y^{-1} higher than the yield of the P0 and the P1 treatments respectively.

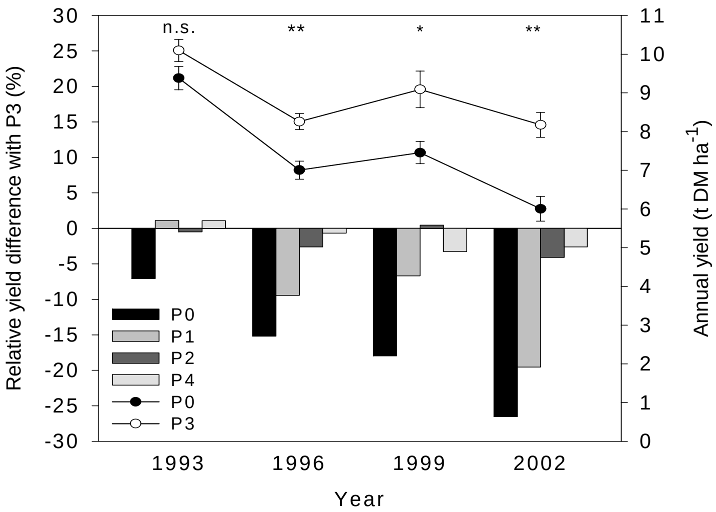

Figure 1. Changes over time of the relative difference between the yield of the P3 treatment and the yields of the P0, P1, P2 and P4 treatments, and changes over time of the annual yield of the P0 and the P3 treatments. The bars present the relative yield difference and the points the annual yield (mean ± SE of 4 replicates). n.s. = no significant difference, * and ** = significantly different at the 5 % and the 1% level, respectively.

The yields of the P2, P3 and P4 treatments were not significantly different. The P content of the harvested parts was roughly maintained between 1993 and 2002 in the P4 treatment but decreased in all other treatments. In 1993, the P content in the harvested parts was already 0.5 g P kg^{-1} lower in the P0 than in the P4 treatment. It was 1 g P kg^{-1} lower in 2002 (Table 1).

Table 1. Amount of P isotopically exchangeable within 1 minute (E_{1min}) in the 0-10 cm soil layer, P content of the harvested herbage and P off-take with the crop for the five P treatments in 2002. The P balance is cumulated from 1993 to 2002. Data are means ± SE of 4 replicates. Means followed by a common letter are not significantly different at the 5 % level by DMRT.

Treatments	Yearly P input (kg P ha^{-1})	E_{1min} 0-10 cm (mg P kg^{-1} soil)	P content of harvested parts (g P kg^{-1} DM)	P off-take with the crop (kg P ha^{-1})	Cumulated P balance (kg P ha^{-1})
P0	0	2.36 ± 0.34 a	1.5 ± 0.08 a	8.8 ± 0.33 a	- 135
P1	5.8	2.88 ± 0.19 ab	1.7 ± 0.19 ab	11.6 ± 2.03 ab	- 97
P2	11.6	4.05 ± 0.31 c	1.9 ± 0.03 ab	14.5 ± 0.28 b	- 59
P3	17.4	3.90 ± 0.43 bc	2.0 ± 0.12 b	16.0 ± 1.30 bc	-14
P4	23.2	4.33 ± 0.42 c	2.5 ± 0.05 c	19.5 ± 1.04 c	19

In 1993, the amount of immediately plant available P in the soil, measured as the P isotopically exchangeable within 1 minute (E_{1min}), was on average 6.8 mg P kg^{-1} soil in the 0-10 cm soil layer and 1.7 mg P kg^{-1} soil in the 10-20 cm soil layer. The 10-year balance between P off-take by the crop and P input was negative in all treatments except the one receiving 23.2 kg P ha^{-1} y^{-1}. In all the treatments, P availability decreased from 1993 to 2002 in the 0-10 cm soil layer but remained similar in the 10-20 cm soil layer. In 2002, P availability in the surface soil was almost 2-fold higher in the P4 than in the P0 treatment. The proportion of grasses in the sward increased between 1992 and 2002 in all the treatments at the expense of the proportion of other species (Table 2). The yield share of *Anthoxanthum odoratum* L. increased considerably. The proportion of legumes was 6 %

lower in the P0 than in the P4 treatment. *Trifolium dubium* Sibth. was common while *Trifolium repens* L. and *Trifolium pratense* L. did not exceed a yield share of 1 %. The rate of P application accounted for 9 % of the variability in botanical composition.

Table 2. Changes with time and P application of the yield share of the grasses, legumes and other species. The yield share of the main grass species is also given. P0, P1, P2, P3 and P4 stand for yearly P applications of respectively, 0, 5.8, 11.6, 17.4 and 23.2 kg P ha^{-1} y^{-1}.

	Yield share (%)					
	1992	2002				
		P0	P1	P2	P3	P4
Grasses	62	76	74	71	75	73
Legumes	7	3	7	5	5	9
Other species	31	22	20	24	21	19
Anthoxanthum odoratum	6	21	19	13	17	18
Arrhenatherum elatius	7	8	8	4	7	8
Dactylis glomerata	10	11	11	10	9	8
Festuca rubra	12	11	11	11	12	9
Holcus lanatus	8	14	13	11	12	16

Discussion

In 1993, P availability in the soil was sufficient in the 0-10 cm soil layer but low in the 10-20 cm soil layer. The soil volume with sufficient available P was therefore small despite an effective soil depth of 50 to 70 cm. An effect of P fertilisation was observed very quickly, expressed by lower shoot P content in the low P treatments from the second experimental year. Differences in P content of the harvested parts between the P treatments could not be attributed to differences in the botanical composition. This was also true for the yield differences that were due to a general poorer growth of the sward in the low P treatments. Smith *et al*. (1985) found that *Lolium perenne* L. will produce about 80% of the maximum DM yield with a shoot P content of 1.5 g P kg^{-1} DM. The P content found in the P0 and P1 treatments was therefore probably limiting plant growth. The lower proportion of legumes in the P0 treatment might have reinforced the yield decrease by negatively influencing the nitrogen economy of the sward. This experiment showed that herbage P content and yield of the low input meadow were strongly limited by P when the amount of P isotopically exchangeable within 1 minute was lower than about 2.5 mg P kg^{-1} soil. A decrease from sufficient to low P availability in the soil was brought about by a yearly imbalance between P input and P offtake by the crop, averaged over 10 years, of about -10 kg P ha^{-1}.

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Long term phosphorus supply from soil reserves in two grassland trials

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Abstract

The objective of this work was to evaluate the long-term phosphorus (P) supplying ability of two grassland soils differing in P fertility levels. These differences arose as a result of the cumulative effects of different annual nitrogen (N) and P fertilisation rates, and hay cuts. For this purpose we studied the evolution of molybdate-reactive P in solution (MRP) and Olsen-extractable soil P in relation to the cumulative P budget. For a given soil, MRP and Olsen-P values are fitted to the P budget by a linear regression. The long-term P supply depends on the soil P buffer power that may vary widely according to the soil type, initial soil P status and P balance.

Keywords: grassland, phosphorus, P buffer power, P budget, soil solution P

Introduction

In most temperate areas, sustainable management of grassland ecosystems has to deal with evaluation and management of phosphorus, which is the second nutrient limiting production after nitrogen. Within the general context of environmental and economic concerns, accurate management of mineral resources becomes a priority. In some grasslands where large P reserves have accumulated over the years from organic or mineral inputs, soils display a high residual fertility and P fertilisation is not always required (Tunney *et al*., 1997). On the other hand, long-term P resilience is an obstacle to grassland restoration: conservation practices recommend soil fertility reduction in order to promote and sustain species-rich vegetation (Olde Venterink *et al*., 2001). In both situations we need to know the soil's ability to supply P over the long-term in order to choose appropriate management practices.
Our objectives are to evaluate the long-term changes in the soil mobile P fraction in response to contrasting soil P budgets. This work relies on two experimental fields, where the cumulative effects of practices have differentiated a wide range of P fertility levels, as estimated by the measurement of molybdate-reactive P in solution (MRP) and Olsen-extractable P.

Materials and methods

The experiments started in 1998 for Gramond (Massif Central) and in 1999 for Ercé (French Pyrénées). Both soils exhibited features characteristic of permanent grasslands, with high organic matter and N contents, and large P reserves (Table 1).
The experimental design was chosen to study, under frequent defoliation, the effects of N and P supplied as 4 treatments, N_0P_0, N_0P_1, N_1P_0 and N_1P_1, where 0 = nil, P_1 = 50 kg ha^{-1} y^{-1}; N_1 = 160 kg ha^{-1} y^{-1}. The plots (4 x 5 m) were arranged in four randomised blocks; plots were cut 3 times a year and herbage analysed for total P concentration in order to calculate P budgets, i.e., the cumulative annual differences between P applied in fertiliser and P exported in hay.
The 0-5 cm soil layer was sampled at the end of winter 2003. Molybdate-reactive P (MRP) in soil solution (16 h pre-equilibration of soil suspension 1 g: 10 ml, and filtration at 0.20 µm) and Olsen-extractable P (0.5 N sodium bicarbonate extraction of 1 g: 20 ml for 30 min) were measured. The Cp value is an estimate of the phosphate ion concentration in solution and is

highly and closely related to the soil mobile P fraction (Morel *et al*., 2000). Each data value is the mean of 4 replications.

Table 1. Physico-chemical characteristics of the 0-10 cm soil horizon at the initiation of the experiment.

	Clay g kg^{-1}	Silt g kg^{-1}	Sand g kg^{-1}	pH	O.M. g kg^{-1}	N total g kg^{-1}	Olsen P ppm P	Soil solution P mg l^{-1} P	Total P %P
Gramond (1998)	187	177	636	5.3	47.1	2.53	59	1.31	0.08
Ercé (1999)	244	486	270	6.0	75.7	4.58	11	0.09	0.176

Results and discussion

The initial soil P status was very different in the two field experiments (Table 1): Ercé soil had been regularly fertilised with farmyard manure, and exhibited higher organic matter and total P contents. At the beginning of the experiment Gramond soil presented a high Cp value, although its reserves were moderate, whereas Ercé soil displayed a very low Cp and high total P content. Changes in Cp and Olsen P were related to the changes in cumulative P budget calculated between the start of the experiment and 2002 (Figure 1). Initial Cp values were extreme, increasing with a positive P budget and decreasing with negative ones. For a given soil, the Cp values were closely and linearly correlated to the P budget. The Cp value when the net P budget is nil is 2.08 mg P l^{-1} for Gramond and 0.14 mg P l^{-1} for Ercé. The two soils display very different abilities to replenish the soil solution with P (negative budget) or adsorb P from the soil solution (positive budget). The variation in Cp per unit of P budget, i.e., the P buffer power of the soil, was 7.1 10^{-3} (mg P l^{-1}) / (kg P ha^{-1}) for Gramond, whereas it was 0.5 10^{-3} (mg P l^{-1}) / (kg P ha^{-1}) for Ercé. The relationships between Olsen-extractable P and Cp also demonstrated that the Ercé soil had a much greater buffer power than that of Gramond (Figure 2).

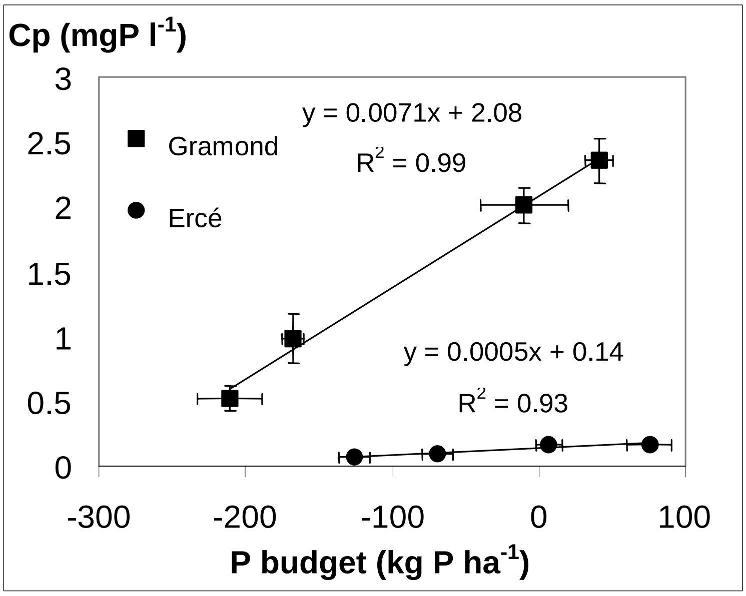

Figure 1. Evolution of MRP concentration (Cp) as a function of the P budget after 5 and 4 years of experiment in Gramond and Ercé trials, respectively.

These results can be explained both by the textures (the sandy soil having a much lower buffer power than the loamy one) and by the high reactivity for P of the Ercé soil due to its large amorphous aluminium and iron fractions (amorphous minerals or non-crystalline components), which result in a large phosphorus fixing capacity and buffer power. The

allophanic fraction calculated according to Shoji and Fujiwara (1984) is equal to 3 mg kg^{-1} and is typical of soils which display andic properties.
These results emphasised the relationships between soil capacity for long-term P supply and the presence of highly reactive fractions which control P ion transfer properties, and which buffer the P concentration in the soil solution. A future objective is to predict, by means of laboratory studies, the P buffer power of the soils used for these two field experiments.

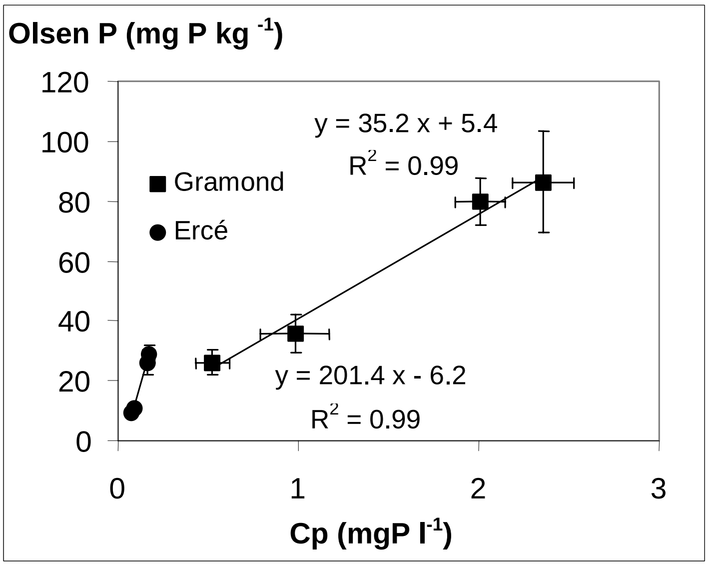

Figure 2. Relationship between Olsen-extractable P and MRP (Cp).

Conclusions

Our results demonstrate that grassland soils display contrasting abilities for long-term P supply, according to their P buffer power which may vary widely according to the soil type, initial soil P status and P balance. Moreover, they show that some mineral fractions, although present in small amounts, are highly reactive and control the P transfer properties at the soil solution interface.

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Grass / clover for phosphate mining on abandoned arable land

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Abstract

Abandoned arable land that is in conversion to nature conservation areas, often has an imbalance in regard to chemical, physical and biological soil fertility. A major problem on sandy soils is the high soil phosphate level, which inhibits the development of nature target types. The current management on abandoned arable land, aiming to impoverish the soil, leads to a depression in dry matter production and consequently inhibits the removal of phosphate. This is probably due to limited availability of nitrogen and potassium. To solve these problems, a grass / clover management is proposed including supplementary potassium fertilisation. In an experiment in both a one year old as well as a five years old sward, four levels of potassium were applied. Productivity and phosphate removal were measured. Results suggest that grass / clover management may indeed support phosphate mining.

Keywords: phosphate mining, abandoned arable land, grass / clover, potassium fertilisation

Introduction

In the Netherlands each year on average 6500 hectare of agricultural land is converted into nature conservation area. The national Nature Policy Plan is aiming at a total conversion area of 151.500 hectare in 2018 (Natuurcompendium, 2003). On abandoned arable land the chemical, physical and biological soil fertility is often unbalanced due to former intensive agricultural practices. In the short term, this coincides with dominant occurence of ruderal species, like broad-leaved dock (*Rumex obtusifolius)* and creeping thistle (*Cirsium arvense).* In the long term the imbalance in chemical, physical and biological soil fertility is supposed to interfere with the development of target vegetation (Critchley *et al*., 2002). In a survey, Sival and Chardon (2002) collected evidence that the high levels of phosphate, occurring in almost all arable sandy soils in the South and the East of the Netherlands, inhibit this kind of development. Furthermore high phosphate levels may damage the environment because of leaching to the ground and surface water. The current management on abandoned sandy arable lands, aiming to impoverish the soil, includes sowing and cutting of a perennial grass sward. This management may however, not remove the high phosphate levels on these sandy soils. After some years the dry matter (DM) production of the vegetation will probably decrease due to a restricted availability of nutrients like nitrogen and potassium. The depressed DM production subsequently inhibits the phosphate mining. The current practice on sandy soil also seems to enhance noxious weeds like ragwort *(Senecio jacobaea)* and also limits soil organisms that are important food items for birds and mammals (e.g., blacktailed godwit, curlew and badger). Therefore specific management techniques might be necessary to remove phosphate from abandoned arable land and meanwhile safeguard the development of nature target types. Possibly the adoption of a grass / clover management may offer a solution in regard to both objectives. The grass / clover was planted with a seed mixture of grasses (*Lolium perenne*, *Pheum pratense*, *Festuca pratensis* and *Poa pratensis*) and clovers (*Trifolium repens* and *T. pratense*). The sward was cut rather intensively and received supplementary fertilisation in regard to nutrient (i.e., potassium) deficiencies. The objective of this research was to test the hypothesis that a grass / clover sward by means of nitrogen fixation and potassium fertilisation increases the phosphate removal (‘mining’) in nature reserves.

Materials and methods

Experiments took place in 2001-2002 on two different locations in the National Park the 'Loonse and Drunense Duinen'. The soil consisted of coversands of plistocenic origin. The fields were formely cropped with maize that was manured excessively by slurry. Location 1 was a grass / clover sown in 1997 ('old') and location 2 a recently established grass / clover ('young') (Table 1). Seed rate for both locations 30 kg ha^{-1} grass mixture, 5 kg ha^{-1} red clover (*Trifolium pratense*) and 3 kg ha^{-1} white clover (*Trifolium repens*).

Table 1. Soil characteristics of the two experiments in March 2002 (0-10 cm).

Location	Year establishment grass / clover	P-Al (mg P_2O_5 100 g^{-1} soil)	P-total (mg P_2O_5 100 g^{-1} soil)	K-HCl (mg K_2O 100 g^{-1} soil)	pH (KCl)	Organic matter (%)
1 'old'	1997	135	186	3	5.5	2.4
2 'young'	2001	57	116	4	5.3	3.3

Both locations had the same randomised experimental design including four different levels of potassium fertilisation (0 %, 50 %, 100 % and 150 % of 480 kg K_2O y^{-1}) in four repetitions. The potassium treatments were performed on plots of 4 x 10 m. Plots were harvested simultaneously with the surrounding parcel; at location 1 this meant four times and at location 2 five times in 2002. Preceding each harvest plots were sampled in subplots of 6 x 1 m. Measurements of samples included: DM yield, Clover-yield and N-, P- and K-content. Statistical analyses were conducted using GENSTAT. Differences between potassium levels and locations were tested with ANOVA ($P < 0.01$).

Results

In old grass / clover the potassium levels of 50 %-150 % as compared to 0 % fertilisation, had significant ($P = 0.005$) positive effects on the clover fraction. No significant differences were observed between 50 %, 100 % and 150 % potassium level in regard to clover fraction over the year (Figure 1).

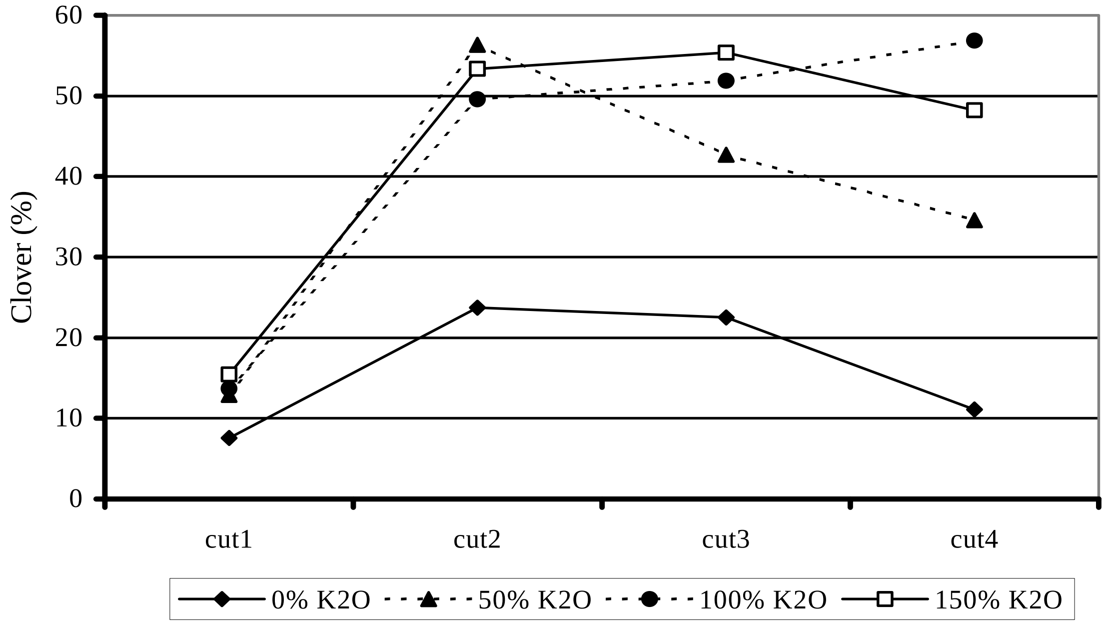

Figure 1. Effect of potassium fertilisation on clover fraction in 'old' grass / clover in 2002.

In the ‘young’ grass / clover no reaction was observed, despite the equally low level of potassium (Table 1). Without potassium supply the total DM yield on the ‘old’ grass / clover sward was 4.06 t ha^{-1} (Table 2). As a result of potassium fertilisation the DM yield significantly increased with 66 percent to 6.76 t ha^{-1}. This related to an increase of phosphate removal of 48 %. In the ‘young’ grass / clover, however, the phosphates mining was much faster related to a higher total DM yield.

Table 2. Comparison of the results at a ‘old’ grass/clover and a ‘young’ grass/clover in 2002.

	‘Old’ grass/clover			‘Young’ grass/clover		
Potassium fertilisation[1]	0 %	100 %	s.e.d	0 %	100 %	s.e.d
Total DM yield (t ha^{-1})	4.06	6.76	0.47^{*}	11.94	12.20	$0.81^{n.s.}$
Total clover yield (t ha^{-1})	0.57	2.62	0.27^{*}	2.61	2.17	$0.61^{n.s.}$
Clover fraction (%)	14	39		22	18	
Nitrogen yield (kg N ha^{-1})	89	196	13.98^{*}	345	347	$20.1^{n.s.}$
Phosphorous yield (kg P ha^{-1})	21	31	2.59^{**}	48	49	$3.84^{n.s.}$
Potassium yield (kg K ha^{-1})	60	192	13.66^{*}	393	485	32.0^{***}

[1] 0 % = 0 kg K_2O ha^{-1}, 100 % = 480 K_2O ha^{-1}, * $P < 0.001$, ** $P < 0.05$, *** $P < 0.1$, n.s. not significant.

Discussion and conclusion

The results show that the concept of phosphate mining by grass / clover cultivation and potassium fertilisation can work. However on a ‘young’ grass / clover, the potassium fertilisation seems not to be necessary in the first year even when the potassium status of the soil is low. A possible explanation was found in the fact that the roots of a young grass / clover were better developed. The ‘young’ sward with less nitrogen deficiency was possibly also part of the reason for the difference in production between the ‘old’ and ‘young’ grass / clover. Besides that an ‘old’ grass / clover sward with an existing potassium deficiency in the plants, probably takes some time for the clover and the grass to recover and to produce on full strength. In the coming years the focus of this research will be on the degree of phosphate mining in the different soil layers, how this affects the botanical composition and the density of earth worms.

Acknowledgement

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Effects of liming and phosphoric fertilisation on the productivity and quality of Basque Country mountain pastures

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Abstract

A study was carried out to evaluate the effect of some of the most used agricultural practices on the structure of mountain pastures in the Gorbeia Natural Park (Basque Country). An experiment was established, for a period of five years (1995-99), four liming and phosphoric fertilisation treatments were arranged in a randomized complete block experimental design. Several soil physicochemical parameters (e.g., pH, P, Ca, % Al saturation) as well as species cover, yield, and nutritional quality of the pasture were determined. Liming had a significant effect on soil characteristics that derived structural changes in pasture composition, causing a decrease in the cover of *Agrostis curtisii* (the most frequently found species in these pastures), together with a concomitant increase in *Festuca* gr. *rubra* cover. In addition, liming significantly increased DM yield. When both treatments (i.e., liming and fertilisation) were applied simultaneously, the nutritional quality of pasture improved. The ultimate goal of our studies is to acquire scientific knowledge on pastures as a basis for their sustainable management.

Keywords: *Agrostis curtisii*, yield, floristic composition, fertility, nutritional quality, sustainability

Introduction

Mountain areas are regions of great fragility and clear multifunctional character. In the Basque Country, mountain areas are extremely important due to the fact that they occupy 85 % of the territory. One of the most relevant traditional uses in these mountain areas is grazing. An activity that has shaped very complex ecosystems, where different interaction mechanisms between plant communities and herbivores take place, with humans having a decisive role. In this respect, the two most used agricultural practices are liming (pH adjustment to neutralize exchangeable Al) and phosphoric fertilisation (to increase levels of this limiting nutrient).

Materials and methods

A field assay of pH amendment and phosphoric fertilisation was established in a brush cleared area on a siliceous pasture (Usotegieta, Gorbeia Natural Park) in 1995. A randomized complete block experimental design (10 × 10 m plots, 4 replicates per treatment) was used, using four treatments, i.e., C: control; L: 9 t CaO ha^{-1} as a liming product; F: 250 kg P_2O_5 ha^{-1} as 18 % superphosphate; *L + F*: both liming and phosphoric fertilisation. Soils (depth: 0-10 cm) were sampled throughout the experimental period to determine physicochemical parameters (pH, P, Ca, % Al saturation). Plant community structure was determined by throwing a 50 × 50 cm square (5 times per plot), recording the number of plant species present together with their corresponding % cover. A monthly control of pasture yield (inside and outside the exclusion cages) at the grazing period was carried out from spring 1995 to autumn 1997. Finally, plant mineral compositions were determined in 1995 (data not shown) and 1997.

Results and discussion

Liming led to significant changes in pH, in exchangeable Ca (CEC), and % Al saturation, which were manifested during the whole experimental period. Phosphoric fertilisation caused an increase in soil P content the first year, decreasing during the following two years (Table 1). In 1998, there was as a general increment of P in all the treatments due to an increase of animal presence created by a new nearby water point. While in the C the second year there was an increase in P probably due to P run off among treatments (Table 1). When liming and fertilisation were applied simultaneously, available P values were higher than those found when only fertilisation was used only in the first year. This agrees with data reported by Helyar (1974). Liming causes a pH increase which, in turn, leads to lower P precipitation rate (as aluminum phosphate), this could explain the increase in available P (Duchaufour, 1987).

Table 1. Soil pH, P Olsen content, Ca content and % Al saturation mean values (± SE). Treatments: C, control; L, liming; *L + F*, liming + fertilisation; F, fertilisation. Values followed by the same lowercase letter within each column do not differ significantly ($P < 0.05$) according to Fisher´s test. Values followed by the same capital letter within each line do not differ significantly ($P < 0.05$) according to unpaired data test.

		Treatment			
	Year	C	L	*L + F*	F
pH	1995	3.80 ± 0.02 ^{aA}	4.58 ± 0.06 ^{aB}	4.51 ± 0.12 ^{aB}	3.68 ± 0.03 ^{bC}
	1996	3.83 ± 0.03 ^{aA}	4.61 ± 0.06 ^{aB}	4.51 ± 0.04 ^{aB}	3.78 ± 0.03 ^{aA}
	1997	3.89 ± 0.04 ^{aA}	4.48 ± 0.05 ^{aB}	4.45 ± 0.11 ^{aB}	3.86 ± 0.03 ^{aA}
	1998	3.56 ± 0.04 ^{bA}	4.38 ± 0.23 ^{aB}	4.33 ± 0.08 ^{aB}	3.58 ± 0.01 ^{cA}
P (mg kg^{-1})	1995	4.90 ± 0.76 ^{aA}	6.70 ± 0.28 ^{aA}	25.82 ± 3.42 ^{aC}	14.64 ± 2.17 ^{bB}
	1996	10.69 ± 1.78 ^{bAB}	10.19 ± 1.42 ^{bA}	16.98 ± 2.52 ^{bB}	12.63 ± 0.65 ^{abAB}
	1997	7.94 ± 0.48 ^{abA}	8.29 ± 0.67 ^{abA}	11.23 ± 0.59 ^{cB}	11.72 ± 0.78 ^{aB}
	1998	11.84 ± 2.28 ^{bAB}	10.87 ± 0.79 ^{bA}	16.66 ± 1.81 ^{bB}	16.22 ± 2.07 ^{bB}
Ca (cmol (+) kg^{-1})	1995	1.91 ± 0.23 ^{aA}	17.24 ± 0.75 ^{aB}	15.33 ± 2.28 ^{aB}	2.36 ± 0.26 ^{aA}
	1996	1.97 ± 0.13 ^{aA}	11.32 ± 0.89 ^{bB}	10.17 ± 1.02 ^{bB}	2.46 ± 0.30 ^{aA}
	1997	2.01 ± 0.10 ^{aA}	7.92 ± 0.32 ^{cB}	8.58 ± 0.58 ^{bB}	2.54 ± 0.29 ^{aA}
	1998	1.85 ± 0.16 ^{aA}	9.13 ± 1.95 ^{bcB}	9.93 ± 0.42 ^{bB}	2.34 ± 0.41 ^{aA}
% Al Sat.	1995	60.25 ± 2.84 ^{aA}	11.50 ± 3.98 ^{aB}	9.75 ± 3.61 ^{aB}	56.50 ± 3.30 ^{aA}
	1996	56.75 ± 1.49 ^{aA}	17.75 ± 2.63 ^{aB}	20.25 ± 2.87 ^{bB}	54.00 ± 2.04 ^{aA}
	1997	48.50 ± 12.56 ^{aAB}	33.25 ± 0.95 ^{bA}	31.50 ± 1.32 ^{cA}	57.50 ± 2.63 ^{aB}
	1998	63.75 ± 1.32 ^{aA}	22.00 ± 7.27 ^{abB}	14.00 ± 0.71 ^{abB}	60.50 ± 4.65 ^{aA}

Changes in soil parameters lead to new competence relationships between plant species (in this case, particularly, between *Agrostis curtisii* and *Festuca* gr. *rubra*) (Marriott *et al*. 1999). In fact, and in response to L and *L + F* treatments, *F.* gr. *rubra* increased its cover and frequency, being negatively correlated with *A. curtisii* (Spearman’s correlation coefficient, R = -0.641, $P = 0.0130$) (Table 2).

The interaction between type of treatment and climatological conditions was close to being statistically significant for annual yield (ANOVA of repeated measures: $F_{6,24}= 2.180$; $P = 0.0808$). In 1995, L and *L + F* treatments led to significantly higher yield values than C and F treatments, according to results obtained from unpaired data test (kg DM ha^{-1}; C: 3338 ± 256; L: 4263 ± 356; *L + F*: 4210 ± 197; F: 3821 ± 210). However, during the second year (1996), only L treatment resulted in higher yield values (C: 3893 ± 248;

L: 4875 ± 199; *L + F*: 4693 ± 340; F: 4564 ± 348). Finally, in 1997, no differences were observed among treatments (C: 4050 ± 405; L: 3544 ± 172; *L + F*: 3177 ± 383; F: 3809 ± 176).

Table 2. Mean coverage in % (± SE) of the plant species showing significant differences between treatments in 1999. Treatments: C, control; L, liming; *L + F*, liming + fertilisation; F, fertilisation.

	C	L	*L + F*	F
A. curtisii	40.95 ± 2.58 [a]	27.47 ± 0.80 [bc]	21.30 ± 4.54 [c]	35.15 ± 3.41 [ab]
F. gr. rubra	7.71 ± 1.65 [a]	20.84 ± 2.23 [b]	23.98 ± 4.48 [b]	17.49 ± 5.55 [ab]

Values followed by the same letter within each species do not differ significantly ($P < 0.05$) according to Fisher's test.

Liming and fertilisation have an effect on plant mineral composition, since the application of a certain nutrient generally leads to higher concentrations of that nutrient in the plant (Lambert and Litherland, 2000). Both L and *L + F* treatments showed higher Ca concentration values from the beginning of the experiment until spring 1997 (Ca concentrations in mg g^{-1} for spring 1997; C: 1.89 ± 0.13; L: 4.40 ± 0.17; *L + F*: 4.90 ± 0.46; F: 2.58 ± 0.26). Similarly, P concentration increased as a response to F and *L + F* treatments (P concentrations in mg g^{-1} for spring 1997; C: 0.92 ± 0.07; L: 1.19 ± 0.07; *L + F*: 2.23 ± 0.03; F: 1.83 ± 0.11) as was observed for soil P content.

Conclusions

Liming and fertilisation, especially when applied simultaneously, tend to improve soil fertility, increase pasture yield, improvement in soil structure, and increased plant nutrient concentrations, leading to an improvement in pasture quality. Management of these mountain pastures requires the knowledge of the structure and yield of plant communities, together with the identification of key factors and determinant processes. This enables the prediction of responses to different management practices of anthropic origin, in an attempt towards ecological and economical sustainability.

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Long-term effects of grazing and PK application on herbaceous-rich pasture in central Lithuania

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Abstract

The objective of the present study was to evaluate the residual effects of different K fertilisation rates on DM yield, botanical composition, nitrogen, humus and mobile humic acids accumulation in the soil and to study long-term productivity of herbaceous-rich pasture ecosystem. Long-term trials were conducted at the Lithuanian Institute of Agriculture over the period 1993-2002. Before this period the experiments were carried out during 1961-1992. Five fertilisation treatments were investigated: P_0K_0; $P_{60}K_0$; $P_{60}K_{30}$; $P_{60}K_{60}$; $P_{60}K_{90}$. No PK fertilisation resulted in a significantly lower pasture productivity (-2.54 t ha^{-1}). But there was no reduction in DM yield observed in long-term. After 40 years' of pasture use a herbaceous-rich grass phytocenosis was formed. The application of the inorganic PK fertiliser on the background of grazing had a strong and stable effect on the N and humus accumulation in the soil. The content of mobile humic acids (C_{HA}) depended on PK fertilisation level and increased mostly in the topsoil in the fertilisation treatment $P_{60}K_{60}$ y^{-1}. Grazing management of long-term multi-component swards maintains natural soil fertility and in the long term improves sward quality parameters.

Keywords: pasture, grazing, PK fertilisation, botanical diversity, humus

Introduction

Agricultural policies in the EU are enhancing the increase of biodiversity in all ecosystems. The higher biodiversity inorganic pastures is a result of the extensive farming, i.e., low farm mineral inputs (Baars, 2002). The floristic diversity and productivity of long-term Lithuanian pasture ecosystem is closely related to management practices and environmental factors. Annual inputs of organic matter are greater in grasslands than in agriculture. Grass leys supply two to three times more organic matter to soil than annual crops such as cereals (Lægreid *et al.*, 1999). In pasture ecosystem the organic matter and livestock excreta accumulate in the topsoil and take part in the processes of mineralisation and humification there (Gutauskas and Slepetienė, 2000). Soils with much organic matter and few nutrients are difficult to manage. Rational use of the nutrients accumulated in the soil and fertilisation are increasingly becoming important grazing management aspects in farm gate balances in dairy farming. One of the main sources of plant nutrient, that is readily available is potassium. The aim of this study was to compare the performance of long-term grass / white clover / forbs swards under grazing. The objective of this experiment was to evaluate the residual effects of different K fertilisation rates on DM yield, botanical diversity, accumulation of N, humus and mobile humic acids in the topsoil and subsoil and also to study the long-term productivity of multi-component pasture ecosystem.

Materials and methods

Long-term trials were conducted at the experimental site of the Lithuanian Institute of Agriculture in Dotnuva (central part of Lithuania) over the period 1993-2002. Annual rainfall: 626 mm (April-October: 409 mm), average temperature: + 6 ^{0}C (April-October: + 12.3 °C), vegetative growth period: 194 days (grazing season: 150-160 days). Before this period, the experiments were carried over the period 1961-1992. Five fertilisation treatments were investigated during the experimental period: 1) P_0K_0. 2) $P_{60}K_0$. 3) $P_{60}K_{30}$. 4) $P_{60}K_{60}$. 5) $P_{60}K_{90}$. The experiment is on going. The experimental soil is sod gleyic light loam (*Cambisol*). The plot size was 33.25 m^2 (13.3 m x 2.5 m). Each treatment of the field trial had four replicates. Experimental pastures were grazed 3-4 times per season on a rotational basis with a herd of dairy cows. Before each grazing cycle, the plots in the pasture were cut to grazing height to measure herbage biomass and to take samples for DM and nutrition value were taken. A mean sample for each treatment was made before each grazing cycle, on which botanical composition was determined by hand separation on a DM basis. The following analytical methods were used: for the determination of total K–flame photometry, total P–colorimetry, total Kjeldahl N, humus (SOC × 1.724)–Tyurin. Mobile humic acids were extracted (0.1 *M* NaOH), afterwards the humic substances were separated into humic and fulvic acids fractions by acidifying the extract to pH 1.3-1.5 using 0.5 M H_2SO_4 at 68-70 °C, and humic acids were separated by filtering. The separated humic acids were re-dissolved in 0.1 M NaOH solution. Some humic acids solution was evaporated, organic carbon content was determined as for soil samples.

Results and discussion

No PK fertilisation resulted in a significant lower pasture productivity. But there was no trend of DM yield reduction was observed in long-term (Table 1). During the experimental period (1993-2002) the average pasture sward DM yield on the background of P_{60} fertilisation was 3.81 t ha^{-1}, on the background of $P_{60}K_{30-90}$ fertilisation DM yields of 4.62-5.32 t ha^{-1} were obtained without N application. The most efficient K fertiliser rates for DM yield were K_{30} and K_{60}. After 40 years of pasture use a grass phytocenosis with a rich, from a biodiversity point of view, botanical composition formed. The long-term grazing management increased number of grass and forbs species in the pasture sward. On the background of P_{60} and K_{60-90} the grasses accounted for 535-592 g kg^{-1} of DM yield, legumes for 193-219 g kg^{-1}, forbs for 195-272 g kg^{-1}. The lower level of K and P fertilisation increased the portion of herbs in the sward. The main species of the forbs were *Taraxatum officinale* L.*, Achillea millefolium* L., *Ranunculus repens* L., *Plantago major* L., *Polygonum aviculare* L.

Table 1. Average annual DM yield (t ha^{-1}) and botanical composition of long-term pasture in Lithuania over 40 year period.

Treatment	1961-1992 t ha^{-1}	1993-2002 t ha^{-1}	Botanical composition after 40 years under grazing management (g kg^{-1} DM)		
			Grasses	Legumes	forbs
Control P_0 K_0	2.30	2.59	550	181	269
P_{60} K_0	3.80	3.81	560	158	282
P_{60} K_{30}	4.15	4.62	535	193	272
P_{60} K_{60}	4.42	5.01	549	219	232
P_{60} K_{90}	4.50	5.32	592	213	195
LSD_{05}	0.12	0.29	362	174	278
SD	0.90	1.09	21.3	24.7	36.2

Long-term grazing management on the background of the inorganic PK fertiliser application had a significant effect on N and humus accumulation in the soil (Table 2). A positive effect of the grasses on the accumulation of humus and mobile humic acids was determined. The humus and mobile humic acids tended to accumulate in the topsoil (0-10 and 10-20 cm). The concentration of mobile humic acids shows a close correlation with the humus content in the soil. The content of mobile humic acids (C_{HA}) depended on PK fertilisation level and increased to the highest level with the fertilisation treatment $P_{60}K_{60}$ y^{-1}.

Table 2. Total nitrogen, humus and mobile humic acids content in different soil layers in the 40 year-old pasture.

Treatment	Soil layer (cm)			
	0-10	10-20	20-30	30-50
		Total N g kg^{-1}		
Control P_0 K_0	2.82	1.57	0.63	0.61
P_{60} K_0	3.27	1.68	0.55	0.68
P_{60} K_{30}	3.32	1.81	0.74	0.78
P_{60} K_{60}	3.38	1.81	0.83	0.97
P_{60} K_{90}	3.32	1.90	0.93	0.62
LSD $_{05}$	0.44	0.21	0.31	0.55
SD	0.19	0.09	0.14	0.24
		Humus g kg^{-1}		
Control P_0 K_0	49.7	26.6	16.8	6.02
P_{60} K_0	56.8	28.4	15.8	6.14
P_{60} K_{30}	59.1	30.6	17.6	6.75
P_{60} K_{60}	59.8	31.7	19.9	7,06
P_{60} K_{90}	61.5	33.3	21.3	7.38
LSD $_{05}$	4.66	3.42	4.69	2.30
SD	2.02	1.48	2.04	1.00
		C of HA g kg^{-1}		
Control P_0 K_0	2.17	0.74	0.53	0.10
P_{60} K_0	2.37	0.94	0.41	0.10
P_{60} K_{30}	2.46	1.09	0.66	0.14
P_{60} K_{60}	2.98	3.33	0.66	0.10
P_{60} K_{90}	2.83	1.23	0.75	0.10

Conclusions

It was determined that long-term (40 years) grazing management of multi-component grass / legume / forb swards maintains natural soil fertility and in the long run improves its quality parameters. In the case of no PK fertilisation DM yield is not at a high level, but no reduction in DM yield was observed. This creates substantial preconditions for organic farming.

The application of the inorganic PK fertiliser on the background of grazing had a strong and stable effect on the N, humus and mobile humic acids accumulation in the soil.

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Effect of fertility levels on perennial ryegrass for seed production

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Abstract

Perennial ryegrass (*Lolium perenne* L.) is a popular forage grass species in Latvia, for which more information is needed concerning fertilisation (fertility) for seed production. The objectives of this study were to: (i) examine the effect of fertility level on perennial ryegrass seed production and (ii) determine relationships among perennial ryegrass seed trials.
Field plot experiments were carried out in 1999-2003. Swards were developed on sod-podzolic sandy loam soil in 1999, 2000, and 2001. A randomised complete block design with four replications was utilised in this research. The following mineral fertiliser rates were applied: N and P at 0, 13, 26, 39, 52 and K at 0, 33, 66, 100, 133 kg ha^{-1}. The highest seed yield of perennial ryegrass was 611, 1459 and 1037 kg ha^{-1} in 2000, 2001 and 2002, respectively. The corresponding high seed yields were obtained with mineral fertiliser rates N_{90} P_{13} K_{100} for the year 2000 while for the years 2001 and 2002 they were obtained with N_{120} P_{52} K_{133}. Lodging was higher with high fertilisation rates. The simple correlation indicated that seed yield was highly significantly correlated with seed weight, generative tiller numbers, and stem length. The number of spikelets was not significantly correlated with seed yields in perennial ryegrass.

Keywords: *Lolium perenne*, fertility levels, seed production

Introduction

Perennial ryegrass (*Lolium perenne* L.) is the most commonly used forage grass in temperate regions of the world (Wilkins, 1991). Its popularity is due to its excellent forage quality, high digestibility, ease of establishment, tolerance to grazing, and high seed yields.
Grass seed crops generally need supplemental nitrogen (N) fertilisation (Youngberg and Buker, 1985). Spring application of N generally increases seed yield of perennial ryegrass. High seed yields of perennial ryegrass in Latvia depend on abundant plant-available N.
The seed yield response of cool-season grasses to spring-applied N is usually limited because of lodging (Young *et al*., 1999). Lodging of perennial ryegrass plants is a widespread problem as it reduces seed yield and interferes with seed harvest (Young *et al*., 1996). Lodging is usually associated with conditions such a high rainfall, mild temperatures, and high levels of available soil N that would otherwise favour rapid plant growth and high seed yields. Both the timing and severity of lodging influence seed yield. When perennial ryegrass receives enough N to maximize seed yield, lodging often begins around the time of spike emergence (Hebblethewaite *et al*., 1980).
Seed weight is often thought to be important in determining seed yield and, even if not always, is also a factor in obtaining good establishment (Negri and Falcinelli, 1990).
Presently there is no research in Latvia on which it is possible to make good fertiliser use recommendations and to provide advisory support for farmers involved in the perennial ryegrass seed production.
The objective of this research was to obtain seed yield information for perennial ryegrass at different rates of mineral nutrition.

Materials and methods

Field experiments were carried out on sod podzolic sandy loam soil (Luvic Phaeozem, WRB 1998), $pH_{(KCl)} = 6.5$, plant available P = 48 and K = 169 mg kg^{-1} (Egner-Riehm), soil organic carbon = 21 g kg^{-1} (Tyurins' method). Meteorological conditions of the growing season were characterized by increased rainfall (280-370 mm) during the seed production period (June-August) in the years 2000, 2001 and 2002. The plots were established according to a randomised complete block design with four replicates. The plot size was 16 m^2. Five fertiliser rates were applied in both years. Perennial ryegrass 12 kg ha^{-1} was planted using a Nordsten seed drill in May 1999, 2000 and 2001 after field preparation. The following mineral fertiliser rates were used: N and P were applied at 0, 13, 26, 39 and 52 kg ha^{-1}, K at 0, 33, 66, 100 and 133 kg ha^{-1}. Weed control was performed using MCPA herbicides (l l ha^{-1} in a mixture with 8-10 g ha^{-1} granstar).

Lodging of the perennial ryegrass stand was evaluated during the growing season using a scale from 1-9 (1 when the stand is completely lodged and 9 when lodging is not observable). The biomass, dry matter content and seed yield as well as biomass chemical composition were determined. Seed yield was recorded in the 1st year and 2nd year of seed production. Analysis of yield components and other parameters were also recorded.

Results and discussion

Perennial ryegrass cv. 'Spidola' was developed at the Latvia University of Agriculture (LUA) Skriveri Research Centre. It is a tetraploid cultivar developed by doubling the chromosomal count of perennial ryegrass 'Priekulu 59'. The 'Spidola' attributes are higher productivity, better winter hardiness, good disease resistance, providing a good feed output. Also the 'Spidola' cultivar shows a preference for certain growing conditions, as it is better suited to mineral soils, prefers loamy or loamy sand soils and does quite well on clay soils. It is somewhat less responsive to light soils. Peat soils are not suitable for growing this cultivar of perennial ryegrasses, as the cultivar does not have the ability to tolerate excessive moisture for the long growing season. But, it is suitable for inclusion in seed mixtures for establishment of permanent pastures and is a late maturing pasture grass, good for late grazing.

All mineral fertiliser rates applied had a positive effect on seed yield of perennial ryegrass. The seed yield increased by 14 to 74 % depending on mineral fertiliser rates applied and the ratio of fertiliser elements (Table 1). Mineral fertiliser-use efficiency was significantly influenced by meteorological conditions over the trial years.

The number of generative tillers is a component of potential grass seed yield established during vegetative plant development and before flowering (Hebblethewaite *et al*., 1980). Seed yield increased with the growth of generative tiller numbers. The greatest seed yield was obtained with average generative tiller numbers 1200-1300 per m^2. The seed yield and generative tiller numbers was positively correlated ($R^2 = 0.53$).

Increased plant density at sowing decreased stem resistance to lodging. However, it did not have a significant influence on 1000-seed weight, as plants in the sowings were already lodged during the seed maturation phase. The average 1000-seed weight was 2.9-3.1 g and seed yield was correlated with seed weight ($R^2 = 0.42$). The highest seed yield of perennial ryegrass was 611, 1459 and 1037 kg ha^{-1} in the years 2000, 2001 and 2002, respectively.

Lolium perenne is a nitrophilous grass, which requires high nitrogen fertilisation when it is grown for seed. This was confirmed by our research findings, as higher seed yields were obtained at increased nitrogen levels.

In our experiments the highest seed yields were obtained using a balanced application of NPK: N_{120} P_{52} K_{133} -1019 kg ha^{-1} and N_{90} P_{39} K_{100} –923 kg ha^{-1}.

Table 1. Effect of fertility levels on seed yield of perennial ryegrass 'Spidola' (average of 3 years, 1st year of use).

Levels of fertiliser element (kg ha $^{-1}$)			Seed yield (kg ha^{-1})	Fertiliser utilisation rate*	1000-seed weight (g)	Lodging resistance (1-9)	Number of generative tillers (p. m^{-2})
N	P	K					
0	0	0	584	0.0	2.9	8.8	1003
0	26	66	809	1.4	3.0	8.6	1059
30	13	33	663	1.1	2.9	7.0	1128
30	13	100	670	1.1	2.9	6.2	1163
30	39	33	772	1.3	2.9	6.9	1269
30	39	100	776	1.3	2.9	6.6	1222
60	0	66	808	1.4	3.0	5.7	1267
60	26	0	839	1.4	2.9	5.6	1330
60	26	66	838	1.4	3.0	5.0	1298
60	26	133	823	1.4	3.1	4.6	1221
60	52	66	793	1.4	3.0	4.9	1228
90	13	33	844	1.4	3.1	3.8	1212
90	13	100	883	1.5	3.1	3.4	1328
90	39	33	906	1.6	3.1	3.5	1364
90	39	100	923	1.6	3.0	3.6	1204
120	26	66	909	1.6	3.1	2.5	1307
120	52	133	1019	1.7	3.0	2.6	1318
Average			805	-	3.0	5.2	1235
$LSD_{0.05}$			92	-	0.1	0.8	133

*Fertiliser utilisation rate = (plant nutrient uptake in fertilised plots minus uptake in unfertilised plots) / (quantity of nutrients applied with fertilisers).

Conclusions

Application of balanced NPK provides comparatively high (900 to 1000 kg ha^{-1}) seed yields of perennial ryegrass under Latvia's agro-climatic conditions.

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Effects of sulphur fertilisation on Belgian grasslands

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Abstract

During the last two decades, both the atmospheric supply of sulphur and the utilisation of sulphur containing fertilisers has dramatically decreased, whilst yields have increased. Consequently, sulphur could be limiting for plant growth. The effects of factorial combinations of sulphur and nitrogen fertilisation on grasslands at four locations were studied. Sulphur fertilisation increased annual yield at three sites in 2002. These increases were observed mainly at the highest nitrogen fertilisation level. Supplying sulphur also increased protein production (up to an equivalent of 40 kg N ha^{-1}) in 2002. It appears that the environment does not always supply enough sulphur for grass growth anymore and that sulphur deficiency depends on the nitrogen fertilisation level.

Keywords: sulphur, yield, grassland, deficiency

Introduction

Sulphur is essential for plant growth. It is a component of numerous molecules such as chlorophyll and proteins. Sulphur is mainly provided to agricultural crops by fertilisers, atmospheric deposition and mineralisation of soil organic matter. During recent decades, the reduction of industrial emissions of sulphur has lead to a decrease in deposition and to crop sulphur deficiencies in Europe (Chyi and Philips, 1998; Murphy and O'Donnell, 1989). Today, the depositions are estimated at 20-25 kg S ha^{-1} y^{-1} in the Walloon region of Belgium. Moreover, sulphur supplied by fertilisation has also decreased because of the utilisation of sulphur poor fertilisers. Exportation of sulphur from grasslands for silage amount to about 25 kg S ha^{-1} y^{-1}. Considering these data and also that sulphur leaching occurs during winter, it appears that sulphur balance in grasslands may be negative. Different levels of sulphur were combined with three levels of nitrogen on grasslands grown in various pedo-climatic conditions to determine whether sulphur supplied naturally (atmospheric deposition and mineralisation) to the crop is sufficient for maximum plant growth.

Materials and methods

Four field trials (Table 1) were set up in *Lolium multiflorum* (site 3) and *Lolium perenne* (sites 1, 2 and 4) temporary grasslands. The experimental design was a randomised block with 4 replicates and 2 × 5 m^2 plots.

Table 1. Site characteristics and fertilisation (N in kg N ha^{-1} y^{-1} and S in kg SO_3 ha^{-1} y^{-1}).

	Soil			N		S	
				2001	2002	2001	2002
Site	Texture	%C	pH	N_1-N_2-N_3	N_1-N_2-N_3	S_0-S_1-S_2-S_3-S_4	S_0-S_1-S_2-S_3-S_4
1	Sand	2.8	5.3	210-420-540	200-400-520	0-60-150	0-60-150
2	Silt loam	1.9	5.6	120-240-310	160-330-430	70-160-220	70-160-220
3	Silt	1.7	7.5	80-160-210	170-340-440	0-20-40-60-100	0-30-60-90-150
4	Sand	2.4	4.9	210-420-550	200-400-520	0-60-150	0-60-150

Effects of sulphur fertilisation on Belgian grasslands

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Abstract

During the last two decades, both the atmospheric supply of sulphur and the utilisation of sulphur containing fertilisers has dramatically decreased, whilst yields have increased. Consequently, sulphur could be limiting for plant growth. The effects of factorial combinations of sulphur and nitrogen fertilisation on grasslands at four locations were studied. Sulphur fertilisation increased annual yield at three sites in 2002. These increases were observed mainly at the highest nitrogen fertilisation level. Supplying sulphur also increased protein production (up to an equivalent of 40 kg N ha^{-1}) in 2002. It appears that the environment does not always supply enough sulphur for grass growth anymore and that sulphur deficiency depends on the nitrogen fertilisation level.

Keywords: sulphur, yield, grassland, deficiency

Introduction

Sulphur is essential for plant growth. It is a component of numerous molecules such as chlorophyll and proteins. Sulphur is mainly provided to agricultural crops by fertilisers, atmospheric deposition and mineralisation of soil organic matter. During recent decades, the reduction of industrial emissions of sulphur has lead to a decrease in deposition and to crop sulphur deficiencies in Europe (Chyi and Philips, 1998; Murphy and O'Donnell, 1989). Today, the depositions are estimated at 20-25 kg S ha^{-1} y^{-1} in the Walloon region of Belgium. Moreover, sulphur supplied by fertilisation has also decreased because of the utilisation of sulphur poor fertilisers. Exportation of sulphur from grasslands for silage amount to about 25 kg S ha^{-1} y^{-1}. Considering these data and also that sulphur leaching occurs during winter, it appears that sulphur balance in grasslands may be negative. Different levels of sulphur were combined with three levels of nitrogen on grasslands grown in various pedo-climatic conditions to determine whether sulphur supplied naturally (atmospheric deposition and mineralisation) to the crop is sufficient for maximum plant growth.

Materials and methods

Four field trials (Table 1) were set up in *Lolium multiflorum* (site 3) and *Lolium perenne* (sites 1, 2 and 4) temporary grasslands. The experimental design was a randomised block with 4 replicates and 2 × 5 m^2 plots.

Table 1. Site characteristics and fertilisation (N in kg N ha^{-1} y^{-1} and S in kg SO_3 ha^{-1} y^{-1}).

	Soil			N		S	
				2001	2002	2001	2002
Site	Texture	%C	pH	N_1-N_2-N_3	N_1-N_2-N_3	S_0-S_1-S_2-S_3-S_4	S_0-S_1-S_2-S_3-S_4
1	Sand	2.8	5.3	210-420-540	200-400-520	0-60-150	0-60-150
2	Silt loam	1.9	5.6	120-240-310	160-330-430	70-160-220	70-160-220
3	Silt	1.7	7.5	80-160-210	170-340-440	0-20-40-60-100	0-30-60-90-150
4	Sand	2.4	4.9	210-420-550	200-400-520	0-60-150	0-60-150

The fertilisation was three levels of nitrogen (N_1, N_2 and N_3) crossed with three (S_0, S_1 and S_2) or five (S_0, S_1, S_2, S_3 and S_4) levels of sulphur. Fields were fertilised at the beginning of the growing period with K (KCl) and P (triple super phosphate or single super phosphate on site 2) following advice based on soil analyses. Nitrogen was applied as NH_4NO_3 and sulphur as K_2SO_4 except in site 2 ($MgSO_4$). On all sites sulphur was applied in equal amounts before each of the first three cuts. Yields were recorded and forage analysed for quality (protein and nutritive value by NIRS). Protein concentration was calculated by multiplying N concentration by 6.25.

Results

The sulphur fertilisation significantly increased ($P < 0.05$) (ANOVA 3; Dagnelie, 1970) annual yields on 3 sites (1, 2 and 4) in 2002 (Table 2). The increases were greater at the highest N fertilisation level (N3).

Table 2. Temporary grassland annual yield (t DM ha^{-1} y^{-1}, (SE)), for the second year of the experiment (2002) at sites 1, 2 and 4 as a function of the N and S fertilisations.

Site	Fertilisation																	
	N_1						N_2						N_3					
	S_0		S_1		S_2		S_0		S_1		S_2		S_0		S_1		S_2	
1.	10.2	(0.5)	10.5	(0.7)	10.8	(0.3)	12.2	(0.6)	12.6	(0.3)	13.3	(0.4)	11.7	(0.7)	12.7	(0.4)	12.9	(0.4)
2.	6.2	(0.4)	6.6	(0.3)	6.5	(0.4)	9.6	(0.4)	9.5	(0.5)	10.6	(0.1)	9.7	(0.5)	10.2	(0.2)	11.2	(0.4)
4.	10.0	(0.2)	10.7	(0.8)	10.5	(0.2)	10.7	(0.5)	11.7	(0.8)	11.7	(0.3)	10.3	(0.6)	11.0	(0.6)	11.3	(0.5)

Supplying sulphur also increased annual yields at site 1 in 2001 and site 3 in 2002 but not significantly (about 0.8 t DM ha^{-1} y^{-1} for each of the two sites between N_3S_0 and respectively N_3S_2 and N_3S_4 treatments). The positive sulphur fertilisation effects on annual yield were mainly due to increases at the first (site 1 and 2) or third cut (site 1 and 4) (Figure 1). We also observed a significant effect ($P = 0.03$) of S on the yield of the first cut at site 1 in 2001 but this response was masked in the annual yield by high variability in the following cuts (Mathot *et al.*, 2003).

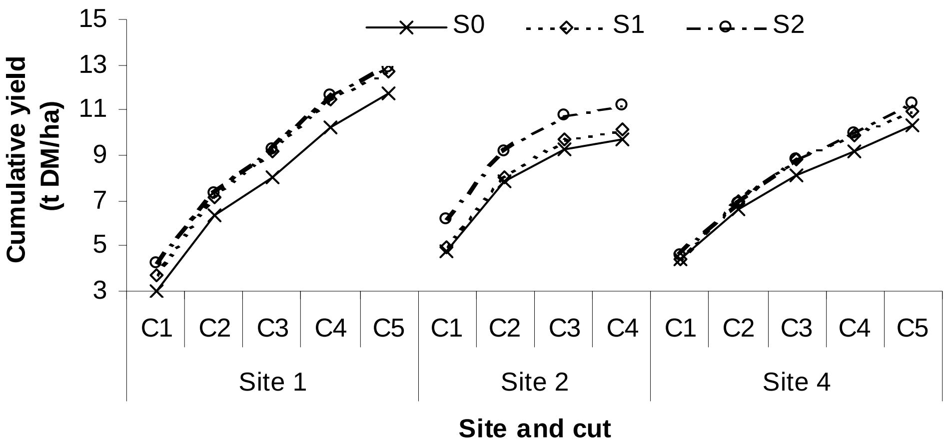

Figure1. Cumulative yield (t DM ha^{-1} y^{-1}) of *Lolium perenne* swards for the second year of the experiment (2002) at sites 1, 2 and 4 as a function of the cuts of the temporary grasslands. Only the highest N fertilisation level (N_3) is considered. N_3 = 540, 310 and 550 kg N ha^{-1} y^{-1} for sites 1, 2 and 4, respectively.

Protein production (expressed as N) was also increased by S fertilisation in 2002 (Table 3). This effect was significant (P = 0.01) only at site 4. However, for the highest N fertilisation level, S dressing allowed an increase in N exportation of 22 to 43 kg N ha^{-1} y^{-1} in 2002.

Table 3. Temporary grassland annual protein exportation (expressed in kg N ha^{-1} y^{-1}, (SE)) for the second year of the experiment (2002) at sites 1, 2 and 4 as a function of the N and S fertilisations.

Site	Fertilisation																	
	N_1						N_2						N_3					
	S_0		S_1		S_2		S_0		S_1		S_2		S_0		S_1		S_2	
1	260	(15)	263	(15)	267	(9)	385	(22)	405	(16)	426	(18)	384	(20)	429	(15)	427	(11)
2	127	(10)	138	(5)	135	(8)	219	(12)	227	(11)	249	(30)	282	(14)	288	(4)	304	(11)
4	261	(5)	269	(14)	268	(7)	327	(15)	354	(22)	359	(15)	340	(14)	359	(18)	370	(12)

Discussion and conclusions

Applying large amounts of nitrogen and adequate K and P fertilisations led to sulphur deficiencies on three of the four sites studied in 2002. In these cases, sulphur fertilisation increased annual yield and protein production by about 10 %. Annual yield and protein increases were mainly due to the effects of sulphur on one of the cuts (first or third) early in the growing season.

While applying high nitrogen fertilisation, sulphur deficiencies may appear. In the future, according to the diminution of sulphur atmospheric depositions, more sulphur deficiencies could be observed in Belgium, depending on the organic matter capacity to supply available sulphur to plants and on nitrogen fertilisation level. Nitrogen and sulphur fertilisation should therefore be matched to ensure optimum plant growth and minimize ground water pollution by nitrate.

Acknowledgement

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Requirement of potassium in organic meadow cultivation

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Abstract

In this study the aim was to reveal the influences of potassium in organic meadow cultivation on soil with low K-status. Results from an experiment on peat soil in the 3rd harvest year showed that 50 to 100 kg K ha^{-1} in addition to 30 t diluted cattle manure ha^{-1} raised the total DM yield by about 20 %. Content of both timothy and red clover in the 3rd harvest year were strongly dependent on K-fertilisation. Potassium outputs in DM yield were larger than K inputs in fertiliser. DM yield in the sandy soil, which showed no response to K-treatments, was supported with K from the soil, even although the acid-soluble K was low ($KHNO_3$ = 450 mg kg^{-1} dry soil). The concentrations of K in plant tissue were low, both in grass and red clover. 1.5 % K in plant tissue was satisfactory for plant growth.

Keywords: organic farming, manure, potassium, K-deficiency, *Trifolium pratense* L., *Phleum pratense* L.

Introduction

Organic meadow cultivation on soil with low K-status gives the farmers huge challenges. In Norway we have a lot of sandy and peat soils with very low acid-soluble K-values. In conventional dairy farm systems, meadows on these soils normally are fertilised with 100-200 kg K ha^{-1}, but according to Debio, the Norwegian control and certification body for organic agricultural production, fertilising with mineral K can only be done if a special license is given. In such cases the farmer has to prove that there is a lack of potassium.

Materials and methods

In 1999 four field trials were established at four different sites in the southern part of Norway (‘Fureneset’ and ‘Ølve’ on peat soils, and ‘Surnadal’ and ‘Tynset’ on sandy soils). The experiment was a randomised factorial complete block design with four replicates. The meadows were sown with a grass-clover mixture with 40 % timothy (*Phleum pratense* L.), 30 % meadow fescue (*Festuca pratensis* Huds.), 10 % smooth meadow grass (*Poa pratensis* L.), 10 % red clover (*Trifolium pratense* L.) and 10 % white clover (*Trifolium repens* L.) and cut twice a year. All plots were fertilised with 30 t ha^{-1} strongly diluted cattle manure (50 % manure and 50 % water) with about 1.8 kg K t^{-1} in late April every year. Three levels of extra K (0, 50 and 100 kg ha^{-1} y^{-1}) were given as potassium chloride (K 49 %). Half the amount was dressed in spring and the rest after the 1st cut. The project period was five years.
In 2002 grass and clover from the experimental site ‘Fureneset’ were sorted and analysed separately.

Results and discussion

At the experimental site ‘Fureneset’ (peat soil) in the 3rd harvest year both 50 and 100 kg K ha^{-1} raised the total DM yield by about 20 % (Table 1). Content of both timothy and red clover were strongly dependent on K-fertilisation. The amount of timothy at the 1st cut increased from 54 % to about 70 % when 50 and 100 kg K ha^{-1} was dressed in addition to 30 t diluted cattle manure. Lack of potassium and decreasing timothy content led to establishment of rough meadow grass. Red clover showed the same reaction as timothy when K-fertilisation was depressed, and the difference was largest at the 2nd cut.

In organic meadow farming systems red clover is an important N-supplier (Warda and Krzywiec, 2001). Results from Western Norway on soil types with a high organic matter content and a very small amount of reserve K show that it is important to supply K-fertiliser, so that the quantity of timothy and red clover can be sustained over several years.

Table 1. Total herbage yield (DM), content of timothy and red clover after different K-treatments in addition to 30 t diluted cattle manure ha^{-1} in the 3rd harvest year. Results from the site ‘Fureneset’ on peat soil, *P* = 0.05.

Extra K (kg ha^{-1})	DM (t ha^{-1})	Timothy (%)	Red clover (%)
		1st cut	
0	5.6 a	54 a	5 a
50	6.4 b	71 b	13 b
100	6.4 b	72 b	15 b
		2nd cut	
0	1.0 a	-	10 a
50	1.6 b	-	22 b
100	1.8 b	-	28 b

The results indicate that under organic farming conditions in Western Norway it seems to be acceptable with 1.5% K in DM to get maximum yield (Table 2). The results show small differences between timothy and red clover. Also the visual K-deficiency on timothy by harvest indicate that 1.5 % K in DM is adequate.

Table 2. K, Ca and Mg concentrations (% of DM) after different K-treatments in addition to 30 t diluted cattle manure ha^{-1} in the 3rd harvest year. Visual K-deficiency scaled from 0-3 (0 = no deficiency and 3 = large deficiency). Results from the site ‘Fureneset’ on peat soil, *P* = 0.05.

	K		Ca		Mg		K-deficiency
Extra K (kg ha^{-1})	Grass	Red clover	Grass	Red clover	Grass	Red clover	
				1st cut			
0	1.0 a	0.9 a	0.5 a	1.5 a	0.16 a	0.48 a	1.1 a
50	1.2 b	1.4 b	0.5 a	1.3 b	0.14 ab	0.40 b	0.4 b
100	1.4 c	1.6 c	0.4 a	1.2 c	0.12 b	0.34 c	0 c
				2nd cut			
0	0.6 a	0.5 a	0.6 a	2.4 a	0.26 a	0.66 a	2.9 a
50	1.1 b	1.1 b	0.5 b	1.9 b	0.15 b	0.44 b	1.4 b
100	1.3 c	1.5 c	0.4 c	1.7 b	0.11 c	0.33 c	0.5 c

Plant analysis gives a good picture of the K-status in the plant-soil system (Hopper and Clement, 1966; Lunnan, 1999). In conventional meadow cultivation a herbage content of 2.0 % K of DM has been shown to be associated with 95 % of maximum yield (Clement and Hopper, 1968).

Results from the experiments at the sites ‘Surnadal’ and ‘Tynset’ on sandy soils did not show any yield response to more than 60 kg K ha^{-1} given through the cattle manure. Low values of N indicate that lack of nitrogen is a bigger problem on the sandy soil than on the peat soils.

In both experiments on peat soils and one of the experiments on sandy soil, the K outputs in DM yield are larger than K inputs in fertiliser. This means that DM yield in the sandy soil, which showed no response to K-treatments, is supported with K from the soil, even although the acid-soluble K was low ($KHNO_3$ = 450 mg kg^{-1} dry soil).

Conclusions

Application of a minimum of 100 kg K ha^{-1} is necessary to maintain yield in organic meadow cultivation on soil with low K-status. Visual K-deficiency cannot be detected with K-concentration in plant tissue above 1.5 % in timothy. Both timothy and red clover content decreased if only 30 t diluted cattle manure ha^{-1} was used. 50 kg K ha^{-1} in addition to 30 t ha^{-1} diluted cattle manure raised the content of both timothy and red clover on peat soil.

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Manipulation of grass growth by altering nitrogen application

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Abstract

The objective of this study was to reduce the grass growth peak during May / June and increase grass growth and availability in the autumn to improve synchrony between grass supply and feed demand on grassland farms at low stocking rates (< 2 LU ha^{-1}).
Three nitrogen (N) levels applied to a perennial ryegrass sward, in two N application patterns (regular and irregular), plus zero nitrogen, set out in two grazing sequences, were replicated three times. Plots were grazed in a four week rotation. Twenty percent of total nitrogen was applied in March. The regular application received 0.20 of total N applied at each of the next two rotations, followed by 0.10 at each of the next four rotations. No nitrogen was applied for the irregular pattern in April and May, and 0.20 was applied at each of the following four rotations.
Although over the 3 years altering the nitrogen application pattern had no significant effect on the amount of herbage removed by grazing over the grazing season, in some years reducing the proportion of total annual nitrogen applied in the spring reduced the amount of DM consumed without reducing the amount consumed annually.

Keywords: irregular nitrogen application**,** nitrogen, nitrogen application pattern, regular nitrogen application

Introduction

Beef and milk production systems in Ireland are largely based on grazed grass. The feed demand curve for dairy and beef systems is poorly synchronised with grass supply, with a surplus of grass from about mid-April to mid-August, and a deficit for the remainder of the year. Traditionally, surplus grass produced in spring and early summer is conserved as silage or hay and fed back to cattle and dairy cows during the winter period. Sixty percent of total nitrogen is generally applied between March and May in order to maximise grass production during this time of high grass growth rates. Frame (1992) reported that the herbage response to fertiliser nitrogen is highest in June and July (20-40 kg DM kg^{-1} N). It is also reported that altering the amounts of nitrogen at each application has little effect on annual DM production but may affect seasonal production (Frame, 1992). The objective of this experiment was to examine the limitations to reducing the peak in grass growth in May / June and increasing DM production and availability later in the grazing season by altering the N application patterns.

Materials and methods

A perennial ryegrass (*Lolium perenne* cv. Spelga) sward was divided into 42 plots (each 200 m^2) at Teagasc Grange Research Centre, Dunsany, Co. Meath (lat. 53° long. 6°). There were three annual nitrogen (N) rates (50, 150, 250 kg N ha^{-1}) with two application patterns each with three replicates, set out in two grazing sequences differing in starting dates (first and third week of March), plus a zero nitrogen plot. Plots were grazed every four weeks by non-lactating cows. Cows were conditioned prior to grazing the plots by grazing in 0.4 ha paddocks receiving the same nitrogen application pattern and nitrogen levels as the grazing plots. Pre- and post-grazing herbage mass was determined in each plot by cutting a 5 m × 0.55 m strip to 0.05 m using a lawnmower. The trial extended over three grazing seasons (March 2001 to October 2003). After the initial applications of 0.2 of total N (Table 1), there were two application patterns, regular (R) and irregular (I). The regular application pattern had 0.2 of total nitrogen applied at each of the second and third grazings, followed by 0.1 at each of the next four grazings. No nitrogen was applied at the second and third grazing in the irregular application pattern, after which there were four applications of 0.2 each of total nitrogen. Nitrogen was applied as calcium ammonium nitrate (CAN). Plots received phosphorus and potassium each March in the form of 100 kg ha^{-1} of 0:10:20.

Table 1. Nitrogen application pattern

Grazing	Month	Proportion N applied	
		Regular	Irregular
1	March	0.2	0.2
2	April	0.2	0.0
3	May	0.2	0.0
4	June	0.1	0.2
5	July	0.1	0.2
6	August	0.1	0.2
7	September	0.1	0.2

As there was no significant effect of grazing sequence, the data were pooled for each month. Data were analysed as a split split plot design for nitrogen application pattern with nitrogen level as a split plot on nitrogen application pattern and year as a sub-plot on N level. The ash content of the pre- and post-grazing material has still to be determined.

Results and discussion

There was no significant interaction between nitrogen application pattern, nitrogen level and year on herbage removed from the plots by grazing (Table 2). The higher removal of herbage from plots receiving the higher levels of nitrogen fertiliser reflects the higher pre-grazing yields on these plots. There was a significant application pattern by year interaction in period 1 (April to June) with generally more herbage being removed from plots receiving the regular nitrogen application pattern during that period except in year 2. Altering the distribution pattern of nitrogen applied did not have a significant effect on annual DM production ($P < 0.1$). This agrees with data reported by Frame (1992) from a study carried out in the west of Scotland. As ash content has still to be determined these data on the effect on the amount of herbage removed from the plots can only be considered provisional.

The grass growth rate was reduced in period 1 and increased in period 2 on the plots receiving the irregular nitrogen application (Figure 1). The mean grass growth (per day) for the three years was not affected by the nitrogen application pattern. Grass growth was reduced by an average of 8 kg DM ha^{-1} d^{-1} in period 1 and increased by an average of 5 kg DM ha^{-1} d^{-1} in period 2. Overall grass growth for the three years was reduced by 0.78 kg DM ha^{-1} d^{-1} on the plots receiving the irregular nitrogen application pattern. There was no significant effect of nitrogen application pattern on growth rate over the grazing season ($P > 0.1$).

Table 2. Herbage removed by grazing (kg DM ha^{-1}) on plots receiving regular N application (R N) and irregular N application (I N) for period 1 (April to June), period 2 (July to October) and for the grazing season.

		Period 1		Period 2		Total	
	kg N ha^{-1}	R N plots	I N plots	R N plots	I N plots	R N plots	I N plots
Year 1	50	2975	2688	2860	3175	5836	5863
	150	4544	4082	4114	4791	8658	8873
	250	5746	4548	5006	4987	10753	9535
Year 2	50	1444	1447	2735	3500	4178	4947
	150	1928	2495	3125	3427	5053	5922
	250	3039	3284	4118	3953	7157	7237
Year 3	50	2546	1132	2966	2200	5512	3332
	150	2470	3009	3163	3414	5632	6423
	250	4498	2704	3476	3369	7974	6074
s.e.		313.315		581.040		651.433	
N Application Pattern (A)		n.s.		n.s.		n.s.	
N Level (B)		***		*		***	
Year (C)		***		*		***	
A x C		**		n.s.		n.s.	
A x B x C		n.s.		n.s.		n.s.	

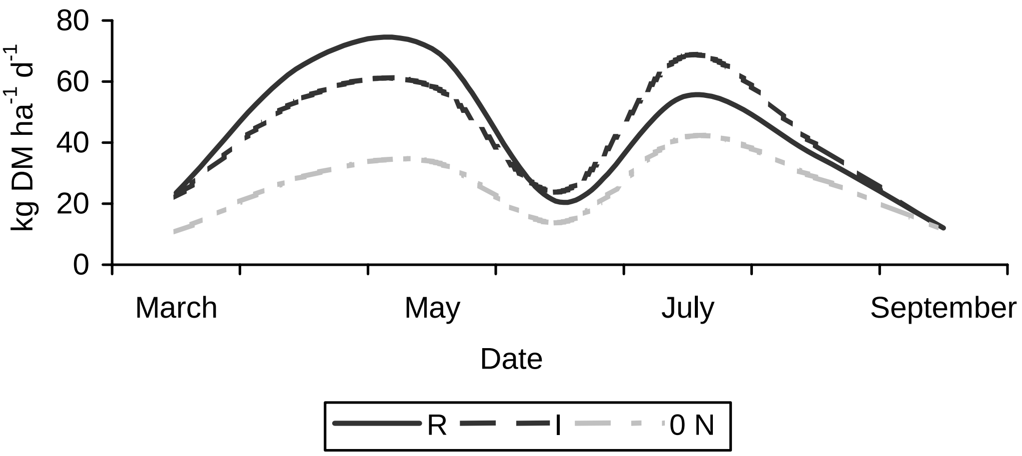

Figure 1. Grass growth curve showing mean grass growth for three years on plots receiving regular N application pattern (R), irregular N application pattern (I) and zero N (0N).

Conclusions

Although variable between years, this study demonstrates that the grass growth curve can be manipulated by altering the distribution pattern of nitrogen fertiliser during the growing season. Altering the nitrogen application pattern will help to improve synchrony between grass supply and feed demand without significantly affecting annual DM yield on grassland farms at low stocking rates (< 2 LU ha^{-1}).

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Environmentally compatible slurry spreading in mountain areas

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Abstract

Ammonia emissions can be reduced by using trailing hose systems to spread slurry. This system represents a step towards environmentally sound slurry spreading. However, farmers in mountain areas are very reluctant to implement it, as they question its operational reliability.
Over 100 users of trailing hose spreaders took part in a survey conducted to collect current experiences on farms. A test bench was also set up, allowing the measurement of spreading accuracy on the level and on hillsides with gradients of up to 30 %.
The written survey was split into the following subject areas: purchase decision, applications and practical experience relating to application limitations, slope gradient, more efficient fertiliser use and odour emission.
The spreader was operated on the test bench at various gradients and flow rates. Using cattle slurry, most spreaders even showed good distribution on hillsides, with an average deviation of less than 15 % from the average flow rate per hose.

Keywords: trailing hose, slurry, mountain area, spreading accuracy, test bench, survey

Introduction

The mountain areas of Switzerland are characterized by a high proportion of grassland. The forage produced there is utilised by ruminants, mainly in strawless or low-straw housing systems, thereby producing slurry. A system that evenly spreads slurry at ground level, including on hillsides, is needed so that the plant nutrients in the slurry can be returned to the grassland in an environmentally compatible manner.
Uniform spreading helps the grass sward to take up the nutrients contained in the slurry. In addition, good spreading allows well-adapted stock management of forage areas and prevents local over-fertilisation or under-supply. The spreading of slurry at ground level with trailing hoses also reduces ammonia (Frick and Menzi, 1997) and odour emissions. In lowland areas, the benefits for plant production and the environment have led to the increasing use of trailing hose spreaders. However, in mountain areas, the adoption of this system has been slow, as there are doubts about the operational reliability of trailing hose spreaders on steep hillsides.
The purpose of the study was firstly to collect experience on the trailing hose spreaders used to date, and secondly to measure the spreading accuracy on hillsides of the spreaders currently available in Switzerland.

Materials and methods

Questionnaires were sent to over 150 farms currently using trailing hose spreaders. The questionnaire was split into the following subject areas: technical data, purchase criteria, applications, problems which occurred in use and satisfaction with the system.
A special test bench was constructed to investigate the spreading accuracy of spreaders. The test bench was built in accordance with standard prEN 13406 (Anonymous, 1998). This provides for stationary spreader operation and collection of the slurry flowing from individual spreader hoses. After a measuring period of approx. 30 seconds, the flow from each individual hose was scaled and the average deviation from the overall mean was calculated. A

unique feature of the FAT test bench is that a slewing mechanism on the spreader suspension can simulate any desired gradient. Experiments were conducted with six types of spreader available on the Swiss agricultural machinery market (Table 1) with working widths of 7.8-9 m, using different flow rates (450 and 750 l min^{-1}), gradients (0, 15 and 30 %) and supply methods (pressure tank, spiral pump). All the treatments were carried out three times with diluted cattle slurry, whose DM content varied between 3.8 and 4.3 %.

Table 1. Tested trailing hose spreader.

Manufacturer / Selling agency:	Address:	Type:
Brunner Landmaschinen	CH 9536 Schwarzenbach	RAB 8.40 m
Fankhauser Maschinenfabrik	CH 6102 Malters	Perfekt 9 m
Landtechnik Zollikofen	CH Zollikofen	Garant 9 m
Hadorn's Gülletechnik	CH 4935 Leimiswil	Spider Compact 9 m
Hochdorfer Gülletechnik	CH 6403 Küssnacht	Excenter-Cut 9 m
Schweizer AG	CH 9536 Schwarzenbach	Terracare 7.8 m

Results and discussion

Over 100 responses were used to analyse current experiences on farms. It was shown that the most important criterion for the purchase of a trailing hose spreader was more efficient N utilisation of farmyard manure. 97 % of respondents gave this as their reason for investing in this system. The reduction of odour emissions was also important for 95 % of respondents. 81 % of the investment was made without government subsidies, a much higher proportion than in other countries.

Contrary to the expectations that led to the purchase of this system, only 76 % were able to confirm better N utilisation of farmyard manure in practice. However, 95 % found that odour was reduced during slurry spreading. 93 % of all respondents approved this method of slurry spreading and would invest in this system again.

As regards spreading accuracy, it was shown that the spreaders reacted differently to flow rates and slope gradients. Spreading accuracy tended to improve as flow rate increased and to deteriorate as the gradient increased. Spreading accuracy on the level fluctuated between 2 and 10 % (average deviation). An average deviation of between 4 and 24.3 % was measured at a 30 % gradient and a flow rate of 750 l min^{-1} (Figure 1). Between the spreaders tested, differences were also found in the maximal negative and positive deviation of individual hoses from the average flow rate (Table 2).

Table 2. Average deviation and maximal positive and negative deviation (%) from the mean flow rate per hose (total flow rate: 750 l min^{-1}).

		Type of trailing hose		Excenter-Cut 9 m	Garant 9 m	Perfekt 9 m	RAB 8.4 m	Spider Compact 9 m	Terracare 7.8 m
gradient	0%	Average deviation	(%)	2.2	2.9	10.0	1.8	6.2	8.4
		Maximal -/+ deviation	(%)	-3.7 / 4.3	-13.3 / 5.2	-21.2 / 30.9	-4.2 / 3.6	-11.3 / 18.3	-24.8 / 19.3
	15%	Average deviation	(%)	1.8	11.5	9.4	1.7	8.7	8.8
		Maximal -/+ deviation	(%)	-3.7 / 4.3	-35.9 / 15.0	-18.5 / 35.7	-4.3 / 4.3	-14.5 / 22.8	-24.3 / 17.1
	30%	Average deviation	(%)	7.1	24.3	9.2	3.9	5.5	7.6
		Maximal -/+ deviation	(%)	-41.1 / 59.1	-59.0 / 33.6	-25.9 / 28.9	-14.0 / 8.2	-12.2 / 15.8	-21.1 / 16.0

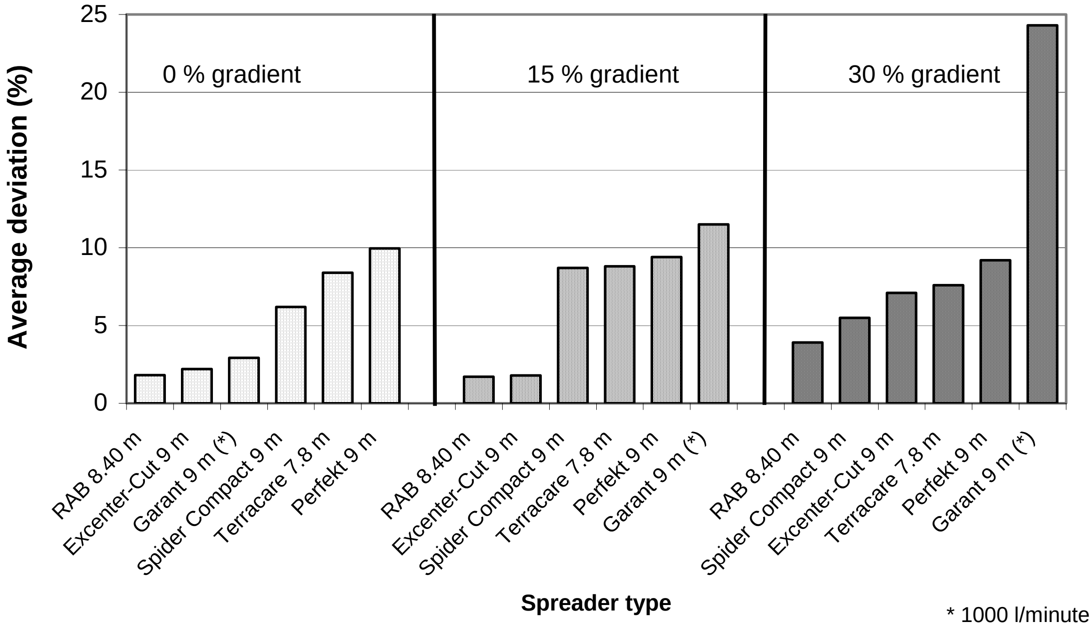

Figure 1. The influence of gradient on the average deviation at a total flow rate of 750 l min^{-1} for different spreader types.

Conclusions

Trailing hose spreaders are already being successfully used by farmers on hillside grassland. The reduction of odour emission is perceived as a major benefit. Not all the respondents considered that their expectations of a more efficient use of the nitrogen contained in the slurry had been confirmed in practice.

Measurement on a test bench showed that the spreaders varied in their ability to spread accurately on hillsides. Most spreaders tested complied with the maximum 15 % average deviation value specified by standard prEN 13406.

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Yield and residual nitrate nitrogen in soil of grazed grassland with different slurry applications

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Abstract

This experiment aimed to compare the effects of the maximum possible use of cattle, pig or sow slurry combined with mineral fertiliser permitted by the Flemish decree on manure under cattle grazing conditions. The 4-year experiment was executed on a sandy (Geel) and on a sandy loam soil (Merelbeke). Slurry was applied by shallow injection. To determine the dry matter (DM) yield, strips (10 m^2) were mown before and after grazing. Net DM yield was the highest for the control (300 kg N ha^{-1} y^{-1} as mineral fertiliser only) with 9.8 t ha^{-1} in Geel and 12.0 t ha^{-1} in Merelbeke. In Geel, cattle slurry applied in spring, and in spring + after the first cut, yielded significantly less than the control. In Merelbeke no significant yield differences were found. The residual N content in the soil was determined at the beginning, at the end of the growing season and during the winter. In Geel the NO_3-N concentration in the soil in November was significantly higher in the control than in the treatments with cattle slurry. In the same period at Merelbeke, the use of sow slurry resulted in a significant lower amount of NO_3-N in the soil compared to pig slurry and cattle slurry. From December until March no significant differences were found for this parameter at the 2 experimental sites.

Keywords: grazing, slurry, soil nitrate, fertilisation strategy, DM yield

Introduction

In the framework of the Manure Action Plan (MAP), the Flemish Government has planned since 1999 a maximum use of 130 kg P_2O_5 and 500 kg N ha^{-1} y^{-1} on grassland. From 2003 limits were planned for mineral fertilisers (max. 350 kg N ha^{-1}) and for organic and originally animal N fertilisers (max. 250 kg N ha^{-1}). The limit of 250 kg non mineral fertiliser N ha^{-1} y^{-1} can only be exceeded when phosphate input is respected and when the nitrate nitrogen content in the soil profile 0-90 cm does not exceed 90 kg ha^{-1} at the end of the growing season (1 October – 15 November). Farmers have a lot of slurry available because of the high cattle density on their farm and because it is economically attractive to use slurry surpluses from other farms. On the other hand, exceeding the 90 kg NO_3-N ha^{-1} y^{-1} limit has also substantial financial consequences. Therefore, farmers and officials from the government were very interested in the effects of the maximum possible use of organic manure in combination with grazing in terms of grass yield and nitrate nitrogen residues at the end of the season.

Materials and methods

The study was carried out in Flanders on pastures dominated by perennial ryegrass (*Lolium perenne* L.) on a loamy sand soil in Merelbeke and on a sandy soil in Geel (De Vliegher *et al*., in prep.). The trial was established in 1999 in a complete block design with 4 replicates. Each experimental plot had a size of 280 m^2 (14 m × 20 m). The following treatments were imposed: A) cattle slurry 25 t ha^{-1} in spring, B) cattle slurry 25 t ha^{-1} in spring + 15 t ha^{-1} after the first cut (May), C) sow slurry 15 t ha^{-1} in spring, D) pig slurry 15 t ha^{-1} in spring and E) no slurry.

Every treatment received a total of 500 kg N ha^{-1} y^{-1} from slurry + deposition by the grazing animals (the same for every treatment) + a variable quantity of mineral fertiliser. Slurry was analysed to determine as good as possible the N input in the different treatments (quantity calculated with average P_2O_5 and N content). Deposition by animals was calculated by an estimation of the number of grazing days and a N excretion value of 97 kg N y^{-1} cow^{-1} and 30 kg P_2O_5 y^{-1} cow^{-1}. The gap between 500 kg and the N input by slurry and grazing animals was made up by mineral fertiliser and was different for all the treatments (Table 1). The distribution of the mineral fertiliser during the season was in agreement with a good agricultural practice. Each treatment received the same amount of P_2O_5, K_2O and MgO (slurry + mineral fertiliser). During the experiment the pasture was grazed in a rotational system by dairy cattle and grass yield was determined by mowing strips of at least 10 m^2 before and after grazing. The grazing period was short, just a few days, so grass growth during the grazing period was negligible. In the period October-February the soil was sampled monthly with a high drilling frequency for determination of the nitrate nitrogen residue in the profile 0-90 cm.

Results and discussion

There were substantial differences between the treatments in the quantity of mineral N fertilisers and in the N availability for grass growth from the different kinds of slurry. Despite these differences no significant differences for net grass yield were found in Merelbeke in the period 1999-2002 (Table 1). The application of cattle slurry in spring + after the first cut (B) or pig slurry (D) resulted in a significant lower grass yield before grazing but due to a higher grazing efficiency these differences were not present in the net yield. The use of slurry by injection and the management system with one cut in spring for silage restricted the potential negative influence of slurry on the palatability of grazed grass.

Table 1. Nitrogen input and grass yield in the 2 experimental sites (average 1999-2002).

	N-input (kg ha^{-1})				Grass yield (kg DM ha^{-1})		
Site Treatment	slurry	grazing cows	mineral fertilisers	total	before grazing	after grazing	net
Merelbeke							
A	106	208	171	485	13,802 ab	2,291 bc	11,511 a
B	170	208	107	485	13,122 a	2,170 ab	10,952 a
C	95	208	184	487	13,442 ab	2,347 bc	11,096 a
D	137	208	150	495	13,227 a	1,942 a	11,285 a
E	0	208	278	486	14,494 b	2,487 c	12,007 a
Geel							
A	123	162	204	489	10,716 ab	1,895 a	8,821 ab
B	193	162	133	488	10,397 a	2,007 a	8,390 a
C	59	162	278	499	12,024 c	2,328 a	9,695 b
D	96	162	238	496	11,491 bc	2,292 a	9,199 ab
E	0	162	336	498	11,979 c	2,165 a	9,813 b

In each location and column, data followed by different letters are significantly different at the $P < 0.05$ level.

In Geel, the cattle density was lower in comparison with Merelbeke (3.4 cows ha^{-1} vs 4.3 cows ha^{-1} during 180 days) and more mineral nitrogen was applied in every treatment. The ranking of the treatments for net grass yield corresponded with the ranking for mineral fertiliser use. The net yield of treatment C (sow slurry) and E (no slurry) was significantly higher than for treatment B (cattle slurry in spring + after the first cut). The difference can be explained by a reduction in grass growth due to the injection itself and by another pattern in the availability of N for grass growth. The changes in the nitrate nitrogen content in the soil are given in table 2. Only in the first sampling period (Nov = 1 October – 15 November) were significant differences found at both sites. In Merelbeke, the use of pig slurry (D) or cattle slurry (B) gave significantly higher nitrate residues in comparison with the use of sow slurry

(C). The limit of 90 kg NO_3-N ha^{-1} y^{-1} at the end of the growing season was only exceeded by the use of pig slurry. Contradictory results are found in Geel: the application of pig slurry (D) and cattle slurry (A, B) resulted in the lowest nitrate residues. The treatments without slurry (E) and the use of sow slurry (C) gave high nitrate nitrogen values and exceeded the limit of 90 kg NO_3-N ha^{-1} y^{-1}. In both treatments, the N input by mineral fertilisers was high. A clear explanation for these contradictory results is not available but differences in soil type and grassland management, such as the level of available nitrogen, distribution of N over the season, grazing and cutting regime, etc. will play an important role.

Table 2. Nitrate nitrogen residue at the end of the growing season and in wintertime in the 2 experimental sites (average 1999-2002).

	N-input kg ha^{-1}			Nitrate N content in the soil (kg ha^{-1} in 0-90 cm layer)				
Site Treatment	slurry	grazing cows	mineral fertilisers	Nov	Dec	Jan	Feb	March
Merelbeke								
A	106	208	171	81ab	70a	53a	41a	40a
B	170	208	107	89b	99a	58a	38a	35a
C	95	208	184	57a	68a	49a	34a	36a
D	137	208	150	97b	110a	56a	39a	42a
E	0	208	278	78ab	92a	57a	29a	33a
average				80	88	55	36	37
Geel								
A	123	162	204	74a	77a	59a	45a	-
B	193	162	133	62a	74a	50a	31a	-
C	59	162	278	93ab	126a	48a	33a	-
D	96	162	238	88ab	78a	51a	35a	-
E	0	162	336	109b	156a	56a	37a	-
average				85	102	53	36	-

In each location and column, data followed by different letters are significantly different at the $P < 0.05$ level

Conclusions

There is a tendency for the shallow injection of slurry to result in a decrease in net grass yield in a grazing regime. But only in one location was a significantly lower yield established for a double application of cattle slurry compared with with no slurry injection. The nitrate nitrogen contents of the soil at the end of the growing season at the two experimental sites are contradictory. In Geel we observed the highest nitrate residue when no slurry or sow slurry has been applied, in Merelbeke it was the opposite.

Acknowledgements

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Role of farmyard manure on upland meadows

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Abstract

Investigations were carried out during 1997-2003 on a permanent meadow situated in the upland region of Poland. The experiment compared the following four treatments: unfertilised control, mineral fertilisers (150 kg N, 26 kg P and 66 kg K ha^{-1}), organic manuring (12.5 t ha^{-1} farmyard manure) + complementary mineral fertilisation and organic manuring (25 t ha^{-1} farmyard manure) + complementary mineral fertilisation. The grasses: *Arrhenatherum elatius* and *Holcus lanatus* dominated the sward. Manuring of the meadow favourably influenced the botanical composition of the sward. Mineral fertilisers alone stimulated mainly *Arrhenatherum elatius*. The effects of organic + mineral fertilisers were similar to mineral fertilisers alone. When unfertilised the sward produced 5.87 t DM ha^{-1}, but with mineral fertilisers DM output increased to 9.89 t ha^{-1}. The addition of organic manure produced no further increment in DM yields. A low crude protein (CP) output was characteristic of the control plot, which produced annually an average of 612 kg CP ha^{-1}. The fertilised swards produced 55-60 % more protein.

Keywords: meadows, mineral fertilisation, farmyard manure, DM yield, crude protein

Introduction

The prices of agricultural products, which are relatively low in comparison to production costs, limit the profitability of agricultural production (Kasperczyk and Radkowski, 1999). Thus farmers are seeking ways to lower the costs of production especially of fodder production from grassland where many are trying to reduce expensive mineral fertilisation. Studies reveal that mineral fertilisation accounts for between 55 and 60 % of outlays for hay production (Szaro and Kuczek, 1991; Van den Ham, 1992). Thus home produced manures, particularly farmyard manure, become more important (Baars *et al.,* 1995). We undertook investigations into the manurial value of cattle manure for permanent grassland in comparison with mineral fertilisers.

Materials and methods

The experiment was carried out from 1997 to 2003 on a permanent mountain meadow situated in an upland region on brown soil (granulometric composition = medium loam, pH_{KCl} = 5.4, available elements: P = 13 mg, K = 82 mg and Mg = 140 mg kg^{-1} of soil). At the start of the experiment the meadow sward was thin and with a poor species diversity. Three species were most abundant: *Arrhenatherum elatius* (35 %), *Holcus lanatus* (30 %) and *Plantago lanceolata* (15 %). The experiment compared the following four treatments:

- Unfertilised control
- Mineral fertilisation (150 kg N, 26 kg P and 66 kg K ha^{-1})
- Organic manure(12.5 t ha^{-1} farmyard manure) + complementary mineral fertilisation
- Organic manure (25 t ha^{-1} farmyard manure) + complementary mineral fertilisation.

The plot size was 15 m^2 (3.0 m × 5.0 m) and there were four replications. In organic + mineral fertilisation treatments the mineral fertilisers were supplemented to achieve the same nutrient supply as in the treatment with mineral fertilisation, i.e., 150 kg N, 26 kg P and 66 kg K ha^{-1}.

Cattle farmyard manure (FYM) containing 3.1-3.3 g N kg^{-1}, 0.4-0.7 g P and 2.5-2.7 g K was applied. The farmyard manure at the lower rate (12.5 t) supplied 39-41 kg N, 5-9 kg P and 31-34 kg K. It was applied every year in one application in the early spring after the snow had disappeared. Mineral fertilisers were applied as follows: all the phosphorus in spring, potassium and nitrogen in two dressings, 60 % in spring and 40 % after the 1^{st} cut. The meadow was cut twice, the first during the initial period of *Arrhenatherum elatius* flowering, the second eight weeks later. Sward composition was determined using Klapp's assessment method prior to the first cut. Dry matter (DM) contents were assessed by drying samples at 105 °C and the crude protein (CP) content was measured using Kjeldahl's method. Effects of fertilisation were evaluated using one-way analyses of variance.

Results and discussion

Manuring had a positive impact on the botanical composition of the sward. Mineral fertilisation stimulated mainly *Arrhenatherum elatius* (70 %) at the expense of *Holcus lanatus* (Table 1).

Table 1. Proportions of the most important species in the sward after 7 years [%].

	Treatment			
Species	Unfertilised	Mineral fertilisation	Organic (12.5 t) + mineral	Organic (25 t) + mineral
Holcus lanatus	30	8	25	30
Arrhenatherum elatius	35	70	40	35
Festuca rubra	13	2	2	2
Festuca pratensis	1	3	6	5
Dactylis glomerata	+	5	8	7
Poa pratensis	+	2	4	5
Plantago lanceolata	5	-	+	+
Trifolium pratense	5	-	+	+

The proportion of *Arrhenatherum elatius* in the sward reached only 35-40 % under organic + mineral fertilisation. All treatments with manures clearly limited the growth of *Festuca rubra* and promoted an increase in *Festuca pratensis*, *Dactylis glomerata* and *Poa pratensis*. Both the combined manurial (organic + mineral) treatments kept *Holcus lanatus* at its initial level. The positive impact of farmyard manure on botanical composition (Jankowska-Huflejt and Niczyporuk, 1996), especially on the growth of *Trifolium pratense*, was not shown in our experiment.

Table 2. DM yields, crude protein content and crude protein yields (mean of 7 years).

Treatment	DM yield (t ha^{-1})	Crude protein content (g kg^{-1} DM)	Crude protein yield (kg ha^{-1})
Unfertilised control	5.87	106.0	612
Mineral fertilisation	9.97	107.0	1058
Organic (12.5 t) + mineral fertilisation	9.93	98.5	977
Organic (25 t) + mineral fertilisation	9.91	96.1	951

The yield potential of the meadow was relatively high and the unfertilised sward produced 5.87 t DM ha^{-1} (Table 2). There were no significant differences between the mineral (9.97 t ha^{-1}) and the combined manuring treatments (9.93 and 9.91 t ha^{-1}). In comparison with control the increase from manuring was about 70 %. Under our conditions farmyard manure should be applied to grassland instead of mineral fertilisers, though Mikolajczak and Bartmanski (1992) found a lower utilisation of nutrients from FYM. We observed yield fluctuations during the experiment depending on soil moisture conditions (Figure 1). Plant crude protein content was low due to late harvests and high dry matter production. Generally, the control sward and that receiving mineral fertilisers showed higher CP content (on average 5 g kg^{-1}) than the swards receiving combined manuring.

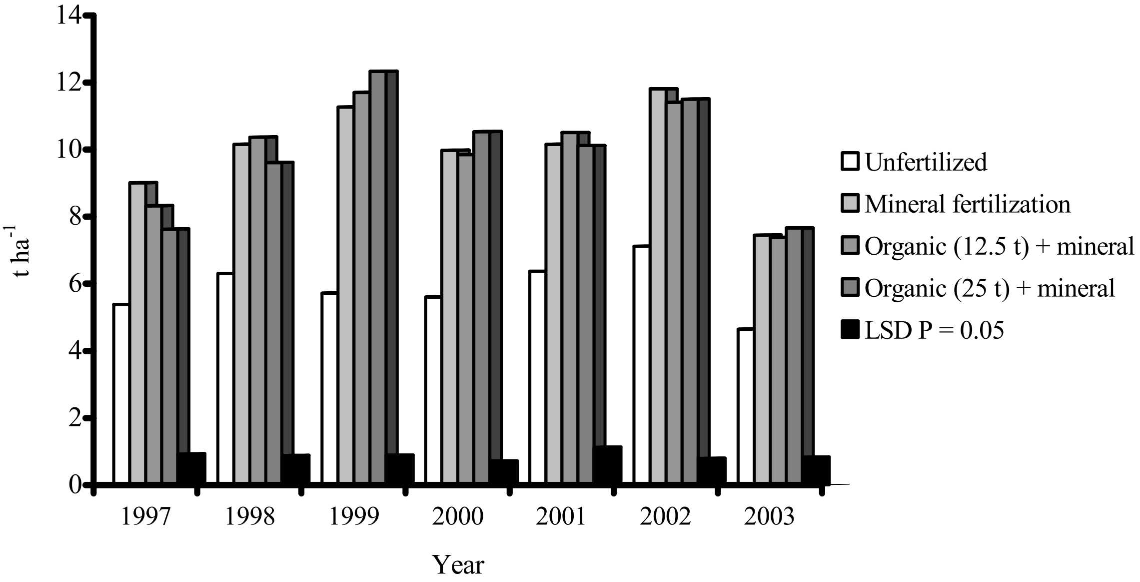

Figure 1. Effect of manurial treatment on annual DM yields.

Conclusions

By these results combined (organic + mineral) manuring of upland grassland is almost as effective as mineral alone and is considerably less expensive. This suggests a possible substitution of mineral by organic manures, especially in upland regions of Southern Poland, where permanent grasslands are predominant.

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Effect of NP fertilisation on the production of mountain pastures at different altitudes

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Abstract

To promote the rational utilisation of mountain pastures, this research analyses the effects of low mineral NP fertilisation on forage production of pastures during five grazing seasons. The pastures belonged to the association *Brizo (mediae)-Brometum erecti* and were located at different altitudes on Monte Catria (Central Apennines).
A low NP fertilisation increased the DM yield and the growth rate of the pastures at each altitude and throughout the vegetative season. Under particular climatic conditions, a low NP fertilisation produced an earlier beginning of the vegetative period. Compared to the higher altitudes, the lower elevation gave higher forage production, and an earlier start to and longer duration of the vegetative period.

Keywords: mineral fertilisation, mountain pastures, forage production, seasonal growth rate

Introduction

Natural pasturelands are a very important forage resource for the rational management of animal production systems adopted in marginal areas (Santilocchi, 1989).
In this context, the present research aims to analyse the effects of low mineral NP fertilisation on the forage production of mountain pastures located at different altitudes on Monte Catria. These pastures are spread across the middle and high elevations of the Italian Central Apennines (Biondi and Ballelli, 1982).

Materials and methods

The research was carried out on the pastures of Monte Catria 1,701 m asl, in Pesaro and Urbino province, Central Italy. These pastures are traditionally grazed by cattle and horses during the summer period. The bedrocks are of calcareous origin and the soils are characterised by medium or medium-clay texture, acid pH and low depth (10-25 cm). The climate of the nearest meteorological station located in Frontone (570 m asl, PU province) is characterised by mean annual precipitation of 1,152 mm with maximum values occurring during the spring and autumn and minimum values in July. The mean annual temperature is 12.2 °C; the values of the coldest (January) and of the hottest (July) months are -0.8 and 25.6 C, respectively.
In the studied pastures, that are to be referred to the association *Brizo (mediae)-Brometum erecti* (Biondi and Ballelli, 1982), *Bromus erectus*, *Cynosurus cristatus*, *Anthoxanthum odoratum* and *Carex caryophyllea* were the most abundant species.
On surfaces located at 850, 1,220 and 1,670 m asl the pastures were fertilised (F) with 70 kg N and 70 kg P_2O_5 ha^{-1} y^{-1} at the beginning of each growing season immediately after the snow thawing, or not fertilised (NF). On both treatments the pasture utilisation was simulated according to the method of Corrall and Fenlon (1978).
From the beginning to the end of the grazing season (in general from May to the beginning of November), the dry matter (DM) yield and the seasonal growth rate were assessed during five years (1984-1988) according to the method of Corrall and Fenlon (1978).
The data were statistically analysed using the ANOVA procedure with software SPSS (1999) and according to Gomez and Gomez (1984).

Results and discussion

The overall mean DM yield of the pasture was 1.90 t ha^{-1} y^{-1} (Table 1). This result was obtained from a wide range of annual values, probably due to large differences in the annual climatic conditions. In this regard, a strong influence of climatic regime on annual pastures production was already observed (Santilocchi, 1989).

Table 1. DM yield (t ha^{-1} y^{-1}) of the pastures not fertilised (0-0) and fertilised (70-70) located at 850, 1220 and 1670 m asl.

Altitude (m asl)	850			1220			1670			All altitudes		
Fertilisation (N-P_2O_5)	0-0	70-70	Mean	0-0	70-70	Mean	0-0	70-70	Mean	0-0	70-70	Mean
1984	1.72	2.57	2.14	0.72	0.99	0.86	2.03	1.92	1.98	1.49	1.83	1.66 ^{B}
1985	2.45	2.76	2.61	2.10	2.88	2.49	1.29	1.84	1.56	1.95	2.50	2.22 ^{A}
1986	1.42	2.73	2.08	-	-	-	0.57	1.60	1.08	1.00	2.16	1.58 ^{B}
1987	2.37	3.55	2.96	0.95	2.19	1.57	0.86	2.30	1.58	1.39	2.68	2.04 ^{A}
1988	2.80	3.54	3.17	0.86	1.78	1.32	1.19	1.91	1.55	1.61	2.41	2.01 ^{A}
1984-1988*	2.15 ^{B}	3.03 ^{A}	2.59 ^{A}	1.16 ^{b}	1.96 ^{a}	1.56 ^{B}	1.19 ^{b}	1.91 ^{a}	1.55 ^{B}	1.49 ^{B}	2.32 ^{A}	1.90

*Means with no common letter differ significantly at the 0.05 (lower case letters) or at the 0.01 (capital letters) level (Duncan test). Superscript letters show differences between the treatments into the altitude. Non superscript letters show differences between the altitudes or between the years.

The fertilisation significantly increased the DM yield of the pastures on average over the five years, both on average across the three altitudes (increase of 0.83 t ha^{-1} y^{-1}) and at each altitude (mean increase of 0.88, 0.80 and 0.73 t ha^{-1} year^{-1} at 850, 1,220 and 1,670 m, respectively).
The lower elevation determined higher forage production compared to the higher altitudes (increase of 1.03 and 1.04 t ha^{-1} y^{-1} respectively, in average of both treatments). The two higher altitudes did not differ probably because of a better exposition at the highest altitude (NW at 1,220 m and S at 1,670 m). In spite of the presented results, the significance of the interactions altitude × year and of fertilisation × year highlighted the strong influence of the climate on the pasture production.

At each altitude, the fertilisation consistently raised the growth rate compared to NF pastures throughout the vegetative period and in particular during the spring period (Figure 1). This is highlighted by the steeper inclination of the curve when the higher growth of the vegetation occurs. The increase reached on average 4.8 kg ha^{-1} d^{-1}, but maximum values of 21.1, 15.2 and of 23.3 kg ha^{-1} d^{-1} were recorded at 850, 1,220 and 1,670 m, respectively.
In years characterised by cold springs the fertilisation caused an earlier beginning of the vegetative period (clearly evident at 1220 m, Figure 1) and reduced the growth variability due to the climatic fluctuations as already pointed out by Santilocchi (1989). This allows to predict in advance and with more accuracy the carrying capacity of the pastures.
Compared to the higher altitudes, the lower elevation determined an earlier beginning (14 and 30 days respectively) and a longer duration of the vegetative period (10 and 26 days).

Conclusions

The results highlighted that low NP fertilisation increased the DM yield of the pastures at each altitude and throughout the vegetative season. Under particular climatic conditions, a low NP fertilisation produced an earlier beginning of the vegetative period. A low NP fertilisation of the more productive surfaces, where mechanisation is possible, could allow increased forage production and reduction of the stocking rate in more sensitive areas.

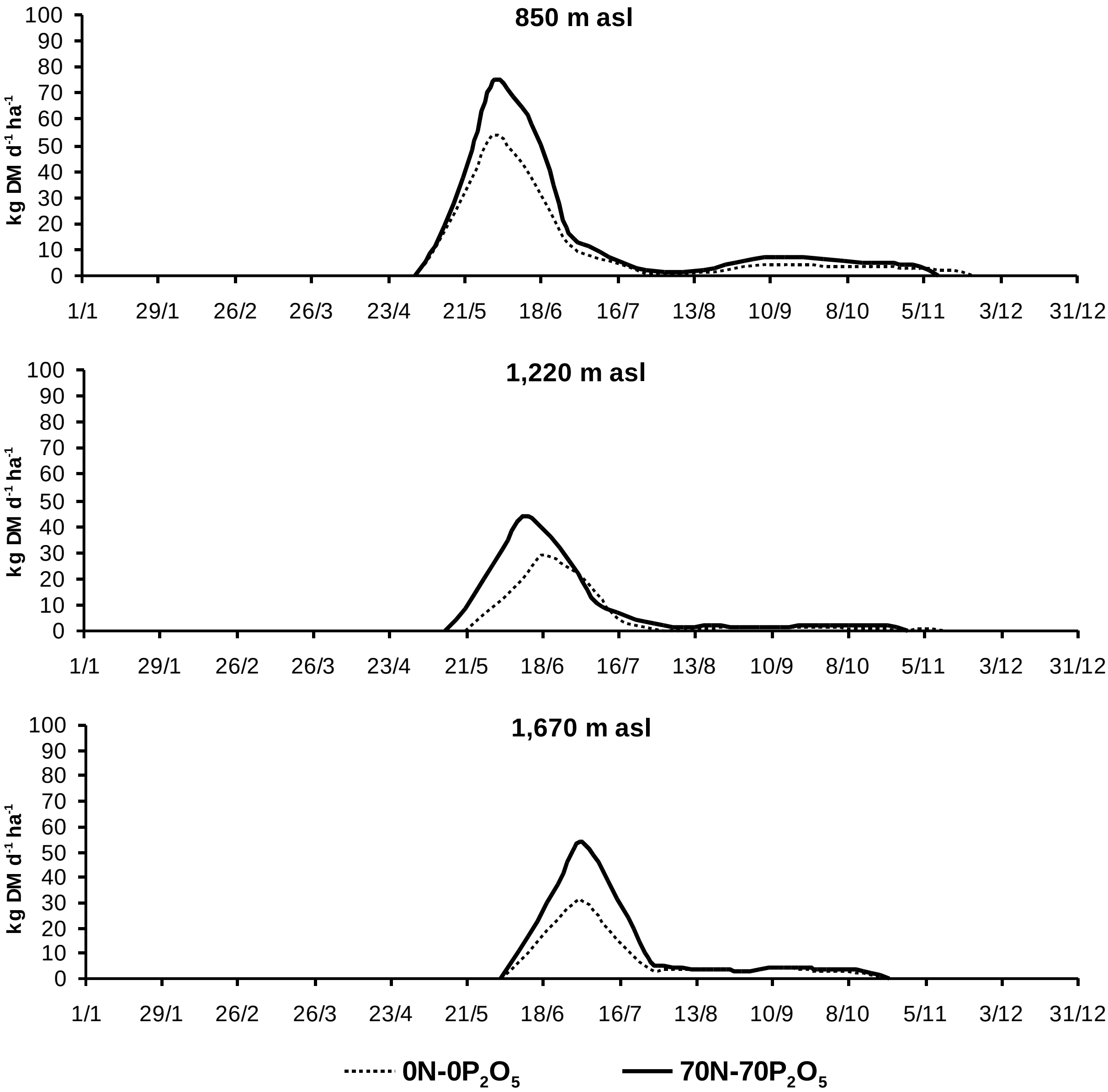

Figure 1. Seasonal growth rate of unfertilised (0N-0P_2O_5) and fertilised (70N-70P_2O_5) pastures located at 850, 1,220 and 1,670 m asl. Mean value of five experimental years.

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The influence of fertilisation and liming on some soil chemical features and on pasture yield

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Abstract

The soil is an important factor determining quality and quantity of forage production from *Festuca rubra* mountain pastures in the Cindrel Mountains. Both low pH and low degree of base saturation limit the proportion of valuable species such as legumes and perennial grasses. In these conditions (Pãltiniş, Cindrel Mountain, 1348 m asl) we have tested, since 1998, many technological treatments. These treatments had to meet demands for sustainable forage production in this area. We tried to improve certain soil chemical features, and therefore the pasture floristic composition, through utilisation of chemical fertilisers, organic fertilisers and $CaCO_3$. In some treatments oversowing with *Trifolium repens* was utilised. After five years the best results were obtained with 22 kg P and 83 kg K ha^{-1} y^{-1}, 5.5 t ha^{-1} $CaCO_3$ and with oversowing of *T. repens.* In this case the pH was 5.67, the degree of base saturation 60.75 %, the legume proportion in the sward 75 % and the dry matter yield 3.96 t DM ha^{-1}.

Keywords: mountain pasture, fertilisation, liming, pH, degree of base saturation, forage yield

Introduction

In Romania *F. rubra* natural pastures (boreal level) occupy an area of about 1 million ha with average yields of about 9 t ha^{-1} fresh matter (Cardaşol *et al.,* 1997). The importance of *F. rubra* mountain pastures in the Cindrel Mountains is given by their large area (5,900 ha) which assures them an important role in the pastoral economy of the region. The low pH and low degree of base saturation of the soil are limiting factors for the yield of these pastures. The purpose of this research was to study the effects of some treatments (fertilisation, liming, oversowing) which can improve both soil chemistry and dry matter yield.

Materials and methods

The research was carried out between 1998 and 2002 in an experimental field (Pãltiniş) at 1348 m asl on a brown acid soil. The climate of the region is characterized by a mean annual temperature of 4.5 ^{o}C and an annual rainfall of 996 mm. The experiment was organized in randomized blocks with four replicates and included the following treatments: 1) control without fertilisation, 2) 100 / 22 / 83 kg N / P / K ha^{-1} y^{-1}, 3) sheep folding during 3 nights (one sheep m^{-2}), 4) 0 / 22 / 83 kg N / P / K ha^{-1} y^{-1} + oversowing with *T. repens,* 5) 0 / 22 / 83 kg N / P / K ha^{-1} y^{-1}. Each treatment was divided into 2 plots, one without liming (1-5) and one receiving 5.5 t ha^{-1} $CaCO_3$ (1'-5'). In spring 2002 soil samples were taken (depth 0-15 cm) for analysis of pH (H_2O) and degree of base saturation.

Results and discussion

After five years, significant increases in pH values were recorded in the block with liming (1'-5') and especially for the plots fertilised just with P and K (Table 1).

Table 1. The combined influence of fertilisation and soil liming on soil pH after 5 years (2002).

Treatment		pH absolute value	pH relative value (%)	Absolute difference as compared to control (+/-)	Significance
1 control	without liming	5.05	100.00	0.00	-
2 100/22/83 N/P/K		5.04	99.70	-0.01	ns
3 sheep folding		5.02	99.30	-0.03	ns
4 0/22/83 N/P/K + oversowing *T. repens*		5.16	102.10	+0.11	ns
5 0/22/83 N/P/K		5.18	102.40	+0.13	ns
1' natural pasture	with liming	5.47	108.31	+0.42	**
2' 100/22/83 N/P/K		5.50	108.91	+0.45	**
3' sheep folding		5.54	109.70	+0.49	**
4' 0/22/83 N/P/K + oversowing *T. repens*		5.67	112.27	+0.62	***
5' 0/22/83 N/P/K		5.76	114.05	+0.71	***

***$P < 0.001$; ** $P < 0.01$; ns not significant.

Concerning the degree of base saturation only the liming block treatments showed positive and significant changes (Table 2).

Table 2. The combined influence of fertilisation and soil liming on soil degree of base saturation (V) after 5 years (2002).

Treatment		V absolute value (%)	V relative value (%)	Absolute difference as compared to control (+/-)	Signifi -cance
1 control	without liming	37.25	100.00	0.0	-
2 100/22/83 N/P/K		35.85	96.20	-1.4	ns
3 sheep folding		36.65	98.40	-0.6	ns
4 0/22/83 N/P/K + oversowing *T. repens*		34.95	93.80	-2.3	ns
5 0/22/83 N/P/K		31.55	84.70	-5.7	ns
1' natural pasture	with liming	48.10	129.12	10.85	*
2' 100/22/83 N/P/K		50.00	134.22	12.75	**
3' sheep folding		56.50	151.67	19.25	***
4' 0/22/83 N/P/K + oversowing *T.repens*		60.75	163.08	23.50	***
5' 0/22/83 N/P/K		59.68	160.21	22.43	***

***$P < 0.001$; ** $P < 0.01$; * $P < 0.05$;; ns not significant.

The positive changes of these two soil values (pH, V) in the case of liming treatments (1'-5') were associated with some qualitative changes in pasture floristic composition. At 50 %, the proportion of *Agrostis capillaris* in treatment 2' (100 / 22 / 83 kg N / P / K ha^{-1} y^{-1} + 5.5 t ha^{-1} $CaCO_3$) was higher than in natural pasture. At 65 %, the proportion of *T. repens* in treatment 4' (0 / 22 / 83 kg N / P / K ha^{-1} y^{-1} + oversowing with *T. repens* + 5.5 t ha^{-1} $CaCO_3$) was higher than in natural pasture. The dry matter (DM) yield (average of five years) showed a significant increase in most treatments as compared to the control (Table 3). The best values were recorded for the treatments with liming (1'-5'). The best yield (5.30 t DM ha^{-1}) was recorded in treatment 2' (100 / 22 / 83 kg N / P / K ha^{-1} y^{-1} + 5.5 t ha^{-1} $CaCO_3$). The better yields resulted from the better plant nutrition (Sima *et al*., 2001), and the floristic composition of the these treatments. From all experimental treatments, those with soil liming (1'-5') provide the best basis for sustainable forage production. Special attention must be paid to the treatment with P and K fertilisation + oversowing with *T. repens* and soil liming (4'). In this treatment we obtained after five years a pH of 5.67 and a V of 60.75 %. In these conditions the proportion of white clover in the sward was 65 %. Due to the ability of legumes to fix N_2 symbiotically this high proportion of white clover provides a better nitrogen supply and ensures better yield, and forage quality.

Table 3. The combined effect of fertilisation and liming on DM yield (average of five years).

Treatment		DM yield (t ha^{-1})	Relative yield (%)	Absolute difference as compared to control (+/-)	Signifi -cance
1 control	without liming	2.49	100.00	0.00	-
2 100/22/83 N/P/K		4.76	191.16	+2.27	***
3 sheep folding		2.52	101.20	+0.03	ns
4 0/22/83 N/P/K + oversowing *T. repens*		3.28	131.80	+0.79	***
5 0/22/83 N/P/K		3.25	130.52	+0.76	***
1’ natural pasture	with liming	2.90	116.46	+0.41	***
2’ 100/22/83 N/P/K		5.30	212.85	+2.81	***
3’ sheep folding		3.03	121.68	+0.54	***
4’ 0/22/83 N/P/K + oversowing *T. repens*		3.96	159.03	+1.47	***
5’ 0/22/83 N/P/K		3.84	154.21	+1.35	***

***$P < 0.001$; ns not significant.

Conclusions

For all treatments with soil liming, we observed, after five experimental years, significant increases in both pH and degree of base saturation of the soil.
The best forage yield was obtained with 100 / 22 / 83 kg N / P / K ha^{-1} y^{-1} and 5.5 t $CaCO_3$ ha^{-1}, but the best combination of both soil chemical features and forage yield was observed with 0 / 22 / 83 kg N / P / K ha^{-1} y^{-1} + oversowing with *T. repens* (3 kg ha^{-1}) + 5.5 t $CaCO_3$ ha^{-1}.

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The use of wood ash as liming and fertilising material in grasslands

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Abstract

Forestry industries, of great importance in Galicia (NW Spain), burn bark to generate energy, which leads to huge amounts of ash that in most cases is stored without any use. In order to develop a use in agriculture, a trial was sown in September 2001 to investigate the liming and fertilising effect of wood ash in the establishment of grass-legume pastures on acid soils. The initial soil analysis was: pH (H_2O) 5.1; P (Olsen) 28 mg kg^{-1}, K (NH_4NO_3) 79 mg kg^{-1} and Al CEC^{-1}(Cation Exchange Capacity) 0.52. Eight treatments were established: 1) Control (no lime or fertilisers), 2) Fertilisers (F) without lime, 3) Limestone3 (3 t ha^{-1} of ground limestone), 4) Limestone3+F, 5) Ash6 (6 t ha^{-1} ash), 6) Ash6+F, 7) Ash12 (12 t ha^{-1} ash) and 8) Ash12+F. F(kg ha^{-1}) = 40N-120P_2O_5-120K_2O. Average 2002 and 2003 dry matter yields (t ha^{-1}) were 3.8, 4.9, 4.8, 6.2, 6.4, 7.3, 7.6 and 8.3, respectively. The soil pH (and corresponding exchangeable Al CEC^{-1}) were 5.1(0.542), 5.1(0.532), 5.7(0.135), 5.7(0.164), 5.5(0.284), 5.5(0.258), 5.9(0.130), 5.8(0.129). These preliminary results show a clear effect of the ash on soil acidity and herbage yield.

Keywords: grass, legumes, acid soils

Introduction

Woodlands account for 1.1 x 10^6 ha, or 39 % of the total area of Galicia (NW Spain). They are the basis of an important sector of forestry industries, which burn bark to generate energy for the whole factory and leads to the accumulation of huge amounts of ash that in most cases is stored at a high cost without any use. Granite and schist are the most common parent materials of Galician soils that are very acidic and low in P and high in aluminium as part of the cation exchange capacity (CEC), before being improved. The need for lime, phosphorous and potash to convert shrub-lands into pastures is well described (Piñeiro *et al*., 1977; Mombiela and Mateo, 1984). In order to develop a use for the wood ash as a resource for improving acid and nutrient deficient soils, a trial was sown in September 2001 to investigate its liming and fertilising effect in the renovation of grass-legume pastures in acid soils, derived from schist, that were initially sown on shrub-land reclaimed soils. The ash was compared with ground limestone, with and without NPK added as fertiliser at establishment.

Materials and methods

The trial was located at Marco da Curra (Monfero, A Coruña, NW Spain) on a plot that was reclaimed from shrub-land and converted into grass-clover pastures in 1978. The sward was very deteriorated and was sprayed with glyphosate (1.8 kg ha^{-1}) in July 2001 and disc-harrowed in August and September in order to renovate it. The initial soil analysis was: pH (H_2O) 5.1; P (Olsen) 28 mg kg^{-1}, K (NH_4NO_3) 79 mg kg^{-1} and exchangeable Al CEC^{-1} 0.52. On the 29th October 2001 ash, ground limestone and NPK were manually spread according with the following eight different treatments: 1) Control (no lime nor fertilisers), 2) Fertilisers (F) without lime , 3) Limestone3 (3 t ha^{-1} of ground limestone), 4) Limestone3+F, 5) Ash6 (6 t ha^{-1} ash), 6) Ash6+F, 7) Ash12 (12 t ha^{-1} ash) and 8) Ash12+F. F(kg ha^{-1}) = 40N-120P_2O_5-120K_2O. The ash used had a pH (H_2O) of 11.5, a total P-K-Ca-Mg content (g kg^{-1} DM) of 4.16-29.2-120.75-34.4 and a DM content of 979.7 g kg^{-1}. The different materials were slightly buried after spreading using a small rotovator and the plots were manually sown afterwards with a mixture of perennial ryegrass (*Lolium perenne* L.), hybrid ryegrass *(Lolium x boucheanum* Kunth) and white clover (*Trifolium repens* L.). The plots were manually raked after seeding and rolled afterwards to bury the seed. Plots of 31.5 m^2 (7 m × 4.5 m) were used, in a randomised complete block design with four replications. The grass was harvested 3 times in 2002 (24/06, 01/08, 04/12) and in 2003 (01/06, 19/08, 20/11). A sample of about 2 kg was taken in each plot, homogenized in the laboratory and sub-sampled in two parts, one of 300 g to determine dry matter content (oven dried at 80 ºC for 17 hours), the other of approximately 150 g to be manually dissected into sown and native grasses, white clover and native legumes, and other species to determine botanical composition on dry weight basis. A 10 cm deep soil sample was taken on 01/08/2002 for analysis. Exchangeable Al and pH (H_2O) were determined. No extra fertiliser were used from sowing until the end of 2003.

Results and discussion

The effect of 3 t ha^{-1} of ground limestone on pH was intermediate between 6 and 12 t ha^{-1} of ash treatments (Table 1).The effect on Al^{3+} CEC^{-1} content was similar to the 12 ha^{-1} of ash treatment, showing a clear liming effect on the soil parameters, as demonstrated in previous trials with wood ash of different forestry industries of the region (Solla-Gullón *et al.*, 2001; Lastra *et al.*, 2002). The rate of 3 t ha^{-1} of ground limestone was chosen because it is commonly recommended to establish pastures in soils of similar chemical features following previous work done by Piñeiro *et al*. (1977) and Mombiela and Mateo (1984). The current trial shows that to reduce the Al content in CEC, near 12 t ha^{-1} of ash should be used to have a similar effect than 3 t ha^{-1} of ground limestone.

Table 1. Soil pH and Al^{3+} content (Al CEC^{-1}) in samples collected in 01/08/03.

Treatment	pH		Al CEC^{-1}	
Control	5.07	a	0.542	a
Fertilisers (F)	5.05	a	0.532	a
Limestone3	5.71	cd	0.135	c
Limestone3 + F	5.68	c	0.164	c
Ash6	5.51	b	0.284	b
Ash6 + F	5.50	b	0.258	b
Ash12	5.92	e	0.130	c
Ash12 + F	5.81	de	0.129	c

CEC = Al+Ca+Mg+Na+K [cmol(+) L^{-1}].
Figures followed by the same letter, within each column, are not significantly different (P = 0.05).

The different treatments affected yield and botanical composition (Table 2) as expected in this type of soils, which are very acid and deficient in K content. The grasses component was mainly perennial and hybrid ryegrass in 1st and 2nd cuts of the 1st year but native *Holcus lanatus* L. was progressively developing and became dominant in the 2nd year except in the plots limestone3+F, ash6+F, ash12 and ash12+F. The absence of N fertiliser through the growing season allowed the growth of white clover, the main legume. Native birdsfoot trefoil (*Lotus cornitulatus* L.) started to develop in the plots without lime or ash and became the dominant legume in these plots in the 2nd year. Total yield was lowest on the control and highest on the plot with 12 t ha^{-1} of ash and fertilised. There were no significant differences between limestone3+F and ash6, and between ash6+F and ash12. A similar trend is observed in the grass and legumes yield. The contribution of the clover to yield was low in plots: 1) control, 2) fertilised without lime and 3) limed but not fertilised. This demonstrates that it was necessary to add P and K to get the clover correctly established. Although given the initial soil P and K content the beneficial effect of the fertiliser on clover was probably mainly due to K, which allowed clover to overcome the competition from grass as the soils were slightly deficient (During, 1972). The fact that clover yield in the ash plots without fertiliser was higher than in the plot limed but not fertilised shows that the ash has an effect as fertiliser.

Table 2. First and second year average yields (t ha^{-1} DM) for grasses (G), white clover (WC), birdsfoot trefoil (BT) other species (OS) and total (T), and relationship between white clover and total yield (WC/T).

Treatment	Grasses		White clover		Birdsfoot trefoil		Other species		Total		WC / T
Control	2.7	a	0.5	a	0.5	a	0.1	a	3.8	a	0.13
Fertilisers (F)	3.1	a	0.9	b	0.8	b	0.1	a	4.9	b	0.18
Limestone3	3.9	b	0.8	ab	0.0	c	0.1	a	4.8	b	0.17
Limestone3 + F	4.7	bc	1.4	de	0.0	c	0.1	a	6.2	c	0.23
Ash6	5.0	cd	1.2	cd	0.0	c	0.2	ab	6.4	c	0.19
Ash6 + F	5.7	de	1.3	cde	0.0	c	0.3	b	7.3	d	0.18
Ash12	6.0	e	1.5	de	0.0	c	0.1	a	7.6	de	0.20
Ash12 + F	6.4	e	1.7	e	0.0	c	0.2	ab	8.3	e	0.20

Figures followed by the same letter, within each column, are not significantly different (P = 0.05).

Conclusions

These preliminary results demonstrate that wood ash is a good resource as liming and fertilising material to establish grass-legume pastures in acid soils.

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Suitability of vermicompost for improvement of low quality woodland pastures used by Shetland ponies

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Abstract

On woodland pastures with low-quality grasses used by Shetland ponies, some preliminary studies were carried out to assess the influence of vermicompost fertilisation (0 t ha^{-1} or 4 t ha^{-1}, produced from sewage deposits) on the botanical composition and nutritional value of the sward, after oversowing of grasses (*Festuca rubra, Poa pratensis, Lolium perenne* or *Phleum pratense)* and white clover (20 % or 0 %). Vermicompost had a positive influence on the floristic composition and on the content of crude protein, phosphorus, potassium and magnesium, but it decreased the calcium content of the sward.

Keywords: sward, floristic composition, crude protein, vermicompost, white clover, macroelements

Introduction

Pastures located within forests with insufficient water supply are usually characterised by a poor sward. Due to the direct influence of the forest, the growing conditions for the pastures are rather stable and hard to change. According to Baran *et al*. (1998) and to Jakubowski and Czyż (1999), the fertilising value of vermicompost may improve the fertility of a habitat. The aim of this study was to assess the influence of vermicompost on the floristic composition and fodder quality of the sward in a mid-forest pasture.

Materials and methods

The studied site is a pasture of the Imno Shetland Pony Stud, the only one in Poland, in Western Pomerania near Nowogard. The area is 20 km away from the Baltic Sea, in a forested area. The soil is sandy with good drainage and a pH of 3.8-5.0. Three factors have been studied: 1) oversowing of grass (*Festuca rubra*: 26 kg ha^{-1}, *Poa pratensis*: 16 kg ha^{-1}, *Lolium perenne*: 22 kg ha^{-1} or *Phleum pratense*: 12 kg ha^{-1}), 2) oversowing of *Trifolium repens* (0 % or 20 % of the grass seeding rate), 3) vermicompost fertilisation (0 or 4 t ha^{-1}). Four replications were used. The plot size was 2.0 x 3.0 m. The vermicompost contained 390.0 g N, 28.0 g P, 30.0 g K, 17.7 g Ca and 9.0 g Mg kg^{-1} DM and had a pH of 6.4. 60 % of the total dose was applied in spring, the rest after the first cut. Mineral fertilisation was constant at an annual rate of 120 kg N ha^{-1}, 70 kg P ha^{-1} and 100 kg K ha^{-1}. Grasses and white clover were sown in spring on the prepared soil. The botanical composition of the sward was determined by the botanical-weight analysis method. Nitrogen content was assessed by the Kjeldahl-method, sugar content by the Loof-Schoorl-method, phosphorus (P) by colorimetry, potassium (K), calcium (Ca) and magnesium (Mg) by using atomic absorption spectrophotometry (ASA).

Results and discussion

The main spontaneous grasses in the studied pasture communities were *Agrostis capillaris, Festuca ovina, Deschampsia flexuosa, Holcus mollis* and *Anthoxanthum odoratum* (Table 1). The primary sward has been described in a previous paper (Trzaskoś *et al.,* 2000). The sowing of valuable grasses and of white clover contributed to improving the botanical composition of the sward (Table 1). The new sward was characterised by a simplified but stable floristic composition with the dominance of grasses. The share of white clover differed and was most stable in the community with *Lolium perenne*. This corresponds to the findings of Frame (1992) and Warda (1998). Application of vermicompost and sowing of *Trifolium repens* limited the growth of grasses of poor quality.

Table 1. Changes in the floristic composition (%) of the sward oversown with *Lolium perenne* or with *Poa pratensis.*

Primary sward		
Groups	(%)	Species
Grass species	43.7	*Agrostis capillaris, Anthoxanthum odoratum, Bromus mollis, Elymus repens, Festuca rubra, Festuca ovina, Deschampsia flexuosa, Holcus mollis, Poa pratensis*
Leguminous species	2.7	*Coronilla varia, Lotus corniculatus, Vicia cracca*
Forb species (herbs and weeds)	53.6	*Achillea millefolium, Crepis biennis, Cerastium vulgatum, Gnaphalium silvaticum, Helichrysum arenarium, Hypericum perforatum, Jasione montana, Hieracium pilosella, Rumex acetosella, Myosotis arvensis, Reseda lutea, Senecio jacobaea,*

New sward (after oversown)								
Treatment	*Trifolium repens* (0 %)				*Trifolium repens* (20 %)			
	vermicompost ($0\ t\ ha^{-1}$)		vermicompost ($4\ t\ ha^{-1}$)		vermicompost ($0\ t\ ha^{-1}$)		vermicompost ($4\ t\ ha^{-1}$)	
Year	1999	2000	1999	2000	1999	2000	1999	2000
community with *Lolium perenne*								
Lolium perenne	65.1	69.1	77.9	87.6	60.3	75.6	73.0	90.8
Other grasses	13.7	13.7	3.1	7.0	14.7	8.0	6.7	1.0
Trifolium repens	-	-	-	-	9.2	7.2	10.1	8.0
Herbs and weeds	21.2	17.2	19.0	5.4	15.8	9.4	10.2	0.2
community with *Poa pratensis*								
Poa pratensis	57.4	65.3	74.6	72.8	54.7	64.9	63.2	66.6
Other grasses	21.0	12.9	5.9	12.9	16.1	9.1	4.0	9.7
Trifolium repens	-	-	-	-	10.3	4.9	11.9	6.0
Herbs and weeds	21.6	21.8	19.5	14..3	18.9	21.1	19.9	18.3

The control sward (0 % *T. repens* and $0\ t\ ha^{-1}$ vermicompost) had the lowest protein and macroelements contents (Table 2). Both the application of vermicompost and the oversowing of white clover improved the quality of the fodder. According to Kalembasa (1998) the nitrogen contained in vermicompost can be easily released and taken up by plants. Independently from the vermicompost fertilisation, the sward with white clover was richer in protein, according to the observations of Warda and Ćwintal (2000). The comparison of the four types of sward shows that the *Lolium perenne* sward (0 % *T. repens*), which received vermicompost ($4\ t\ ha^{-1}$), had the highest protein content ($274\ g\ kg^{-1}$ DM). A similar protein content ($272\ g\ kg^{-1}$ DM) was obtained with a *Poa pratensis* sward oversown with *Trifolium repens.* Warda (1998) has found that *Lolium perenne* which grows together with *Trifolium repens* accumulates more protein. Vermicompost had no distinct influence on the sugar content in the sward.

The phosphorus, potassium, calcium and magnesium contents of the sward which had not been fertilised with vermicompost were too low in terms of fodder quality (Falkowski *et al.*, 2000). The sward with vermicompost application contained optimal amounts of phosphorus and magnesium, but excessive levels of potassium. The content of calcium was low in all treatments. According to Jakubowski and Czyż (1999) and Kalembasa (1998) fertilisation with vermicompost from sewage deposits contributed to a low calcium content in the plants.

Table 2. Contents of crude protein, sugar and macroelements (g kg^{-1} DM) in the different sward treatments (mean for years 1999 and 2000).

Treatment	*Trifolium repens* (0 %)		*Trifolium repens* (20 %)	
	vermicompost (0 t ha^{-1})	vermicompost (4 t ha^{-1})	vermicompost (0 t ha^{-1})	vermicompost (4 t ha^{-1})
Crude protein (CP)				
Festuca rubra	148.5	231.7	194.1	259.5
Poa pratensis	177.5	202.1	194.3	271.8
Lolium perenne	104.1	273.9	207.2	255.2
Phleum pratense	183.8	259.5	204.5	246.1
Sugar				
Festuca rubra	121.1	144.2	113.0	133.7
Poa pratensis	130.4	143.3	103.6	120.0
Lolium perenne	113.5	122.2	154.5	135.9
Phleum pratense	148.5	101.5	134.9	127.3
Phosphorus (P), Potassium (K)				
Festuca rubra	2.1 (P), 21.5 (K)	3.1 (P), 30.5 (K)	2.2 (P), 25.5 (K)	3.4 (P), 35.5 (K)
Poa pratensis	2.0 (P), 13.0 (K)	3.5 (P), 35.0 (K)	2.2 (P), 18.5 (K)	3.6 (P), 37.0 (K)
Lolium perenne	2.1 (P), 11.0 (K)	3.4 (P), 37.5 (K)	2.4 (P), 13.5 (K)	3.7 (P), 32.5 (K)
Phleum pratense	2.2 (P), 16.5 (K)	3.6 (P), 34.5 (K)	2.4 (P), 17.0 (K)	3.9 (P), 36.5 (K)
Calcium (Ca), Magnesium (Mg)				
Festuca rubra	2.3 (Ca), 1.4 (Mg)	2.5 (Ca), 2.3 (Mg)	2.4 (Ca), 1.5 (Mg)	3.7 (Ca), 2.7 (Mg)
Poa pratensis	2.8 (Ca), 1.6 (Mg)	2.5 (Ca), 2.2 (Mg)	2.5 (Ca), 1.8 (Mg)	3.3 (Ca), 2.5 (Mg)
Lolium perenne	3.0 (Ca), 1.8 (Mg)	4.6 (Ca), 2.5 (Mg)	2.7 (Ca), 2.2 (Mg)	3.4 (Ca), 2.4 (Mg)
Phleum pratense	2.9 (Ca), 1.9 (Mg)	3.2 (Ca), 1.1 (Mg)	3.0 (Ca), 1.9 (Mg)	3.6 (Ca), 2.6 (Mg)

Conclusions

Vermicompost applied to forest pastures on sandy soils can promote the development of oversown grasses like *Festuca rubra, Poa pratensis, Lolium perenne* and *Phleum pratense*.
The use of vermicompost as fertiliser caused an increase in the protein, phosphorus, magnesium and potassium contents, but a decrease in the calcium content of the sward.

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Animal performance and nitrogen surplus in suckler cows pastures fertilised with mineral nitrogen fertiliser, pig slurry or cattle compost

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Abstract

Cattle compost (C), pig slurry (S), and mineral nitrogen fertiliser (M) were compared as fertiliser in a pasture grazed by Belgian Blue cows and their calves. Nitrogen inputs by fertilisation were different (166, 161 and 80 kg N ha^{-1} y^{-1} in C, S and M pastures, respectively). Animal performance and sward composition were not changed by the type of fertilisation. Nitrogen surplus was higher in C and S than with M (242 and 228 vs. 150 kg ha^{-1}). The apparent nitrogen efficiency (N capture / N input) was lower with C and S than in M (13, 14 % vs. 21 % respectively). There were no differences in plasma urea concentration of cows (195, 200 and 188 mg N l^{-1}; $P > 0.05$), indicating no increased excretions by animals.

Keywords: fertilisation, suckler cows, nitrogen, slurry, compost.

Introduction

A code of good practice has been established by each European member state according to the nitrate directive. In Belgium, the nitrogen inputs in pastures from slurry or compost are limited to 210 kg N ha^{-1}. This trial aims to study animal performance and nitrogen surplus in pastures fertilised with mineral nitrogen fertiliser, pig slurry or cattle compost, the pastures being grazed by Belgian Blue cows and their calves. Botanical composition and nitrogen nutrition index in grass were also measured.

Materials and methods

During two consecutive years, two pastures were divided in three paddocks. One paddock of each pasture was fertilised with cattle compost (C), the second one with pig slurry (S) and the third one with mineral nitrogen fertiliser (M). S and M were applied on the same date in June, July and August when the weather conditions allowed spreading; rainy weather being needed for S application. C was applied in May, June and July. Similar fertilisation practices were already applied during the two previous years before the trial. The applied amounts of nitrogen conformed to common practice in the south part of Belgium and were calculated to be equivalent on the basis of nitrogen efficiency for plant growth. According to Simon *et al*. (1998), Limbourg (2000) and Bodet *et al*. (2001), the mean nitrogen efficiency for plant growth expressed as a proportion of total nitrogen was estimated at 50 % in slurry and at 30 % in compost during the first year and at 20 % the following year. Each year, 27 suckler cows and their calves were divided into 3 groups of 9 cows, each group being allocated to a different fertiliser treatment and grazed alternately on the two paddocks with the same treatments. The grazing period started in the beginning of May and ended in October. The calves were weaned and removed from the pasture in August. Two cows were also removed in August. The stocking rate was similar in each plot with 3.38 cows + their calves ha^{-1} at the beginning and 2.63 cows ha^{-1} from August to the end of the trial. Grass silage was made during the spring of the first year on the ungrazed parts of the pastures; it was weighed and analysed. The herbage dry matter yield was measured in each plot before the entry of the animals. Grass was analysed for chemical composition. The Ca content in grass was measured by atomic absorption and the P content by colorimetry using vanadomolybdate. Crude protein content was determined according to the official procedure (AOAC, 1975). Botanical composition was estimated each year according to Andries (1950). Nitrogen index in the sward was calculated according to Thélier-Huché *et al.* (1999). The animals were weighed at regular intervals and a blood sample was taken from the cows in order to measure plasma urea by the diacetylmonoxin method. Nitrogen inputs were from legume fixation, atmospheric nitrogen (35 kg ha^{-1}) and fertilisation. The nitrogen fixed by legumes was calculated according to Farruggia *et al.* (1997). Nitrogen in live weight gains and in grass silage represented nitrogen capture. The apparent nitrogen efficiency was calculated as N capture / N input. The results were statistically analysed in a two-way analysis of variance. The parameters analysed were sward heights, crude protein, calcium and phosphorus in sward, animal live weight gains, nitrogen nutrition index, and plasma urea concentration. The interaction effects between years and fertilisers were not significant so the data presented in the tables were pooled averages over the two years.

Results and discussion

Nitrogen inputs by fertilisation were different at 166, 161 and 80 kg N ha^{-1} y^{-1} in C, S and M plots respectively. These levels of fertilisation were similar to those applied in the South part of Wallonia where the cultivated lands are mainly permanent pastures. The efficient nitrogen inputs from the fertilisation were 54 kg in C and 76 kg in S as compared to the 80 kg in M. With compost, there were also inputs of residual nitrogen from applications during the previous years (20 % of the previous applications). Mean grazing duration in a paddock was 21 days. Grass yield and sward heights tended to be higher in M suggesting more available grass, but the animal performance was not significantly different (Table 1; $P > 0.05$). Crude protein, calcium and phosphorus contents in swards did not differ significantly between treatments. The proportions of gramineae, legumes and other plants were similar. These values did not change during the trial. Nitrogen nutrition index followed the same patterns in the three plots (Figure 1). Values between 80 to 100 % were considered as optimal for grass growth (Thélier-Huché *et al.*, 1999). Nutrition index was low at about 67 % on the beginning of May in the three plots; it was about 68 % in S and M at the end of May. Such values can be considered as sub-optimal, suggesting that nitrogen input was too low at the beginning of the grazing season. Fertilisation should therefore be applied sooner in April and May to optimise grass growth.

Table 1. Sward characteristics and animal live weight gains.

	Compost	Slurry	Mineral nitrogen	Significance
Yield (kg DM)	10 054	9 745	11 799	
Sward height at entry (cm)	14.6	14.6	16.7	NS
Sward height at exit (cm)	4.2	4.1	4.9	NS
Crude protein (g kg^{-1} DM)	21.6	20.5	20.7	NS
Calcium (g kg^{-1} DM)	6.4	6.3	6.3	NS
Phosphorus (g kg^{-1} DM)	3.3	3.6	3.2	NS
Botanical composition (%)				
-Gramineae	75.0	74.5	78.2	
-Legumes	22.7	24.1	20.0	
-Others	2.3	1.5	1.8	
Live weight gains (kg d^{-1})				
-cows	0.34	0.46	0.50	NS
-calves	1.05	1.11	1.05	NS

Plasma urea concentration did not differ significantly, indicating that nitrogen excretion by the cows was similar in the three groups (Ciszuk and Gebrekziabher, 1994) (Table 2).

Nitrogen surplus per ha was lower in M (150 vs. 242 and 228 kg N ha^{-1}). Nitrogen surplus per ha calculated on the basis of efficient nitrogen for plant growth from fertiliser was unchanged in M at 150 kg, in C at 131 kg and in S at 144 kg ha^{-1}. The apparent nitrogen efficiency (N capture / N input) was higher in M.

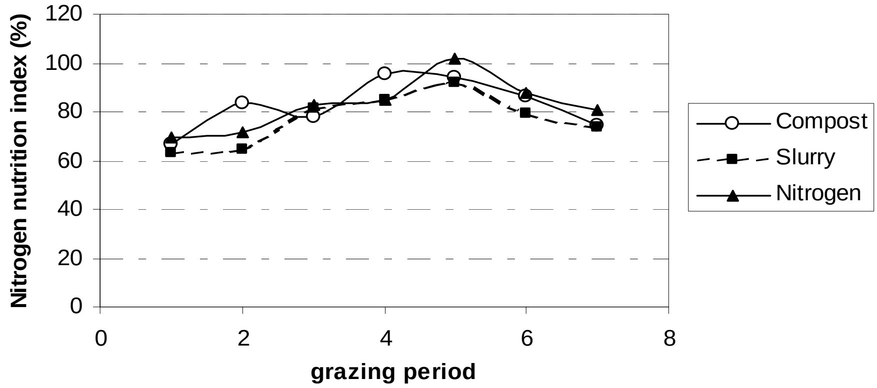

Figure 1. Evolution of nitrogen nutrition index in grass fertilised with cattle compost, pig slurry and mineral nitrogen fertiliser.

Table 2. Plasma urea concentration and nitrogen surplus.

	Compost	Slurry	Mineral nitrogen
Plasma urea (mg N l^{-1})	195	200	188
N inputs (kg N ha^{-1})			
Fertiliser	165	161	80
Fixation by legumes	78	71	73
Total	279	266	188
N capture (kg N ha^{-1})	37	38	38
N surplus (kg N ha^{-1})	242	228	150
Apparent N efficiency (%)	13	14	21

Conclusions

The use of pig slurry and cattle compost as compared with mineral nitrogen fertiliser allowed identical animal performance, but increased nitrogen surplus and reduced apparent nitrogen efficiency. Nitrogen excretion by animals was however not increased by use of slurry or compost.

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Nitrogen mineralisation kinetics following destruction of grazed swards: effects of preceding grassland management

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Abstract

The purpose of this study was to quantify net nitrogen mineralisation rates under field conditions following the destruction of grasslands, which may vary according to previous management (nitrogen fertilisation, grazing or mowing, plant species). Investigations were carried out on three former experiments located in the West of France. These experiments had originally been set up to study the effects of nitrogen fertilisation of grazed swards, or the impact of mowing once or twice a year, on grass production and nitrate leaching. After destroying the grassland chemically in February, the soil was kept bare by using herbicides for two years and the mineral nitrogen was measured monthly. The LIXIM model (Mary *et al*., 1999) was used in the calculation of nitrogen mineralisation rates. These calculations show that the previous fertilisation or pasture type (pure grass or grass white clover mixture) have little effect compared to the rates occurring after grassland destruction. Mowing once or twice was not systematically effective: mineralisation decreased after destruction of pure swards; it was ineffective after destruction of the grass clover mixture.

Keywords: nitrogen fertilisation, grassland management, destruction, N mineralisation

Introduction

The effects of grassland destruction are very important in the context of sustainable agriculture, because of the large amount of nitrogen mineralised. Many studies have been carried out on the mineralisation of organic matter previously accumulated under grassland, more specifically regarding evolution of organic carbon contents in soils. The induced effects on nitrogen mineralisation have also been studied in numerous reports (e.g., Cameron *et al*., 1984; Conijn *et al*., 2002), but few of them have established the kinetics of the process. The knowledge of the kinetics is required to synchronise N mineralisation with the N absorption of following crops in order to minimize nitrate leaching.

Materials and methods

Three experiments were carried out on two sites in the west of France to study the effect on N leaching as a consequence of nitrogen fertilisation, grassland type (pure perennial ryegrass (*Lolium perenne* L.) or grass / clover (*Trifolium repens* L.) mixture) and mowing intensity. The soils are free draining sandy silt loams. Table 1 gives details on previous managements before destruction. Grassland destruction was performed chemically with glyphosate in February. The plots were then kept bare fallow during 2 years (addition of herbicides 4 times per year) without any soil disturbance.
To study the effects of grassland destruction on nitrogen mineralisation, 8 soil cores were taken every 3 or 4 weeks to a depth of 80 or 90 cm. Three layers (0-25, 25-50 and 50-80 cm) were distinguished and analysed for NO_3, NH_4 and water content in triplicate.

Table 1. Experimental sites and previous management of the sward.

Site	Soil C g kg^{-1}	Previous experimental treatments		
		Sward type	Grazing (G) or cutting (C)	N fertilisation kg N ha^{-1} y^{-1}
Kerlavic MP1	37	T1: perennial ryegrass	grazed 7-8 times	0
		T4: perennial ryegrass	per year	400
		T5: perennial ryegrass + white clover		0
Kerlavic MP2	30	T1: perennial ryegrass	GGGGGGG	250
		T2: perennial ryegrass	G CGGGG	250
		T3: perennial ryegrass	C CGG	250
		T4: perennial ryegrass + white clover	GGGGGGG	50
		T5: perennial ryegrass + white clover	G CGGGG	50
La Jaillière MP1	15	T1: perennial ryegrass + white clover		0
		T2: perennial ryegrass	Grazed 4-5	100
		T3: perennial ryegrass	times per year	300
		T4: perennial ryegrass		400

We then used these results as input data in the LIXIM model (Mary *et al.*, 1999) in order to calculate the rates of N mineralisation and leaching, assuming that these are the dominant processes affecting N in bare soil. LIXIM is a layered, functional model, with a daily time step. Input data also include climatic conditions and simple soil characteristics. The variations in N mineralisation with temperature and moisture are accounted for, providing calculation of the 'normalized time'. An optimization routine is used to estimate the actual evaporation and the N mineralisation rates that provide the best fit between observed and simulated values of water and nitrate contents in all measured soil layers.

Results and discussion

LIXIM model was able to reproduce accurately the water content and the mineral N in soil during the two-year experiments (results not shown). The mean RMSE between observed and simulated values were 11, 6 and 15 kg N ha^{-1} for Kerlavic MP1, Kerlavic MP2 and La Jaillière MP1, respectively. They were comparable to standard errors on measurements. The N mineralisation kinetics calculated showed remarkable consistency between the different sites studied. The kinetics were composed of two successive phases: a rapid mineralisation during phase 1 over a period of 160-230 'normalized' days; a slow mineralisation in phase 2, the mineralisation rate (*Vp2*) being 2 to 7 times smaller than in phase 1 (*Vp1*). Comparing the mineralisation rates *Vp1* and *Vp2* with those calculated in other fields without grassland during the last 20 years, suggested that phase 2 could correspond to a return to the 'basal' mineralisation of the soil organic matter. The effect of previous N fertilisation on N mineralisation after grassland destruction was small compared to the amounts mineralised over two years. In Kerlavic MP1 experiment, net mineralisation reached 520 and 550 kg N ha^{-1} in grasslands having received 0 and 400 kg N ha^{-1} y^{-1} respectively, and 670 kg N ha^{-1} after the unfertilised grass-clover mixture (Figure 1a). Extreme N fertilisations (0 or 400 kg N ha^{-1} y^{-1}) did not bring about significant differences in mineralisation after destruction. In La Jaillière experiment, the mineralisation rates ranked in the same order as the fertilisation levels previously applied to grasslands: 445 kg N ha^{-1} after the unfertilised grass-clover mixture, 485, 495 and 515 kg N ha^{-1} after pure grass having received 100, 300 or 400 kg N ha^{-1} y^{-1}, respectively (Figure 1b). Those results were consistent with other measurements (Vertès *et al.* in Conijn *et al.*, 2002). The effect of the number of mowing was analysed in Kerlavic MP2 (Figure 1c). Cumulative mineralisation over 2 years following destruction of purely grazed pastures (7-8 times per year between 1995 to 1998) was 405 and 445 kg N ha^{-1} for pure grass (T1) and mixture (T4), respectively. The N mineralisation following destruction of grazed and mowed pastures of ryegrass was smaller: 350 kg N ha^{-1}

when pasture had been mowed once a year (T2) and 315 kg N ha^{-1} when mowed twice (T3). This effect was not noticed after destruction of the mixed sward: the mineralisation kinetics was identical when the grass-clover had been either grazed (T4) or mowed once a year (T5). Mineralisation rates following destruction of a grass-clover sward were greater (at Kerlavic) or equal (at La Jaillière) than after destruction of ryegrass. Part of this effect is due to the fact that plant residues are richer in N in the mixed sward. Such a variability in results has also been reported in the literature (Hogh-Jensen *et al*., 1997; Davies *et al*., 2001).

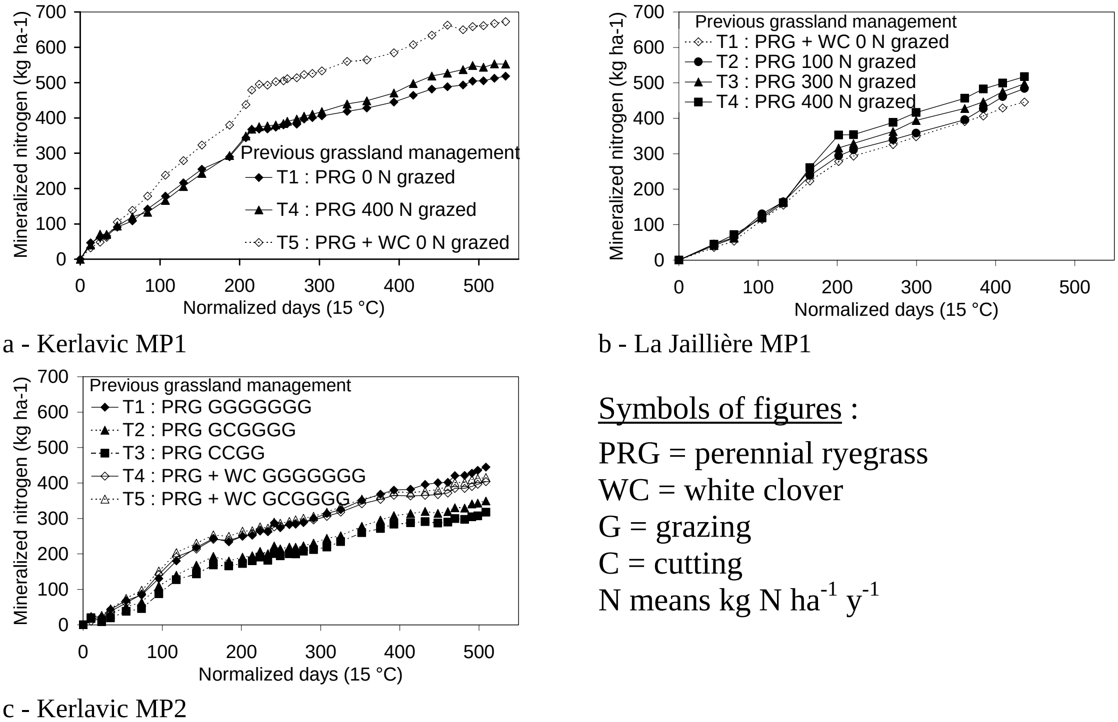

Figure 1. Nitrogen mineralisation kinetics after grassland destruction (versus normalized time).

Conclusions

The model and the results of experiments are in agreement, and the consistency in the mineralisation rates obtained enables us to reconsider the effect of grassland destruction on N mineralisation kinetics. Net mineralisation rate decreased by a 2-7 fold factor after a period of 160-230 ‘normalized’ days. The N mineralisation due to grassland destruction is significantly higher during the following two years, and mainly during the first year, with a higher effect than was previously thought. The previous grassland management has little effect on the N mineralisation: mowing frequency and grass species are the main factors to account for predicting N mineralisation.

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Simulation of nitrogen dynamics in forage maize using the HERMES model

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Abstract

The water and nitrogen (N) balance model HERMES was adapted to allow for the simulation of silage maize production, and model performance was evaluated using data from a five-year N fertilisation experiment. The model calculations showed a satisfactory agreement for biomass and the overall nitrogen supply expressed as the sum of N_{min} in soil and nitrogen in crops. The depletion of soil nitrogen by the crop was overestimated, which will require further model improvements regarding nutrient extraction by the root system.

Keywords: modelling, forage maize, N uptake, soil mineral nitrogen, dry matter yield.

Introduction

Increasing demand for environmental soundness poses a serious challenge to forage production. Silage maize in fodder crop rotations is often managed in a way leading to high N losses by leaching. To investigate N management effects, simulation models provide a useful tool. A number of models deal with N dynamics of maize, e.g., CERES Maize (Jones and Kiniry, 1986). These, however, were developed for environmental conditions substantially different from those in Northern Germany. HERMES, a suitable model for Northern Germany was developed to simulate the nitrogen dynamics of whole crop rotations mainly for cereal production (Kersebaum, 1995). In the current project, we aimed to adapt HERMES to silage maize and to evaluate its performance in predicting yield, N uptake and soil N mineralisation.

Materials and methods

Model calibration was based on 5 years data (1997-2001) from the 'Karkendamm' experimental farm of the University of Kiel (Taube and Wachendorf, 2000). The soil type is a gleyic podzol dominated by sand. The variety 'Naxos' was planted between April 25th and May 5th with a crop density of 10-11 plants m^{-2}, using a split-plot design with four blocks. Treatments consisted of three cattle slurry fertilisation rates (average N content 2.9 kg N m^{-3}) and four mineral N fertilisation rates (Table 1). Slurry was applied in late April and incorporated immediately into the soil. Mineral N fertiliser was given in aliquot dressings at the one-leaf and six-leaf stage. P and K was supplied for all plots in order to adjust to the highest slurry application. Growth and the N content of the crop were recorded fortnightly throughout the vegetation period. Soil mineral nitrogen (N_{min}) was measured in the root zone (0-90 cm) in spring and autumn. The HERMES model was used to simulate the N dynamics in the soil-crop system. The model considered soil water dynamics, nitrogen net-mineralisation from soil organic matter and crop residues, nitrate transport, and denitrification. The crop growth module, originally based on the SUCROS model (van Keulen *et al*., 1982), comprised crop phenology, daily dry matter production, partitioning, nitrogen uptake, and considers water and nitrogen stress. Soil parameters and mineralisation potentials were generated automatically using basic soil information. Model structure was modified with respect to the crop parameterisation through external files, mainly for assimilate allocation within the crop.

Results of a 5 year simulation were then compared with field data of yield, N uptake of the crop, and mineral N in the soil.

Results and discussion

The R-square values of simulated versus observed data were 0.51 for harvested biomass and 0.56 for N content, calculated over all treatments and years (n = 60). Two examples from the different treatments of the field trial were selected to demonstrate the present stage of model performance. Figure 1 shows a comparison between simulated and observed values of biomass production, N uptake by crops and soil mineral nitrogen in the root zone for treatment 10. The simulation started from the first N_{min} observation in April 1997 and ran continuously without any correction until December 2001.

Table 1. Nitrogen treatments and simulated N-leaching (5-year average).

	Treatment no.											
	1	2	3	4	5	6	7	8	9	10	11	12
Mineral nitrogen (kg N ha^{-1})	0	0	0	50	50	50	100	100	100	150	150	150
Slurry (m^3 ha^{-1})	0	20	40	0	20	40	0	20	40	0	20	40
Simulated N-leaching (kg N ha^{-1} yr^{-1})	41	47	57	46	52	71	59	71	107	81	117	156

Growth of above ground biomass was well reflected by the model. Nitrogen uptake observations showed a high variability within the four replications. Simulation results were in most cases within the error bars and had a slight tendency to overestimate N uptake. Consequently, soil mineral nitrogen was mostly underestimated. Table 1 summarises treatment characteristics and results of the simulated N emissions from the root zone (60 cm) by leaching, showing an exponential rise with increasing N application rates.

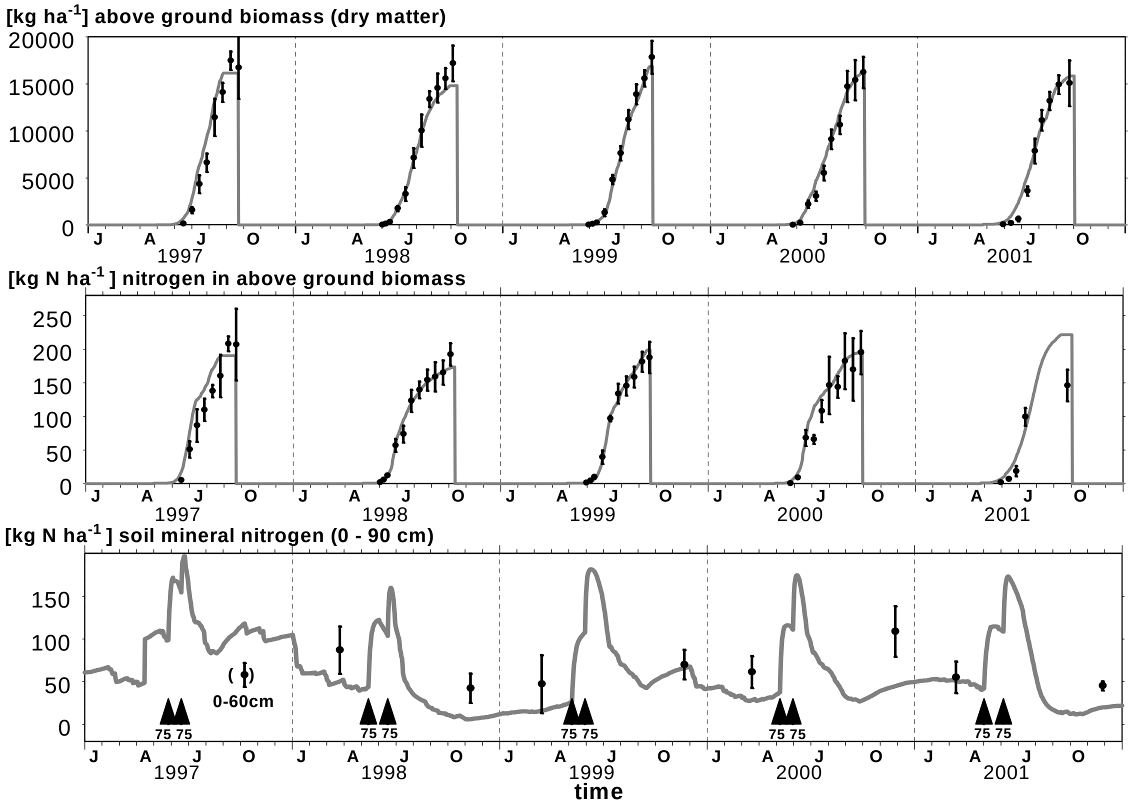

Figure 1. Simulations (lines) and measurements (dots with s.d. bars, 4 repl.) of above ground biomass, nitrogen in above ground biomass and N_{min} in 0-90 cm on continuous forage maize plot (treatment 10) with 150 kg N ha^{-1} annual mineral fertiliser application (scheduling:▲).

The results for the non fertilised treatment are presented in figure 2. The reduction of biomass production due to N deficiency was reflected satisfactorily by the model. Nitrogen uptake was again overestimated by the model, especially during the first year, while soil mineral nitrogen contents were underestimated.

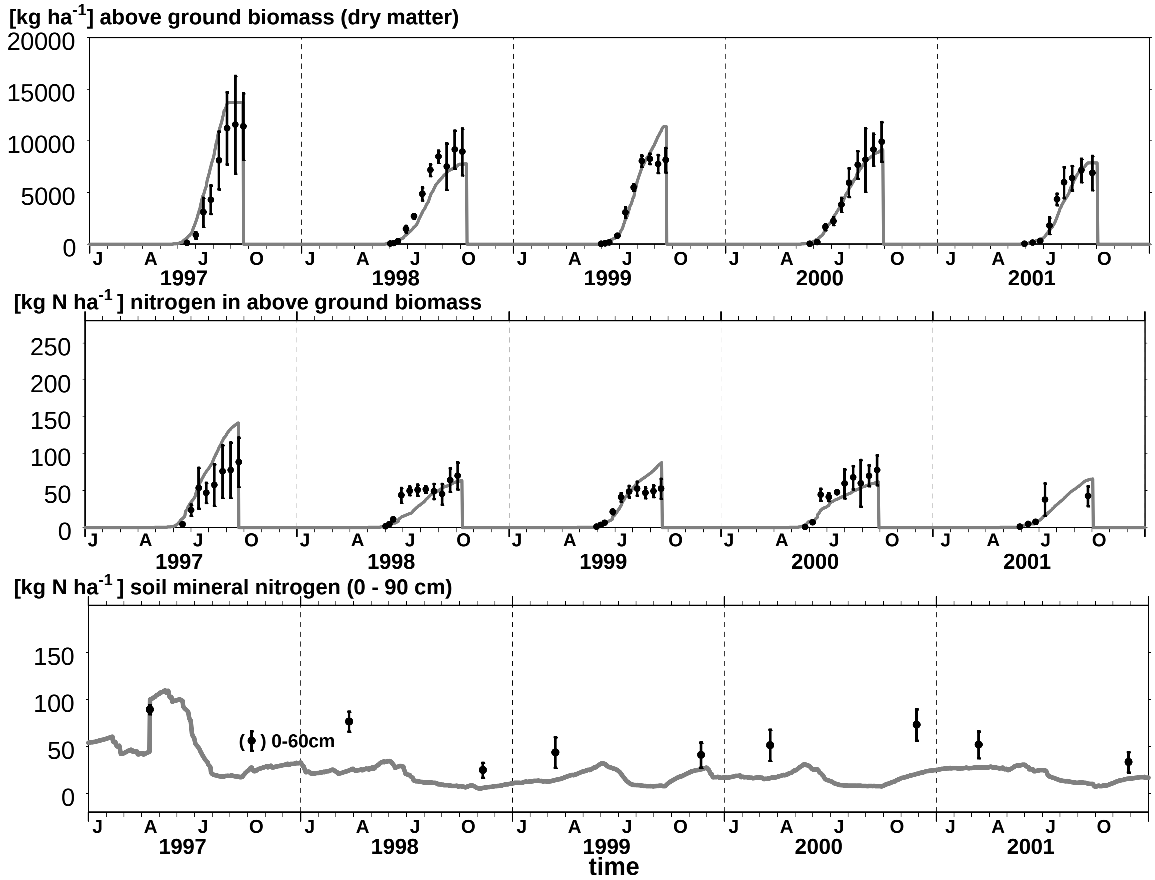

Figure 2. Simulations (lines) and measurements (dots with s.d. bars, 4 replicates) of above ground biomass, nitrogen in above ground biomass and soil mineral nitrogen in 0-90 cm on continuous forage maize plot without any fertiliser application (treatment no. 1: Zero plot).

Conclusions

Although the overall N supply, expressed as the sum of N_{min} in soil and N in crops, was simulated with sufficient accuracy sufficiently accurately, the depletion of soil nitrogen by the crops was overestimated. Further model improvement will therefore address the root distribution and / or the maximum nitrogen flux per cm of root. Another difficulty with respect to model calibration was the high temporal and spatial variability of the ground water table within the field. This had a strong impact on both crop growth and nitrogen movement.

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Below-ground interactions of maize sown into a living Italian ryegrass mulch

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Abstract

Sowing maize into a living cover crop presents environmental benefits in relation to its conventional cropping. The study of maize sown in a bare soil (BS) or together with a living italian ryegrass mulch (LM) in lysimeters with minirhizotrons during three years, showed the following results: (a) LM strongly modified the maize crop by decreasing growth and duration of the leaf area, and thus biomass and grain yield at harvest, (b) BS maize was hardly able to build up root densities similar to those observed in LM at the time of maize sowing, (c) LM reduced the soil water content between 0.3 and 0.9 m soil depth and deep percolation over the entire maize crop season and (d) losses of N in LM did not reach 1 % of the values observed in BS. Water and N dynamics in LM explain the decrease in growth and yield of maize and are in good agreement with its dense root system. The development of living mulch systems depends on the improvement of water and nitrogen uptake by the roots of the main crop without affecting the capacity of the cover crop to prevent N losses by leaching.

Keywords: living mulch, *Lolium multiflorum* Lamm., nitrogen leaching, shoot and root growth, soil water content, *Zea mays* L.

Introduction

An increasing demand for environmentally sound agricultural production has put various management practices and entire cropping systems into question. The cultivation of the thermophilic maize (*Zea mays* L.) crop in temperate humid climates is an example, as it is responsible for environmental problems such as erosion and contamination of surface and ground water (Lütke Entrup and Zerhusen, 1992). The negative aspects of the maize cropping can be traced to the limited duration of a soil protecting plant cover.

Agricultural production in Switzerland often integrates crop and dairy farming. Hence, sowing maize into an existing meadow can ensure soil cover. This is referred to as a living mulch (Feil and Liedgens, 2001). The practical limitation for adopting this practice is yield reduction in maize. From the results of previous studies (Feil *et al*., 1997; Garibay *et al*., 1997), where shoot competition was assumed to be minimal, we hypothesized that decreased maize yield was related to below ground interactions with the cover crop. For this reason we used the rhizolysimeter facility in Eschikon (Liedgens *et al*., 2000) to evaluate shoot and root growth, nitrogen leaching and soil water content in conventional maize cropping, i.e., sowing maize into a bare soil (BS) and the living mulch (LM) system, and sowing maize into a living italian ryegrass (*Lolium multiflorum* Lamm.) mulch in three maize crop seasons.

Materials and methods

The study was conducted in lysimeters (1.0 m^2 square surface area and 1.1 m depth, eight units each year) placed outdoors, near Zurich in Switzerland between 1994 and 1996. In LM a 0.3 m wide strip was kept free of grass around the maize row. The plots were fertilised with 110 kg N ha^{-1} each season. Minirhizotrons (54 mm inner diameter) were horizontally installed at various soil depths between 0.0 and 1.0 m, perpendicular to the orientation of the maize rows. The development of the maize shoot and the rooting patterns were observed non-destructively. Drainage pipes allowed for weekly sampling of leachate. Time-domain reflectometry probes were used for the measurement of water content at various soil depths. (Most results were similar during the three experimental years. For this reason only data from 1995 is displayed (Figure 1)).

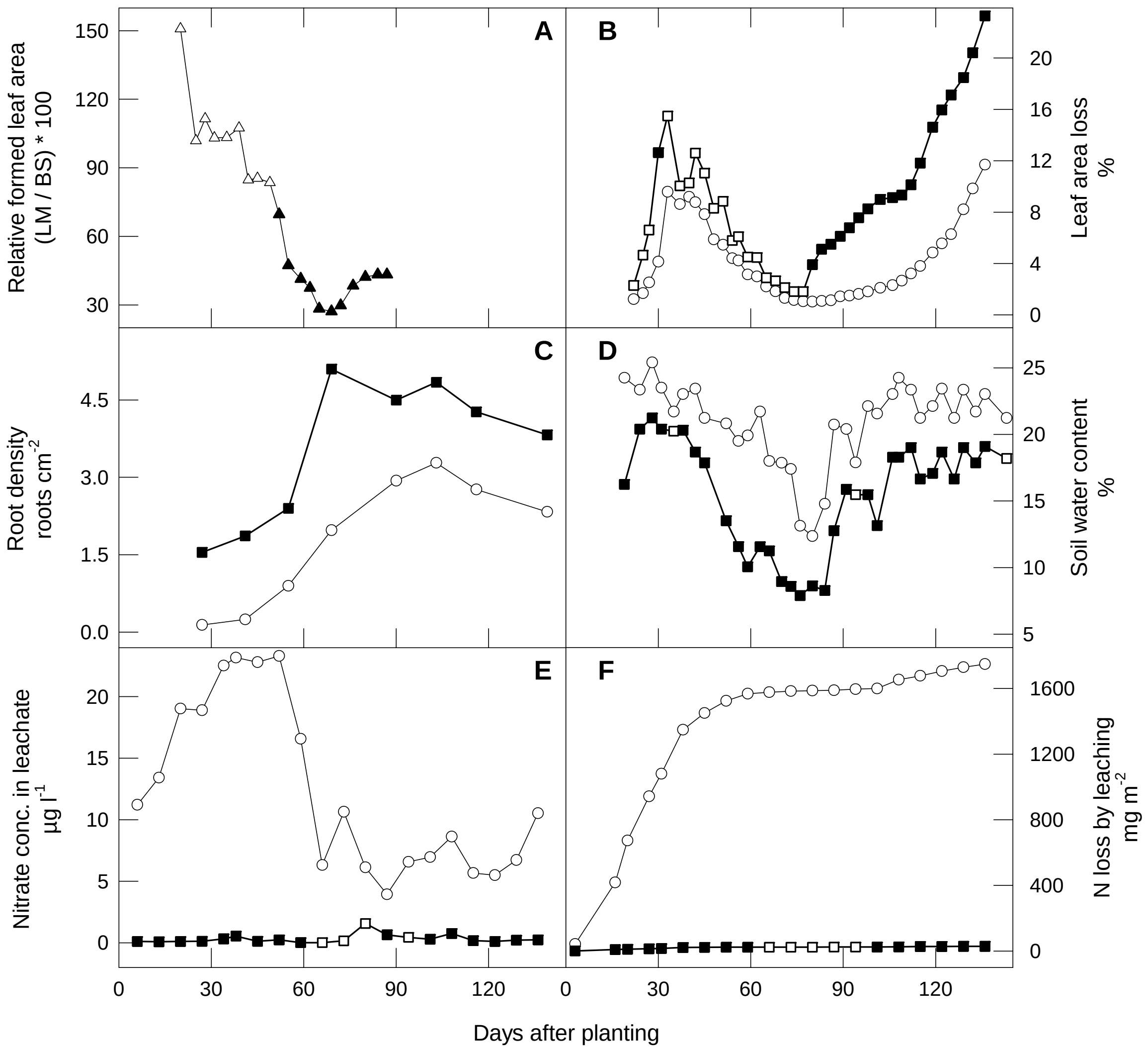

Figure 1. The influence of the BS (○) and LM (□) treatments on the formation (A) and senescence (B) of maize leaf area, on root density at 0.45 m soil depth (C), on soil water content at 0.30 m soil depth (D), on the nitrate concentration in the leachate (E) and on N loss by leaching (F), as observed during the maize crop season in 1995. Filled symbols represent sampling dates for which the measured values in the BS and the LM treatment were significantly different from each other ($P < 0.05$).

Results and discussion

The LM treatment strongly modified the maize crop by decreasing growth (Figure 1A) and duration (Figure 1B) of the leaf area, and thus biomass and grain yield at harvest (Table 1). Maximum root densities in both cropping systems were observed around the time of maize anthesis (Figure 1C). However, BS maize was hardly able, at any time during the crop season, to build up root densities similar to those observed in LM at the time of maize sowing.

Table 1. Maize dry weight (g m^{-2}) at harvest and cumulative seasonal losses of N by leaching, as influenced by the BS and LM treatments during the three experimental years.

Treatment	1994	1995	1996	1994	1995	1996
		Stover g m^{-2}			Grain g m^{-2}	
BS	997 a	1798 a	454	803 a	991 a	655
LM	222 b	1061 b	323	225 b	562 b	563

Means followed by different letters are significantly different from each other ($P < 0.05$).

The living mulch reduced the soil water content between 0.3 and 0.9 m soil depth (Figure 1D), which remained lower even after intense rainfall. In LM the nitrate concentrations in the leachate (usually < 10 mg l^{-1}) were very low (Figure 1E). In BS the nitrate concentration in the leachate reached as much as 70 mg l^{-1} (in 1996, data not shown). Losses of N in LM did not reach 1 % of the values observed in BS (Figure 1F) and confirmed the environmental suitability of these cropping systems in terms of avoiding the contamination of the ground water.

Reduced water and N availability in LM contribute to explain the decrease in growth and yield of the maize plants, and are in good agreement with the dense root system developed in this cropping system as compared to BS. However, the inability of the maize plants to establish a competitive root system (as is evident from the low root densities observed in the BS treatment) certainly contributes for the limited supply of nutrients and therefore reduces its growth and yield in the LM treatment.

Because of the low root density in the BS treatment we believe that good maize productivity in multi-cropping systems, such as living mulches, will depend on the identification of genotypes with fast early root development. This will contribute to a better nutrient and water uptake by the maize plants and improve the competitive ability in relation to the cover crop. Manipulation of the growth of the cover crop (wider strips of killed grass, use of non-lethal doses of herbicide, etc.) may also have a positive impact on maize growth. However, this may be at the expense of the very good protection against loss of N by leaching, one of the main reasons to consider such a complex cropping system.

Conclusions

From the present study, which provides a unique and integrated overview of the effects of a living mulch on maize shoot and root growth and links these to parameters of the dynamics of water and nitrogen, it can be recognized that the challenge for the development of environmentally and economically sound maize cropping systems depends on the ability to improve the uptake of water and nitrogen by the maize roots in a competitive environment without affecting the capacity of the cover crop to prevent N losses by leaching.

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Importance of root litter and rhizosphere for the nitrogen cycle in grassland

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Abstract

We examined the N fluxes in grassland monoliths containing *Dactylis* (D) or *Lolium* (L) litter, grown either with *Lolium* or *Dactylis* stands at a moderate N supply. A factorial design was composed of the DD, DL, LD and LL treatment, where the first letter is the nature of the litter, and the second one, the nature of the living stand. Both factors influenced the N fluxes. For species grown on their own litter, N harvest was greater with DD and N leaching was greater with LL. Other, more hidden, associated mechanisms in LL were: 1) a greater turnover of the SOM, composed of enhanced SOM mineralisation and a greater transformation yield of litter in new SOM and 2) a faster N exchange between the SOM and the mineral pool, the so-called mineralisation-immobilisation turnover. In LL, lower N harvest may mostly be caused by the greater SOM-N immobilisation, and greater N leaching by enhanced SOM-N mineralisation.

Keywords: N harvest, N loss, mineralisation, immobilisation, SOM, grass species strategy

Introduction

N harvest and N losses in grasslands are major variables that characterise the sustainability of land-use systems. These N fluxes can be dependent on grassland botanical composition. A generic functional approach is necessary to achieve greater understanding of the effect of grassland species on these N fluxes (Hobbie, 1992; Hooper and Vitousek, 1998). With this objective, not only the agronomic and environmental output has to be considered, but the entire interrelated set of processes that condition the N cycle in the soil-sward ecosystem. In particular the hidden soil N fluxes determined by the below-ground organs need also to be considered (Aerts *et al*., 1992). This contribution focuses on the effects of two aspects in relation to the dead and to the living roots of forage grasses (Gorissen and Cotrufo, 2000): the nature of the root litter and the nature of the rhizosphere.

Materials and methods

Our experiment in controlled soil conditions was representative of realistic conditions for root growth and root litter incubation in the soil. In a factorial design, we were able to control and to combine the nature of the species that composed the root litter and the growing stand. Soil monoliths containing a pure root litter of *Dactylis glomerata* (D) or *Lolium perenne* (L) were sown with pure stands of *Dactylis* or *Lolium*. The treatments were then: D growing on the D litter (DD), D growing on the L litter (LD), L growing on the D litter (DL) and L growing on the L litter (LL). The grassland monoliths received a moderate amount of N fertiliser (150 kg N ha^{-1} y^{-1}) from N labelled ammonium nitrate. The grass was cut 5 times per year.
Additionally to the N harvest and to the N losses by leaching, we measured 1) the amount of N mobilised in the production of new roots, called N organisation, 2) mineralisation of litter-N and stabilisation of litter N in the soil organic matter (SOM) and 3) the turnover of N mineralisation and immobilisation in the SOM (MIT). The N fluxes under the living stands are here examined during the first year of root litter incubation.

Results

Both the nature of the root litter and of the rhizosphere influenced the N harvest and the N loss by leaching (Table 1). *Lolium* litter lead to greater harvest of N and N leaching than *Dactylis* litter. Nevertheless, the major factor influencing these N fluxes was the effect of the rhizosphere, as more N was harvested in the living stand of *Dactylis*, and more N was leached under the living stand of *Lolium*. Between the DD and LL treatments, less N leaching and more N harvest were recorded in DD (Figure 1).

Table 1. Mean N fluxes and significance level of the factors effects. Data (kg N ha^{-1} y^{-1}) are means of 3 replicates. The fertiliser N supply is 150 kg N ha^{-1} y^{-1}. Root organisation represents N mobilised in new root production. Root litter decay is the total N loss from the root litter, sum of litter-N mineralisation and transformation of litter-N in new SOM-N. SOM mineralisation and immobilisation are the rough N fluxes between the SOM-N and the mineral N pool (The SOM-N balance of this MIT is positive at the experimental N supply).

	Mean values				Treatments effects		
Nature	DD	DL	LD	LL	Litter	Rhizosphere	Interaction
Harvest	123	103	134	104	*	***	**
Root organisation	28	30	38	33	NS	***	NS
Root Litter decay	54	57	43	48	***	**	*
Leaching	13	17	16	22	**	***	NS
Soil mineralisation	67	77	71	83	***	***	-
Soil immobilisation	103	119	97	123	NS	**	-

On one hand, the nature of the root litter and the rhizosphere influenced the N turnover between the mineral N pool and the SOM-N. Gross soil N mineralisation was only influenced by the nature of the living stand, whereas gross N immobilisation in the SOM was driven both by the nature of the litter and the nature of the rhizosphere (Table 1). Greater N immobilisation and mineralisation occurred in the *Lolium* rhizosphere. Additionally, greater gross SOM-N mineralisation occurred with the *Lolium* litter. With the DD and LL treatments, both gross N mineralisation and immobilisation were greater in LL (Figure 1). Therefore the N turnover between the mineral pool and the SOM was more active in LL, but net N immobilisation in the SOM was greater in DD than in LL. On the other hand, the nature of the root litter and of the rhizosphere influenced the fate of decayed root litter towards N stabilisation or mineralisation. Both factors conditioned the root litter decay: it was greater with the *Dactylis* litter and in the *Lolium* rhizosphere (Table 1). With regard to the components of this litter decay, much more stabilisation of litter N was recorded under the *Lolium* rhizosphere. Conversely, more litter N mineralisation was obtained with the *Dactylis* litter and under the *Dactylis* rhizosphere (not shown). As a result, among the DD and LL treatments, more litter N was mineralised with DD and more litter N was stabilised in the SOM with LL (Figure 1).

Discussion

At a moderate supply of mineral fertiliser N, the DD and LL treatments induced numerous significant differences in the set of N fluxes. With greater N harvest and less N leaching, DD was preferable to LL, both from the agricultural and environmental points of view. But, in the variability the species induced in the N fluxes, what was exactly the cause of a negative correlation between the N harvest and the N losses? Gross soil N mineralisation was lower with DD (67) than with LL (83). But greater litter N mineralisation in DD compensated for lower SOM mineralisation. As a result, gross N availability was the same under both stands

(120 and 123, respectively). But greater soil N immobilisation occurred in LL (123) than in DD (103).

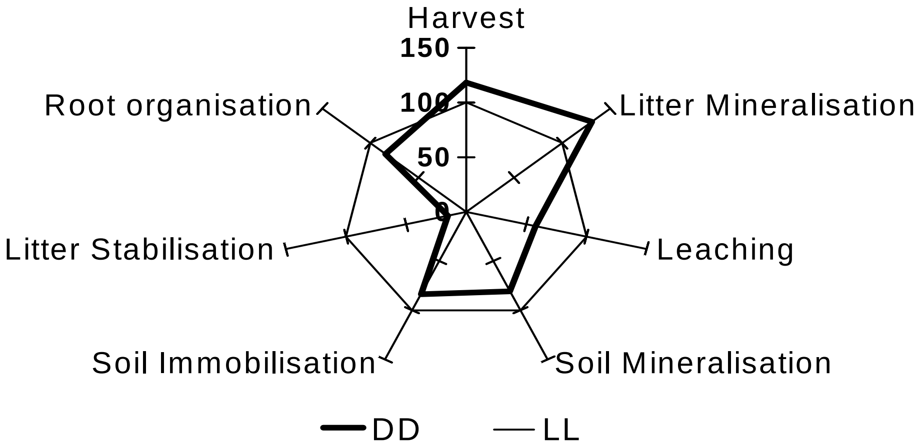

Figure 1. N fluxes in the grassland ecosystem, according to species strategy. N fluxes under the *Dactylis* stand are represented in % of the same fluxes under the *Lolium* stand. Each pure stand grows on soil monoliths containing a root litter of the same species. Root organisation represents N mobilised in new root production. Total root litter N decay of table 1 is here decomposed in litter N mineralisation and litter N stabilisation in the SOM. Soil mineralisation and immobilisation are the fluxes between the SOM and the mineral pool.

As a result, net N availability was greater in DD (167) than in LL (150). Therefore, less N uptake in LL was mostly due to less net N availability. From the factorial experiment, crossing the nature of the litter with the nature of the living roots, this species effect was mostly from rhizosphere origin. N leaching was more important in LL (22) than in DD (13). From the factorial experiment this resulted both from a positive effect of the *Lolium* litter and of the *Lolium* rhizosphere. Increased N leaching under *Lolium* occurred despite lower net N availability. The N flux that was best correlated with N leaching was gross SOM-N mineralisation. Therefore, the positive effect of *Lolium* on gross N mineralisation was presumably the process responsive of increased N leaching.

Conclusions

The species studied here show very different impacts on the N cycle. The impact of *Dactylis* consisted of favouring recycling of litter N, whereas the impact of *Lolium* consisted of favouring the internal soil N cycle, or mineralisation-immobilisation turnover of the SOM. These impacts are likely to have major consequences for the agricultural and environmental output, and also on the soil N balance. More information is required to assess the impact of grassland species on soil N fluxes in interaction with management factors such as fertiliser N supply and cutting frequency. In any case, regarding their important impact on the SOM-N turnover, competitive species such as *Lolium* seem to cause greater N losses.

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Prediction of N offtake in resown grassland based on temperature and soil chemical and physical characteristics

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Abstract

A simple regression model for predicting N offtake in newly resown grassland was developed, based on four main parameters. In order of importance these were: accumulated mean daily temperature, % total soil N, % clay content, and potentially mineralisable N as estimated using a soil chemical (hot KCl) extraction method. Based on 15 experimental sites, for which N offtake in herbage (from nil-N fertilised swards) and other required data were available, a value of $r^2 = 0.84$ was obtained between fitted values and measured N offtake in herbage. Lowest N offtake rates were on upland sites. The approach used has wider potential applications for improving fertiliser recommendations for renovated (resown) grasslands.

Keywords: grassland, renovation, resowing, cultivation, available nitrogen

Introduction

Grassland cultivation, followed by resowing with seeds of grass (or another crop), is a long-established agricultural management practice that enables a short-term gain in productivity associated with the mineralisation of the soil N that has accumulated under a long-term grassland sward. Soil N available for a succeeding crop, or newly renovated sward, varies with site conditions and recent sward history. In this paper, we present preliminary results for a simple regression model derived for N offtake (N content of harvested grass DM) from nil-N (i.e., unfertilised), newly sown perennial ryegrass at 15 sites in England and Wales. This measure of soil-derived N was correlated with results of a soil analysis (hot KCl extraction) of available N at each site. The aim was to develop a simple model for predicting nitrogen dynamics in resown grasslands, which could be tested using using existing experimental data.

Materials and methods

Potentially mineralisable N
Air-dried soil (10 g), sieved (< 2 mm) was placed in a 150 ml *Pyrex* beaker with 50 ml 2 *M* KCl and boiled for 1 h, adding water to maintain the volume. The supernatent was filtered and made to 100 ml with 2 *M* KCl and analysed for inorganic N (Whitehead, 1981).

Development of a regression model
Various combinations of parameters were identified as potential descriptors for the regression model to predict N offtake, including soil type, soil texture, soil organic matter content, soil total N content, soil bulk density, potentially mineralisable N (from hot KCl extraction) and meteorological data.

From a review of results of N-response experiments at 66 grassland sites in England and Wales (Hopkins, 2000), data from one multi-site experiment, conducted in 1984-86 and representing a range of grassland environments, was found include all the required parameters (Hopkins *et al.*, 1990). The experimental treatments included five rates of N fertiliser (including a nil-N rate) on both permanent and reseeded swards. All the sites had a similar cropping history and were previously in permanent grassland. Data used in the model were restricted to newly reseeded swards from 15 sites, receiving no N fertiliser, which were cut 6-7 times per year. At some sites there were data available for 4 years, but the fourth year was not used, for two reasons. Firstly, reseeded swards were selected for use in the model because, following breaking of the old sward, they are somewhat analogous to the situation after ploughing for cereal crops with the incorporation of plant residues. Secondly, grassland receiving no N becomes colonized by white clover after several years and this increases the amount of N available to the grass. Available data included initial assessments of the following: soil type, soil texture, soil organic matter content, soil total N content (0-10 cm soil depth), soil bulk density and also the nil-N offtake in herbage (i.e., N yield from nil-N fertilised plots at each cut). Potentially mineralisable N from the hot KCl method had also been assessed annually. The site elevation and meteorological data (mean monthly air temperature and rainfall, April to September) were also available. Data for soil temperature at 10 cm depth was sought, by examination of Meteorology Office data held on the British Atmospheric Data Centre Internet site (*http://badc.nerc.ac.uk*). Soil temperatures were not available for all sites and air temperature data were used instead. The data used were the accumulated mean (of maximum and minimum) daily temperature (^{o}C) from 1 April to 30 September. The mean of the three-years' data was used.

Field history

Sites were selected from the main grass-growing areas of England and Wales to represent a range of grassland environments and soil types under both high and low rainfall regimes. Elevations ranged from 15 to 400 m above sea level. The existing swards were mostly permanent grassland that was over 20 years old and of mixed species composition (*Lolium perenne* contributing < 30%, and absent at some sites). Previous management had been relatively extensive, with inputs of N less than 200 kg ha^{-1} y^{-1}; most sites had received considerably less.

The permanent swards were treated with glyphosate, then rotovated and resown to *Lolium perenne* during late summer 1983. Prior to reseeding, 100 kg N ha^{-1} was applied to the permanent sward in spring 1983. The seedbed received fertiliser at a rate of 60, 50, 50 kg ha^{-1} of N, P_2O_5, K_2O, respectively. From 1984, no further N was applied to these treatments. In the spring of each subsequent year, fertiliser was applied at a rate of 150, 100 kg ha^{-1} of P_2O_5, K_2O. On the basis of soil tests carried out at the start of the experiment, soil pH values below 6.0 were corrected with the appropriate lime application. Also, where soil P and K status were still low, appropriate amendments were made.

Statistical analysis

Multiple regression analysis on data from the 15 sites was used to select the most suitable predictors of (nil-N) N offtake. N offtake in herbage (mean of 3 years) was used as the dependent variate and the following site descriptors (single estimates of each) were the independent variables: % sand, % clay, % silt, % total soil N, % soil organic matter, soil bulk density and elevation. The seasonally affected descriptors (annual estimates only) comprised: potentially mineralisable N (kg ha^{-1}), accumulated daily mean temperature (April to September) and rainfall. A step regression (i.e., forward selection) procedure was then used to rank the predictors identified as being the best descriptors of (nil-N) N offtake. The selected descriptors were then used in a multiple regression analysis to produce the fitted values for (nil-N) N offtake. The regression estimates were verified using a Bootstrap procedure.

Results and discussion

The step (forward selection) regression analysis identified four parameters (a-d), in the following order of importance: accumulated mean daily temperature (c), % total soil N (a), % clay (d) and potentially mineralisable N as kg N ha^{-1} (b). The value of constant was -292. The model produced by regression analysis is shown in figure 1 including line of equality. Within the data range the model performed reasonably well. A larger database would be desirable to validate this regression model, but we are unaware of any with this complete range of information. Year-to-year variation was considerable, and the small size of the database necessitated the use of means of the first three harvest years for the seasonally affected descriptors. The five sites with the lowest N offtake were upland sites in northern England and Wales. The remaining sites formed a separate group with higher rates of N offtake.

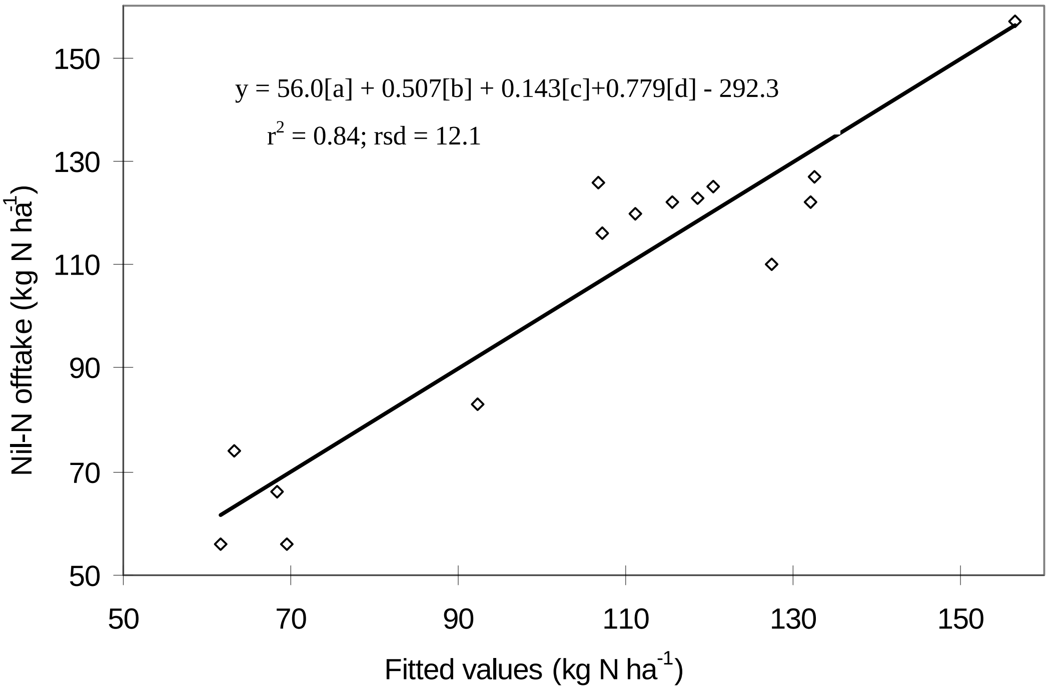

Figure 1. Model for predicting N offtake from nil-N fertilised, newly resown grass at 15 sites in England and Wales (means for 1984-86), using four descriptors. (1:1 line is also shown).

Conclusions

From information on the four main soil parameters, an estimate of OM turnover (i.e., net N release) can be obtained from the simple regression model and this can be made more site-specific by including local soil temperature measurements for refining fertiliser N recommendations for recently renovated grassland.

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Lowering nitrogen inputs to grassland-based dairy production

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Abstract

This three-year experiment examined the impact of lowering N input ha^{-1} on milk output, carrying capacity and N losses. In Ireland, a dairy cow is classified as excreting 85 kg organic N y^{-1}. There were four treatments involving annual inputs (kg ha^{-1}) of organic N + fertiliser N as follows: (1) 210 + 350 (Intensive), (2) 210 + 250 (Moderate), (3) 178 + 175 (Extensive) and (4) 149 + 80 (Environmental) to permanent grassland. There were 18 cows per treatment each year. Concentrates fed were 595 kg $cow^{-1}y^{-1}$. There were no significant differences in yields (mean ± SEM kg cow^{-1} y^{-1}) of solids-corrected milk (6210 ± 97), fat (263 ± 4.4), protein (225 ± 3.3) and lactose (301 ± 5.2) between treatments combined over years. Silage production was sufficient to meet winter-feed requirements (i.e., 1.4 t DM cow^{-1}) on all treatments except Moderate, which was 0.87 of requirement. Measurement of soil mineral N concentrations indicated largest losses from Intensive during the winter. However, measurement of nitrate N in drainage water during the winter indicated low concentrations (< 5.65 mg l^{-1}) on all treatments especially under Extensive and Moderate where concentrations remained < 2.0 mg l^{-1} and, on certain sampling dates, significantly lower ($P < 0.01$) than the other two treatments.

Keywords: nitrogen, milk production, grassland, white clover, nitrate

Introduction

This three-year experiment (2000 to 2003) examined the impact of lowering N-inputs (organic and fertiliser N) to permanent grassland on milk output per cow, stock carrying capacity, soil mineral N concentrations and nitrate N concentrations in drainage water during the winter. In Ireland, a dairy cow is classified as excreting 85 kg organic N y^{-1}.

Materials and methods

There were four treatments involving annual inputs (kg ha^{-1}) of organic N + fertiliser N as follows: (1) 210 + 350 (Intensive), (2) 210 + 250 (Moderate), (3) 178 + 175 (Extensive) and (4) 149 + 80 (Environmental). These organic N inputs represent stocking rates (cows ha^{-1}) of (1) 2.5, (2) 2.5, (3) 2.1 and (4) 1.75. Swards were initially composed primarily of perennial ryegrass (> 750 g kg^{-1} DM) and included white clover (< 50 g kg^{-1} DM). There were 18 cows per treatment each year. The aim on each treatment was to produce (1) sufficient pasture to meet the cows feed requirements during the grazing season and (2) herbage to meet winter-feed requirements as silage. Quantities of silage produced were estimated as 0.75 of herbage dry matter (DM) harvested (Gordon, 1988), i.e., 0.25 DM loss between harvest and feeding. Target quantity of silage required was 1.4 t DM cow^{-1} y^{-1}. Concentrate supplementation amounted to 595 kg cow^{-1} y^{-1}. Mineral N (nitrate N and ammonium N, 2 M KCl Extraction) at four depths in the soil were measured in four paddocks per treatment in late September, late November and early February each winter. Nitrate N concentrations in drainage water at a depth of 1 m in each of the above paddocks were also measured at regular intervals between early October and late February during the winters of 2001-2002 and 2002-2003. Data were subjected to analysis of variance.

Lowering nitrogen inputs to grassland-based dairy production

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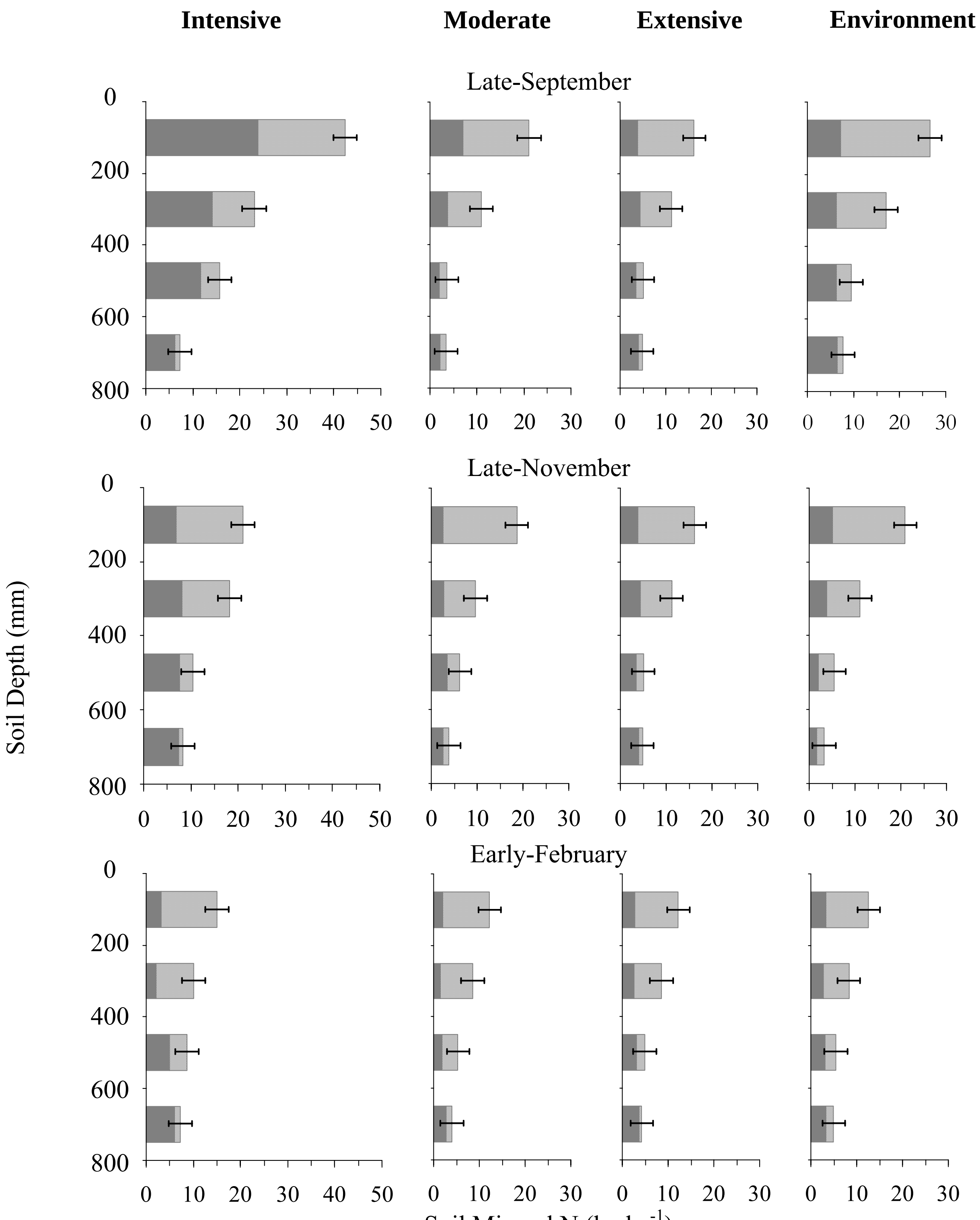

Figure 1. Soil mineral N concentrations (nitrate and ammonium at four depths in the soil on three dates during the winter (data are means of three years; interaction between treatment × sampling date × soil depth, $P < 0.001$, I = ± SEM of mineral N).

Results and discussion

There were no significant differences in yields (mean ± SEM kg cow^{-1} y^{-1}) of solids-corrected milk (6210 ± 97), fat (263 ± 4.4), protein (225 ± 3.3) and lactose (301 ± 5.2) between treatments combined over years. There was a significant (P < 0.05) difference in the

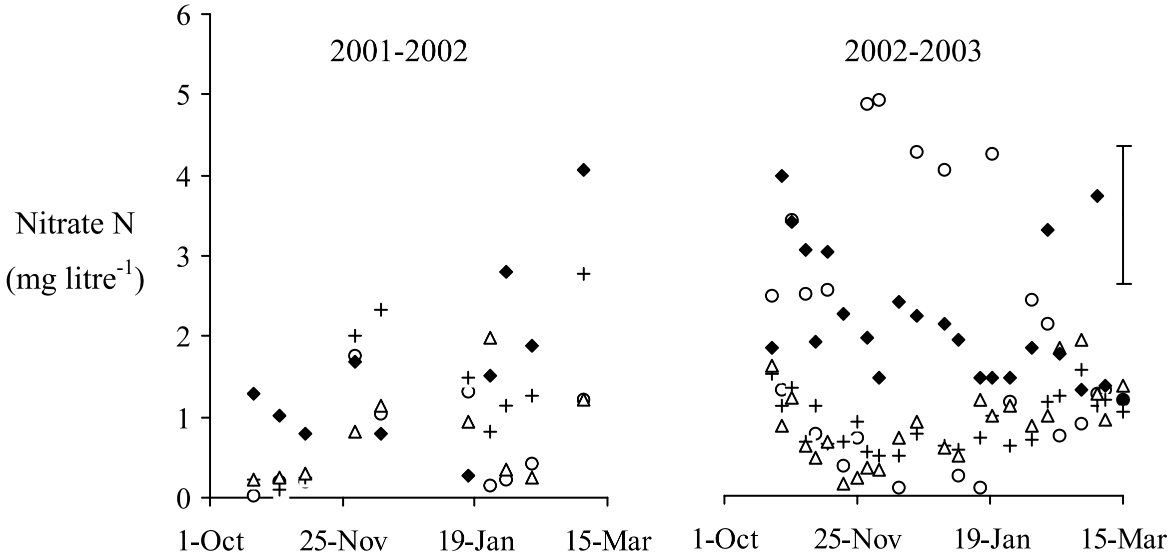

Figure 2. Nitrate N concentrations in drainage water during the winters of 2001-2002 and 2002-2003. Treatments were as follows: Environmental ○, Extensive +, Moderate Δ and Intensive (Interaction between treatment × sampling date, $P < 0.01$, I = ± SEM).

quantities of grass silage produced (t DM cow^{-1} y^{-1}): 1.50 on Intensive, 1.22 on Moderate, 1.38 on Extensive and 1.80 on Environmental, SEM = 0.047. Silage production on both Intensive and Extensive was more or less on target. Moderate was below target; input of fertiliser N was insufficient to meet the stock carrying capacity examined. Silage production (t DM cow^{-1}) on Environmental increased from 1.3 in 2000 to 1.9 in 2001 to 2.2 in 2002. This was attributed to the substantial increase in the white clover content (g kg^{-1} DM) of swards on this treatment from 133 during 2000 to 248 during 2001 and 232 during 2002. The white clover contents of swards in the other three treatments remained relatively low being less than 50 on average within each treatment. While Intensive had higher ($P < 0.001$) mineral N concentrations than Moderate and Extensive in September, there was little difference between treatments by the following spring (Figure 1). Largest losses of N during the winter period were associated with Intensive and Environmental. Nitrate N concentrations in drainage water were higher ($P < 0.01$) on occasions in Intensive and Environmental compared to the other two treatments (Figure 2). High mineral N concentrations in Environmental in September were attributed to the high proportion of white clover; the proportion of white clover in these swards being highest during August and September each year. Furthermore, the sporadic peaks in nitrate N concentrations in drainage water were attributed to the senescence and decomposition of clover stolon during the winter. The relatively low mineral N concentrations in Moderate and Extensive in September were attributed to low white clover content of swards and low fertiliser N input from June onwards. The generally low concentrations of nitrate N recorded in drainage water indicate that N losses were mostly due to denitrification of oxidized-N in the soil. This is consistent with the heavy soil and mild wet winters experienced at this experimental site in Ireland.

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Nutrient cycling in dairy farming systems: potential of eco-technological strategies

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Abstract

The opportunities and constraints for eco-technological management on dairy farms were explored for nitrogen (N) using a mathematical model, which integrated processes of nutrient input, recycling, immobilisation and mineralisation. Recycling is defined as the mineralisation of N within the year of its incorporation into herbage, which occurs through release from animal faeces and urine, and non-harvested biomass. We simulated changes in inorganic and organic N stocks and the associated emission (E), mineralisation (M) and recycling (R) of N for different initial levels of inorganic and organic N. Results demonstrate that the system evolves to equilibrium values for total inorganic and organic N, which are reached after 50 to 100 years and are strongly determined by the imposed management practices. In the equilibrium state, E was reduced by production-related parameters: lowering inorganic fertiliser input rate, and increasing grassland productivity and animal N-use efficiency. E was affected only in the short term (< 50 years) by adjustments in quality-related parameters: lower N content and biomass degradability, and parameters characterizing soil biota. Herbage quality-related parameters had no effect on internal nutrient cycling in the equilibrium state, because adjustments in M were completely compensated by changes in R. A comparison of farming systems demonstrated that farming systems can be designed in such a way that improvement of internal nutrient cycling supports the same animal production level with lower inputs and lower emissions.

Keywords: nitrogen, soil, grassland, emission, mineralisation, modelling

Introduction

In the Netherlands, several large research programmes aiming at quantification of nutrient flows on dairy and mixed farms have yielded valuable information on management alternatives that rely less on external resources. In the VEL & VANLA Nutrient Management Project, strategic adjustment of farm management is based on three categories of management changes that are hypothesized to act synergistically in increasing nutrient use efficiency, in particular for N. Strategy 1 aims to enhance fertiliser use efficiency by reduction of inorganic fertiliser inputs and improved utilisation of slurry manure. Strategy 2 addresses feeding rations with more structural components and a higher C/N ratio, which in terms of nutrient use efficiency is expected to result in: (a) higher animal nutrient use efficiency, (b) reduction of losses from animal excreta due to lower inorganic N content, and (c) build-up of soil organic N through manure with higher C/N ratio, which ultimately increases the N supplying capacity of the soil. Strategy 3 aims at stimulating soil biota and modifying the mineralisation/immobilisation turnover, to increase N supply for plant growth from the soil organic N pool. Methods used are application of manure with a higher C/N ratio, minimization of use of heavy machinery, surface application of slurry manure rather than injection to minimize sward damage and deterioration of soil structure, and application of soil and manure additives. Overall, these changes constitute a movement from increasing inputs to increasing utilisation of internal resources in farming systems, also denoted as a shift from technological to eco-technological management. In the proposed model, essential interactions between inorganic and organic forms of N in the system are represented, based on ecological concepts of nutrient cycling. The model is used to examine strengths and weaknesses of the VEL & VANLA strategies.

Materials and methods

Inorganic N is taken up from the soil and incorporated in organic compounds during plant growth. Nitrogen incorporated in these organic compounds is released as inorganic N after conversion by farm animals and soil biota. In our concept, available inorganic N is defined as cumulative inorganic N present in the soil solution throughout one year. Recycling refers to the N that is incorporated in organic compounds in plants and converted to available inorganic N within one year. Nitrogen that is not recycled within one year remains in the soil organic matter pool, and may be released as inorganic N in subsequent years.
The model described by Groot *et al*. (2003) quantifies the relations between the amounts of inorganic and organic N in the top 20 cm of the soil at a time scale of one year (Figure 1).

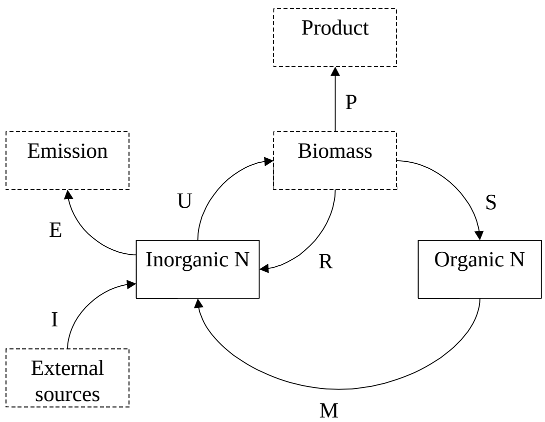

Figure 1. Schematic representation of the model. Solid boxes indicate modelled state variables. Arrows indicate flows of nitrogen, by the processes of external inorganic N input (I), uptake (U), emission (E), production (P), soil organic N accumulation (S), recycling (R) and organic N mineralisation (M).

In table 1 the initial values of relevant parameters for a representative farm on sandy soils in The Netherlands are listed. The desired direction of change to improve N use efficiency and the relation of the parameters to the mentioned strategies and model processes is indicated.
The sensitivity of N emission to a 10 % adjustment in the parameter value in the desired direction (Table 1) was analysed for the short term (< 50 years) and the long term (equilibrium state). The simulations were executed for a range of initial values of the state variables inorganic and organic N. Here, we illustrate results using initial values for inorganic and organic N of 900 and 3000 kg ha^{-1}, respectively.

Results

In the short term the parameter changes in the desired direction reduced emission (Table 1), except for fractional degradation rate for soil organic matter, which results in higher inorganic N availability from the organic N stock. In the equilibrium, only the production-related parameters led to lower emission. Ecological cycling indicators (see Finn, 1980) demonstrated that the quality-related parameters had no effect on internal N cycling in the equilibrium, as only the distribution of N flow between R and M was altered.

Table 1. Production and quality-related model parameters with initial values, the processes affected, the related strategies, the desired direction of change and the relative short term (ST) and long term (LT) effects. For explanation of processes, strategies and change, see text and figure 1.

Parameter	Value	Process	Strategy	Change	ST effect	LT effect
Production related						
Artificial fertiliser N supply	150 kg ha^{-1} y^{-1}	I	1	–	–5.2	–3.9
Maximum N uptake rate by grass	500 kg ha^{-1} y^{-1}	U, E	1	+	–7.2	–3.9
Effectivity of inorganic N uptake in plant biomass	0.68 kg kg^{-1}*	U, E	1	+	–31.3	–30.7
Animal N conversion efficiency	0.23 kg kg^{-1}	P, R, S	2	+	–9.6	–7.7
Quality related						
Herbage N content	0.038 kg kg^{-1}*	R, S	2	–	–2.5	0.0
Herbage dry matter digestibility	0.75 kg kg^{-1}	R, S	2	–	–0.5	0.0
Fractional degradation rate of faeces organic matter	0.40 per year	R, S	2	–	–0.2	0.0
Fractional degradation rate unharvested biomass	0.70 per year	R, S	2	–	–1.1	0.0
Fractional degradation rate soil organic matter	0.03 per year	M	3	+	+2.2	0.0
Efficiency of soil biota	0.30 kg kg^{-1}	R, M	3	+	–1.8	0.0
C/N ratio of soil biota	8.0 kg kg^{-1}	R, M	3	–	–2.3	0.0

* of harvested biomass.

Discussion

The simulation results clearly show that the VEL & VANLA strategies will result in N emission reduction due to adjustments in production-related parameters (Table 1) and a change in the ratio between R and M as a result of changes in quality-related parameters (data not presented). A preliminary farming systems comparison demonstrated that a considerable shift in the ratio between R and M is attainable. The actual desirability of this shift depends on the farmer's opportunities of altering production-related parameters, in particular the effectivity with which inorganic N that is released from organic sources is captured by pasture. This, in turn, is dictated by many farm-specific circumstances, such as soil and crop characteristics, whole farm management (e.g., ration composition, grazing management) and technical means (e.g., stable type, slurry storage and application technique). Consequently, changes in current management should be considered for each farm separately and should primarily aim for possibilities to enhance the effectivity of inorganic N uptake, to improve internal N cycling.

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Forage production in a crop rotation: impact of N supply on performance and N surplus

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Abstract

Nitrogen (N) recovery in specialised dairy farms is known to be low, due to high imports of N with fertiliser and purchased feed, whereas only small amounts are exported in milk and meat. The traditional system of forage production in northern Germany comprises permanent grassland and maize in monoculture, and it is hypothesised, that overall N efficiency is higher when forage is produced in crop rotations. Within an integrated project at the University of Kiel (Taube and Wachendorf, 2001), N fluxes in a forage crop rotation with clover/grass, silage maize, triticale (1 year each) at various levels of N supply were measured over a 3-year-period. N efficiency and energy yield of maize in rotation was high, even at low levels of N supply. Clover/grass and triticale had comparable yields, but N surpluses of the ley were much lower. These data provide the potential to compare forage production systems with the help of simulation models (Rotz *et al*., 2002).

Keywords: Crop rotation, silage maize, permanent grassland, N losses, N surplus, clover/grass

Introduction

From previous experiments with permanent grassland on sandy soils, it became evident that N surpluses and leaching losses were low under cutting, but unacceptably high with grazing animals, due to the low N use efficiency of animals (Büchter *et al*., 2002; Trott *et al*., 2002; Wachendorf *et al*., 2003). At the same site, maize in monoculture proved to be an N-efficient crop with low N surpluses and leaching losses at low to moderate levels of N supply (Volkers *et al*., 2002; Büchter *et al*., 2003). These results lead to the idea that inclusion of grassland in a crop rotation (preceding maize and following cereals) may reduce NO_3 leaching losses through an efficient uptake of N surpluses from the ley phase by maize. On the other hand negative ecological effects of maize cultivated in monoculture, e.g., soil erosion and humus degradation, may also be reduced. To evaluate the potential of this strategy, a field experiment was established in 1999 at the same site as the permanent grassland and maize trials. This paper reports from a three years period.

Materials and methods

The experiments were conducted on the 'Karkendamm' experimental farm (mean precipitation 824 mm; mean temperature 8.4 °C (1980-99); soil type: deep ploughed gleyic podzol; texture: sand with less than 5 % clay; pH 5.6). The data for adjusting stocking densities and amounts of slurry are deduced from a typical specialised dairy farm with 1.8 LU ha^{-1} and 100 grazing days for cows and young stock per annum in northern Germany. About 25 m^3 slurry ha^{-1} y^{-1} would be applied on such farms. The clover/grass ley was managed as a mixed system with 2 cuts and 2 successive grazings. The last cut remained undisturbed on the field and was ploughed in before the sowing of maize in the following spring. Maize was used for whole crop silage and triticale as whole crop silage and grain. Three different scenarios of forage production were established. For all scenarios, the goal was to achieve a certain overall feed supply of roughages plus supplements in order to achieve a given milk quota on the corresponding farms. Scenario 1 was high forage production (average fertiliser N supply

150 kg N ha^{-1} + 25 m^{3} slurry ha^{-1}) with low supplementation; Scenario 2 was reduced forage production (average fertiliser N supply 75 kg N ha^{-1} + 25 m^{3} slurry ha^{-1}) with medium supplementation; Scenario 3 was low forage production (average fertiliser N supply 0 kg N ha^{-1} + 25 m^{3} slurry ha^{-1}) with high supplementation. Mineral N availability within a treatment was lowest for maize in order to achieve maximum advantage of the high N-use efficiency of maize. To increase N_2-fixation by white clover, the grass ley received intermediate amounts of N. Assuming that maize takes up most of the available N from the grass ley, it was presumed that triticale needed the highest N supply to produce satisfactory yields (Table 1). In order to extend the variation in N supply in the trial, all supply levels were conducted with and without the use of slurry. N balances on a field level only considered external N sources and were calculated as shown in table 2.

Table 1. N supply by mineral fertiliser and slurry at various supply rates in the crop rotation trial.

	High Intensity (kg N ha^{-1})			Reduced Intensity (kg N ha^{-1})			Low Intensity (kg N ha^{-1})		
Crop	Fert.†	Slurry$^{\#}$	Total	Fert.	Slurry	Total	Fert.	Slurry	Total
Clover/grass (CG)	150	75	225	100	75	175	0	75	75
Silage maize (SM)	100	75	175	25	75	100	0	75	75
Triticale (TR)	200	75	275	100	75	175	0	75	75
Mean	150	75	225	75	75	150	0	75	75

†: Mineral N fertiliser
$^{\#}$: 3.1 kg total N m^{-3} slurry

The field experiment was conducted from 2000 to 2002. All crops were grown for one year. In each winter the soil was covered by a crop. In the experiment, every crop was grown in each of the three years. The results presented are therefore means over three years.

Table 2. Components in calculation of N balance.

N input	N output
Mineral fertiliser N	N yield in harvestable biomass
+ slurry N	- residual biomass N (grazed swards)
+ biologically fixed N by clover	- excretal N (grazed swards)
+ deposition N	
N surplus = N input – N output	

Results and discussion

Energy yield of silage maize is significantly higher than triticale and about double the yield of clover/grass (Figure 1A). It is remarkable that, even without any N supply from slurry or mineral fertiliser, maize yields were above 90 GJ net energy for lactation (NEL) ha^{-1}. This clearly reflects an efficient use of N released from the soil after incorporation of clover/grass residues prior to the sowing of maize. Energy yields of all crops increased linearly over the whole range of N input via slurry, mineral fertiliser and atmospheric deposition, with maize displaying the lowest marginal yields. Although two cuts were taken in spring, removing considerable amounts of N, N still accumulated in the clover/grass year (Figure 1B). This is due to the low N retention of grazing animals during the second half of the growing season. The high N use efficiency of triticale, and especially maize, resulted in a relatively low N surplus for the whole crop rotation. As a consequence of low surpluses and high energy yields per hectare, the N surplus (per GJ NEL produced) was much lower for maize than either of the other crops (Figure 1C). For all crops, N surplus per GJ NEL was lowest at zero N supply by slurry or fertiliser and increases linearly with further increasing N supply.

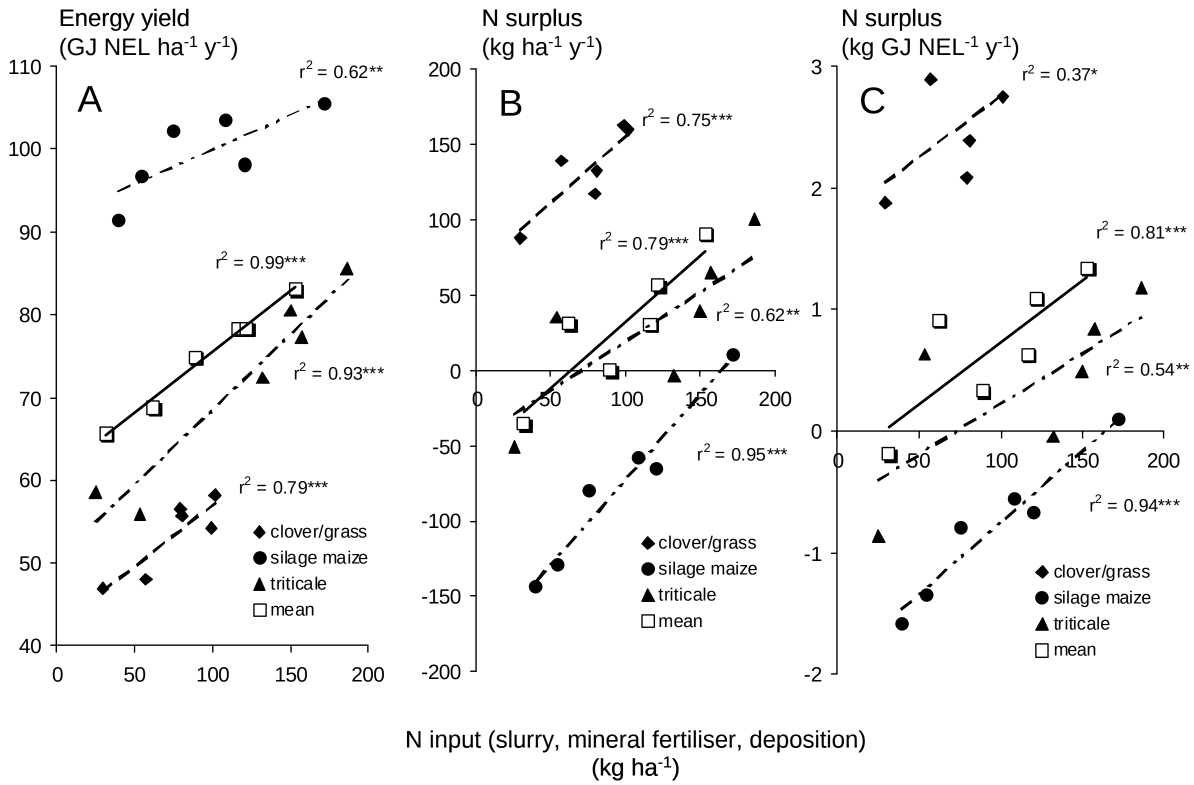

Figure 1. Relationship between (A) energy yield, (B) N surplus per hectare and (C) N surplus per GJ NEL and N input by slurry, mineral fertiliser and atmospheric deposition (Means on an annual basis of 2000 to 2002; *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$).

Conclusions

The reduction of the grassland period to one year and the use of forage maize and cereals in the successive years resulted in relatively high N use efficiency in forage production. A direct comparison with permanent grassland and silage maize in monoculture, which is the common forage production system in major parts of Europe, is not possible due to different climatic conditions in the experimental years. However, these data provide the potential to compare forage production systems with the help of dynamic simulation models (Rotz *et al*., 2002).

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Effects of grassland renovation on farm-gate nitrogen balances and losses

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Abstract

Nitrogen (N) balances were calculated at the farm, field and herd level for specialized Danish (DK) and Northern German (GE) dairy farms. The hypothesis was that crop rotations with short-lasting leys could help to reduce N surpluses at the farm scale, as a result of the carry-over of N from the grassland phase to the succeeding crop. Calculations revealed that under both DK and GE conditions, the farm-gate N surplus could be reduced through the inclusion of crop rotations with 2/3-year leys, at the expense of permanent grassland. The reduction was more pronounced on GE (-11 %) compared to DK (-4 %) dairy farms.

Keywords: grassland resowing, nitrogen balance

Introduction

During two European workshops on nutrient management in dairy farming systems (Taube and Conijn, 2004; Pflimlin *et al*., 2004), it was suggested that grass-arable crop rotations offered the possibility of reducing the currently high farm N surpluses observed in intensive dairy farming. This hypothesis is based on the observation that soil-N accumulated during the grassland phase (especially on grazed swards), can be utilised more efficiently by the succeeding arable crop than by permanent grassland. This N-saving effect has been proven at the plot and field scale, and is already part of fertilising regulations in Denmark. In order to provide an estimate of this effect at the farm scale, N balances have been estimated for typical DK and GE dairy farms combined with two different methods for grassland renovation.

Materials and methods

In DK, grass is usually grown in rotation with other forage and cereal crops. This contrasts with GE dairy farms, which depend on a high proportion of permanent grassland (similar to the situation in many other European regions). Such typical farming systems are described by data sets from a large number of commercial dairy farms (Anonymous, 2001; Kristensen *et al*., 2004). However, due to many interacting factors in crop and livestock production, a simple comparison of N balances as calculated at farm level cannot be used to quantify the effect of grassland duration at the farm scale. In this paper the effect at the farm scale is estimated by adjusting two major factors simultaneously. Factor 1, was the crop rotation; representative farms were ‘converted’ in an opposite direction: i.e., DK to permanent and GE to rotation grassland. The crop rotation system (CR) was defined as a 2-year ley (grass/clover in DK, pure grass in GE) in rotation, while the permanent grassland system (PG) was defined to be resown every 6 years. This was done using the relationship between grassland age and productivity, as determined in DK trials (Table 1). Factor 2 accounted for the carry-over affect equivalent to a reduction of 65 kg N ha^{-1} in the fertiliser applied to the arable crop sown after grassland has been ploughed. This amount was determined at both the plot and the field scale in several trials (Eriksen, 2001), and has become part of DK fertilising regulations.

These were the only factors used to calculate N balances of 'untypical' systems (permanent grassland in DK, and crop rotation in GE). All other factors remained constant *within each country* in order to estimate the pure effect of grassland duration at the farm scale.

The change of grassland duration influence the grass-yield (DM * N) and change the amount of manure on grass and slurry, and thereby the utilisation of N in manure. At the system level, these effects are adjusted by changes in imports of concentrate and fertiliser N. Also the direct effect of soil-N carry over is adjusted by changing N fertiliser import. In GE, only 15 % of the farm area was grown with cash crops, which is only sufficient to allow 45 % of the area to be grown with 3-year-old rotational grass.

Table 1. Yields in Danish field trials as affected by ley age (absolute [t DM ha^{-1}], rel [%] yields).

	Production year after establishment									
	1		2		3		4		5	
	abs.	rel.	abs.	rel.	abs.	rel.	abs.	rel.	abs.	rel.
L. perenne / *T. repens* [1]	8.8	112	7.9	100	7.9	101	8.3	106		
L. perenne (intermediate cultivars) [1]	13.3	118	11.3	100						
L. perenne (late cultivars) [1]	13.1	120	11.0	100						
L. perenne / *T. repens* [2]	10.9	115	9.5	100	7.9	83	7.3	77	7.3	77

[1] Jensen (1987), *pers. comm.*: average of 10 experimental years at 8 sites, 4-6 cuts per season, N fertilisation: 0 kg N ha^{-1} to grass/clover, 450 kg N ha^{-1} to pure ryegrass. Average of +/- irrigation.

[2] Gregersen (1980): 2 × 5 experimental years at 5 sites, 5 cuts per season, 150 kg N ha^{-1}. Unirrigated.

Results and discussion

According to observed ‘real farm data’, there is a considerable proportion of grassland in both countries which cannot be ploughed (9 % and 14 %, respectively, Table 2). On average the farm-gate N surplus on DK dairy farms with a high proportion of leys, is 18 kg N ha^{-1} lower than on the corresponding GE farms. By keeping the prevailing management conditions in each country constant, increasing the proportion of leys at the expense of permanent grassland reduced the farm-gate N surplus in both countries. The reduction was greater under GE (-20 kg N ha^{-1} or -11 %) than under DK conditions (-7 kg N ha^{-1} or -4 %). As the total proportion of grassland is higher on GE dairy farms, a higher permanent grassland area could be replaced by leys (28 % of the farm area vs. 13 % in DK, Table 2). In the calculated GE crop rotation (CR) system, 15 % of the farm area could be grown with cash crops in the first year after the ley. In these crops, the carry-over effect meant 65 kg fertiliser-N ha^{-1} could be saved, which reduced the N-fertiliser input at the farm level by 10 kg N ha^{-1}. The young grassland gave a higher DM- and N-yield compared to permanent grass (Table 1). As the herd N efficiency was constant, the extra N yield reduces the N import through concentrates by 13 %.

Even though the calculated ‘untypical’ systems (DK-PG and GE-CR) cannot be validated by measured farm data, the present calculations give a reasonable estimation since the documented typical farm management practices in DK and GE remained unchanged. The effects measured at the plot and field scale can contribute to reduced N surpluses and, consequently, N losses to the environment, irrespective of other management practices which differ between DK and GE dairy farms (e.g., feeding, herd management etc.). The area of permanent grassland, which can be converted into ley-arable crop rotations, has a predominant role on the amount of N that can be saved within the system. The optimal grass area in relation to reduced losses is probably between the two countries: higher than 20 % in DK because of the 4 years between grass/clover, and lower than the 42 % grass plus 23 % maize in GE, because only one year of cereals can be grown between grass. In DK organic farms, the calculated N-surplus was 40 % lower than the shown DK CR system. Organic farms have 42 % grass/clover-area and low fertilisation level (Kristensen *et al*., 2004).

Conclusions

The present analysis, based on empirical farm data and observations at the plot and field scale, show that grass-arable crop rotations can help reduce farm-gate N surpluses under the soil and climatic conditions of DK and GE. The proportion of permanent grassland, which can potentially be converted into ley-arable rotations, was found to be an important factor for the magnitude of the N-saving effect at the farm scale.

Table 2. N balances (farm-gate, field and herd level) for dairy farming systems in Denmark and Northern Germany, compared for permanent grassland-based (PG) versus ley-arable crop rotation (CR) systems.

	DENMARK		N. GERMANY	
System	CR	PG	CR	PG
Stocking rate [LSU ha^{-1}]	1.43	1.43	1.28	1.28
Milk production [kg FPCM ha^{-1}]	6614	6614	6922	6922
Permanent grassland + ley [% of farm area]	9 + 20	22 + 7	14 + 42	42 + 14
N import (farm gate) [kg N ha^{-1}]				
Mineral fertiliser	95	99	120	130
Biological N_2 fixation	26	23	0	0
Atmospheric N deposition	16	16	30	30
Concentrates	85	91	75	85
Other (livestock, manure, roughage, seeds, *etc*.)	2	2	1	1
N export (farm gate) [kg N ha^{-1}]				
Milk	35	35	34	34
Livestock	8	8	7	7
Cash crops	12	12	19	19
Field N surplus† [kg N ha^{-1}] (field efficiency)	151 (46 %)	159 (44 %)	148 (53 %)	168 (48 %)
Herd N surplus$ [kg N LSU^{-1}] (herd efficiency)	113 (21 %)	113 (21 %)	143 (19 %)	143 (19 %)
Farm-gate N surplus [kg N ha^{-1}]	169	176	166	186

† Field N surplus = (mineral N fertiliser + N_2 fixation + atmospheric deposition + seeds + manure + excreta) – (cash crops + fodder crops).

$ Herd N surplus (amount of manure produced) = (Fodder crops + concentrates + imported livestock) – (milk + exported livestock).

Data sources: Anonymous (2001) (GE-PG), Kristensen *et al*., (2004) (DK-CR), calculated DK-PG, GE-CR) as described in the text.

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Are structural plant traits relevant indicators of fertility level and cutting frequency in natural grasslands ?

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Abstract

Today, technical advisers need some simple and efficient tools in order to manage natural grassland vegetation. In the last few years, in response to this need, a functional trait-based approach has been developed to characterise natural grasslands through the attributes of their dominant species. This approach should provide, in a first stage, a characterisation of the factors acting on the vegetation and then, an evaluation of its 'use value'. In this work, five plant structural traits were tested for their ability to describe gradients of both fertility and frequency of cutting. Plant traits were measured on species contributing at least 80 % of the standing biomass. Measures were taken in an experimental design where both factors were independent. Results show that the fertility gradient is well described by leaf traits irrespective of weighting or not trait values by the specific abundance. On the contrary, no significant effect was shown on the cutting frequency gradient. We hypothesise that this result is the consequence of a lack in size adaptation (reduction) of leaves to the different cutting regimes, due to an excessively late first cut applied in the defoliation treatments.

Keywords: dry matter content, specific leaf area, natural grasslands, environmental factors, diagnosis

Introduction

Despite the use of natural grasslands for centuries, technical advisers today express a need for tools to manage the vegetation of these grasslands. In other words, they need some simple and efficient methods to evaluate the effects of variations in the factors which drive vegetation dynamics in these grasslands on the 'use value' of the grassland, i.e., on its agronomic characteristics (e.g., maximum of production, fodder quality). In the Pyrenees, these two factors, namely the fertility level and the intensity of use, are also the factors that farmers can control through fertilisation and defoliation practices (mowing and/or grazing).

In this context, we tested an approach derived from ecology: the Plant Functional Trait approach (e.g., Weiher *et al.* 1999). Functional traits are characteristics that inform on the functioning of the plants and, by extension, of the vegetation the species belong to. Traits could be used on the one hand, as indicators characterising gradients of the environmental factors acting on the vegetation and on the other hand, as indicators used to assess the agronomic value of the grassland. Testing the pertinence of these traits, respectively 'response traits' and 'effect traits' (Lavorel and Garnier, 2002), in an agronomic context is a preliminary to future work destined to build more complete trait-based tools to manage natural vegetations. In this paper, we present the first stage of this approach, where we studied the ability of plant structural traits to describe gradients of mineral nutrition and intensity of use.

Materials and methods

We used an experimental design set up in 1999 located in Ariège (Pyrenees, France). It separates the two factors, fertility level and intensity of use, whereas in natural conditions these are not independent. In our study, the fertility level is described by the Nitrogen Nutrition Index (Lemaire and Gastal, 1997). Phosphorus and potassium are supplied in quantities that are considered not to be limiting for growth. The intensity of use corresponds here to cutting frequency. Five treatments, replicated four times and distributed along the two gradients, were chosen (Figure 1).

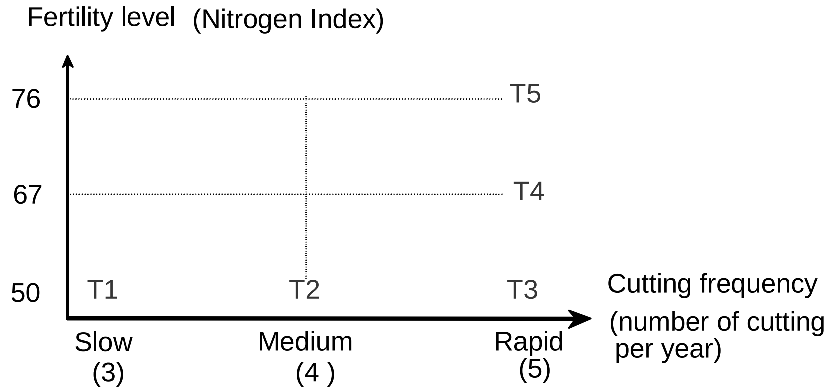

Figure 1. Description of the experimental design with the 2 gradients of fertility level and cutting frequency as axes. The treatments (from T1 to T5) are indicated along them. A Nitrogen Nutrition Index above 80 corresponds to a non-limiting situation, between 60 and 80 corresponds to a nitrogen limitation and below 60, N is very limiting.

In April, at the vegetative stage of most of the plant species, five structural traits were measured: specific leaf area (SLA, equation 1), leaf and stem dry matter content (LDMC and SDMC, equation 2), vegetative height of the plant and length of the blade.

SLA (m^2 kg^{-1}) = leaf area / leaf dry-oven mass (1)
Leaf or stem DMC (g g^{-1}) = (dry-oven mass / fresh mass) (2)

Trait measures were made on species contributing at least 80 % of the standing biomass. Only the results concerning grasses are discussed in this paper. The responses of the plants to each factor, through variations of the traits along the gradients, were studied. The present results concern only the values of these traits at the plant community level i.e., the ‘community average’ values. In order to obtain these values, we used 2 ways of calculation and tested them. The first one corresponds to a ‘weighting method’ in which each specific trait value is weighted by the specific abundance and the whole is summed. The second way, ‘not weighting method’, corresponds to an arithmetic mean; that is to say that all the specific trait values are summed and this sum is divided by the total number of measured species.

Results and discussion

Concerning the fertility level, all the measured traits show a significant variation along the gradient except not weighted blade length. The strongest ‘response’ traits are the two DMC (LDMC and SDMC, Table 1).
In general, there is no difference between weighted and not weighted values (Table 1): taking into account the specific abundance does not provide more information. This is an interesting result to develop new management tools, because it enables a simplification of the botanical assessment so that people will only be required to note the identity of the species present and determine visually which are dominant.
Traits seem less suitable for describing the cutting frequency gradient than the fertility one. Although height and blade length are known to vary with this factor (e.g., Liira and

Zobel, 2000), we observed no significant response in our study. In fact, only weighted SLA increased significantly in response to the variations of the cutting frequency (Table 1).

Table 1. Responses of the traits to fertility and cutting frequency. Significance and direction of variation of each trait, for the two methods of calculation along the two gradients, are specified. '+' indicates an increase when the factor (fertility or cutting frequency) increases. 'w' and 'nw' correspond respectively to weighted and not weighted.

		Fertility level		Cutting frequency	
Method of calculation	Trait	significance	direction of variation	significance	direction of variation
w	SLA	***	+	*	+
nw	SLA	*	+	ns	
w	LDMC	*	-	ns	
nw	LDMC	*	-	ns	
w	SDMC	**	-	ns	
nw	SDMC	**	-	ns	
w	Height	***	+	ns	
nw	Height	**	+	ns	
w	Lamina Length	*	+	ns	
nw	Lamina Length	ns		ns	

This lack of response could be explained by a first cut which occurred too late in the development of the plants, namely at the beginning of the reproductive stage. In fact, as the measured traits are 'vegetative' traits, they could not respond to a cut occurring beyond the vegetative stage. With an earlier first cut, as cutting frequency increases, the blade length should decrease (Duru *et al.*, 1999). Reduction in leaf size would involve a change in cell number but not in cell size (Körner *et al.*, 1989). As a consequence, it should lead to a decrease in the proportion of structural tissue in the leaf, implying a decrease in LDMC and an increase in SLA. This hypothesis needs to be tested under cutting regimes inducing a reduction in leaf size.

Conclusions

Structural traits, and more precisely leaf and stem DMC, seem to be relevant to diagnose the fertility level of natural grasslands. The fact that specific abundances are not useful is important in terms of simplifying future tools (it provides a more simple botanical evaluation). Only one trait responds to the cutting frequency, namely weighted SLA. The reasons for the lack of response of the structural traits to the cutting frequency will be analysed in future work.

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Mapping grazing activity and sward variability improves our understanding of plant-animal interaction in heterogeneous grasslands

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Abstract

At low stocking rates, selective grazing creates and increases heterogeneity of sward in quantity and quality. We hypothesise that after ear emergence, animals preferentially graze previously short well-grazed areas (H0) of better quality, thus reinforcing the development of sward heterogeneity. To test this hypothesis at the plot scale we recorded animal locations during grazing in May, July and September by the Global Positioning System (GPS), and we mapped sward surface height on a 3025 m^2 cocksfoot paddock grazed by 5 dry ewes. Using a Geographic Information System (GIS) we crossed the vegetation maps with animal frequentation to identify functional areas for plant-animal interaction. The proportion of consistent areas for H0 was always higher than that for the reverse hypothesis. The remaining areas could be explained by external factors such as a water point or sleeping area. This confirms that the uneven utilisation of a vegetation resource by animals results from complex plant-animal interactions.

Keywords: grazing behaviour, spatial analysis, Geographic Information System, Global Positioning System, sheep

Introduction

At grazing, when herbage on offer exceeds animals' needs, the development of sward heterogeneity results from the differentiation of well-grazed areas that remain short and vegetative (good quality and low quantity) and under-grazed areas that evolve to the reproductive stage (low quality and high quantity) (Adler *et al*., 2001). As sheep maximise the quality of their intake on heterogeneous grasslands (Garcia *et al*., 2003a), we hypothesise that after ear emergence, the animals preferentially graze the previously short well-grazed areas of better quality. This selective defoliation would be expected to reinforce the development of sward heterogeneity. A way to test this hypothesis at the plot scale is to analyse, through spatially explicit measurements, the relationship between sward height and grazing activity. For a plot managed with a low stocking rate we followed the spatial evolution of the sward height and recorded the spatial utilisation of the plot during grazing, using the Global Positioning System (GPS). Using a Geographical Information System (GIS) we investigated the fit between contrasted grazing activity areas and contrasted sward height areas.

Materials and methods

We conducted the experiment in an upland area of central France (900 m asl). Five INRA401 dry ewes (54.8 kg ± 1.15) grazed a 2-year-old cocksfoot (*Dactylis glomerata* cv. Lupré) plot of 3025 m² from 13 April to 25 September 2000. This low stocking rate ensured marked undergrazing. Grazing activity of the ewes and the sward characteristics were successively mapped during three periods, at the onset of ear emergence (15 May – 8 June); around flowering (26 June – 17 July) and at a mature stage (11 September – 2 October).

For each period, the vegetation was spatially categorized and drawn on 5 × 5 m quadrats covering the whole paddock. We noted the sward height using sward stick for each category (n = 20) within the quadrats. This allowed us to create a map of sward height on a 1 × 1 m grid. Animal locations during grazing were assessed simultaneously using GPS (Magellan GPS ProMark) to record animal positions in the paddock and 'Ethosys' collars (IMF Technology GmbH, Frankfurt, Germany) to record grazing activity. At least two 6 hour recordings per ewe and per period were made. For each period, all the locations recorded in each 1 × 1 m element of the grid were cumulated to create a map of the spatial utilisation of the paddock during grazing. The hypothesis of 'preference for short areas' (H0) was translated by a negative relation between frequentation and sward height. We tested H0 against its reverse 'preference for tall areas' (H1) as follows. We imported the grazing activity and the sward height maps in a GIS (Arcview 3.2.). The grazing frequentation and the sward height data were split into three classes using the 'quantile' method. By crossing the classes of sward height and of frequentation, we defined four compartments of consistency within the nine cells of the coherence matrix (Table 1): consistent for H0, consistent for H1, consistent for H0 and H1, Undefined.

Table 1. Coherence matrix for the hypotheses H0 (preference for short areas) and H1.

		Sward Surface Height		
		Class 1 = short	Class 2 = medium	Class 3 = tall
Frequentation	Class 1 = low	Consistent for H1	Undefined	Consistent for H0
	Class 2 = medium	Undefined	Consistent for H0 and H1	Undefined
	Class 3 = high	Consistent for H0	Undefined	Consistent for H1

Results and discussion

The average sward surface height increased between June and July from 36 ± 14.5 cm to 49 ± 21.3 cm, and then dropped to 37 ± 17.3 cm in the autumn. The sward variability was maximal in the summer period, as shown in the vegetation characteristics maps (Figure 1).

Table 2. Percentages of total areas consistent for hypothesis H0 (preference for short areas), for the reverse hypothesis H1, for both hypotheses, or undefined at each period. The table gives the proportion of short and tall areas within the consistent areas.

	15 May – 8 June		26 June – 17 July		11 September – 2 October	
	H0	H1	H0	H1	H0	H1
Consistent areas:	26.5	19.2	35.1	14.4	30.3	25.9
Short areas	12.1	10.0	14.4	7.6	6.5	21.4
Tall areas	14.4	9.2	20.7	6.8	23.8	4.5
Consistent areas for both hypotheses	11.8		10.8		5.2	
Undefined	42.5		39.7		38.6	

The proportion of consistent areas for H0 was always higher than that for H1 (Table 2). We observed the greatest difference in early summer. However, a relatively high proportion of areas (around 40 %) remained unexplained by our hypotheses. This result may be due to the complexity of the structure created and the existence of attractive points such as the entry to the paddock, the sleeping area and the water point.

In May, the difference in consistency between the two hypotheses was low but the negative correlation between the frequency of defoliation and the tiller height was significant (Garcia *et al.*, 2002). The ewes partially preferred the short areas at the beginning of ear emergence.

In early July, the organisation of heterogeneity was characterised by tall-avoided areas at the left and bottom (Figure 1). The higher proportion of areas consistent for H0 confirms the validity of the hypothesis of ‘preference for short areas’ in the summer period. The areas consistent with the H0 hypothesis were principally tall-avoided areas, suggesting the ewes might be avoiding tall areas rather than preferring short ones. The ewes prefer the areas of better green leaf proportion whatever the sward height but between swards of similar green leaf proportion, they prefer the higher areas (Garcia *et al*. 2003b). This hierarchy of decision may lead to complexity of choices between short and medium areas.
In September, the difference of consistency between the two hypotheses was low. However, the ewes still avoided the tall areas as shown by the high proportion of tall areas within the consistent areas for H0 (78.6 %).

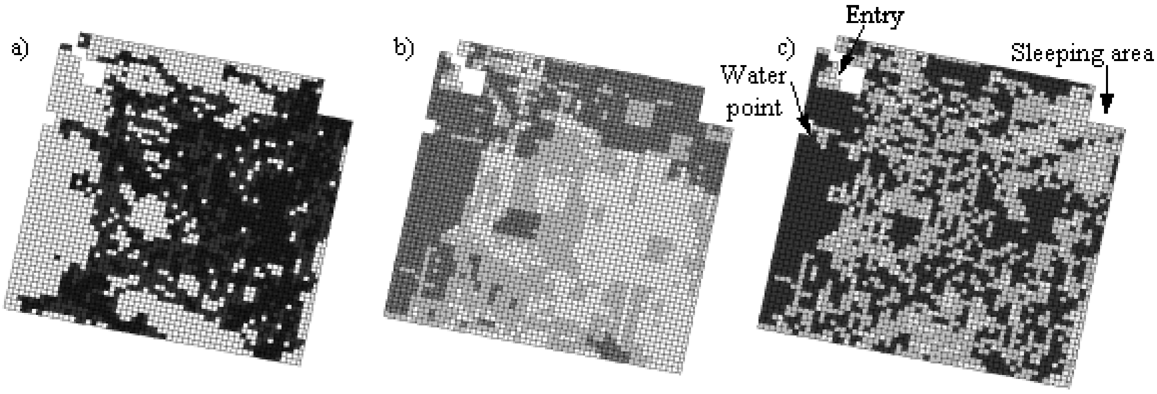

Figure 1. Maps of the frequentation a), the sward surface height b) and the consistency for H0 c) in the summer period. Darker shading indicates higher values of frequentation and sward height. The darker shade on map c) indicates the areas consistent for H0.

Conclusions

The hypothesis of preference for ‘short areas’ seems valid at the end of spring and in summer when the sward becomes uneven in quality and quantity. The constantly higher proportion of areas consistent for H0 than for H1 suggests the positive retroaction of grazing on quality is a key mechanism of the process. However, our results also suggest that this does not take into account the full complexity of the plant-animal interaction.
The use of superimposed maps helped us to test the hypotheses on plant-animal relationships at the plot scale, allowing the spatial referencing of consistent areas. The investigation of more complex hypotheses may allow improvements of this approach through a greater proportion of explained areas.

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Tissue turnover during the winter in a perennial ryegrass sward

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Abstract

The objective of this experiment was to examine the effect of regrowth interval during the winter on tissue turnover in a perennial ryegrass sward in Ireland on which to base decisions on the optimum time to close off and utilise herbage for out-of-season grazing.

Tissue turnover was measured at three-week intervals from mid-October until the end of January at two sites. Thirty tillers were labelled in mid-October in plots with regrowth from the 1 September, 20 September and 10 October. Leaf extension rate (LER) (mm tiller^{-1} d^{-1}), leaf appearance rate (LAR) (leaves d^{-1}) and leaf senescence rate (LSR) (mm tiller^{-1}d^{-1}) was calculated over the winter.

The longer regrowth periods had higher LER, LAR and LSR than the shorter regrowth periods at both sites (P < 0.001). Over the winter, LER was lowest between mid-December and the start of January, after which it increased. Leaf appearance rate was lowest in mid-winter (0.015-0.021 leaves d^{-1}). This increased rapidly to 0.039-0.05 leaves d^{-1} by the end of January. Leaf senescence rate generally decreased to the end of December, after which it increased.

While there is potential to defer grass grown in autumn for grazing in winter, if regrowth interval is unduly long due to earlier closing, high LSR reduces the benefits accrued from high LAR and LER.

Keywords: leaf appearance rate, leaf extension rate, leaf senescence rate, tissue turnover

Introduction

Grazed grass is the cheapest source of feed for beef and milk production in Ireland. However, there is poor synchrony between grass supply and feed demand. Grass growth in Ireland peaks in May/June with a secondary peak in July. Net grass growth is reduced from December to February. However, tissue turnover is continuous during winter with new leaves being produced and older leaves senescing. On farms with low stocking rates there is the potential to provide grass during the winter by using appropriate autumn rotation intervals (French and O'Donovan, 2002). The objective of this experiment was to examine the effect of deferring grass grown in early autumn for winter grazing on tissue turnover in the sward to underpin decision-making on closing dates and subsequent grass utilisation.

Materials and methods

This experiment was part of a larger three year experiment that took place from August 2000 to July 2003. A long-term perennial ryegrass (*Lolium perenne*) sward was divided into 64 plots (90 m^2 each) at 2 sites. The experiment examined the effect of four closing dates (10 August, 1 September, 20 September and 10 October) and four grazing dates (20 November, 20 December, 20 January, and 20 February) at two sites on DM production, subsequent grass growth and tiller densities, as described by French and O'Donovan (2002) and Hennessy *et al*. (2003). Tissue turnover was measured from mid-October 2001 to the end of January 2002 using a randomised complete split block design for site and closing date with measurement period as a split plot on site and closing date. The treatments were two sites –

Teagasc Grange Research Centre, Dunsany, Co. Meath (lat. 53° long. 6°) (site 1) and Teagasc Moorepark Research Centre, Fermoy, Co. Cork (lat. 50° long. 8°) (site 2); three closing dates – 1 September, 20 September and 10 October; and one grazing date – 20 February. Plots were grazed with non-lactating cows. Thirty tillers were selected at 0.15 m intervals along a 1.5 m transect at three random locations within each plot. The tillers were labelled using twists of coloured plastic coated wire. Tillers were measured at 3-week intervals from 16 October to 28 January. At each recording the length of green leaf lamina, stem and pseudostem were measured. Leaf extension rate (mm tiller^{-1} d^{-1}), LAR (rate of new leaf appearance tiller^{-1} d^{-1}) and LSR (leaf senescence rate tiller^{-1} day^{-1}) were calculated for three-week periods over the winter. Data were analysed using ANOVA.

Results and discussion

Leaf extension rate (Table 1) decreased for all treatments from mid-October to early January and increased thereafter. Closing date and measurement period had a significant effect ($P < 0.01$) on LER, and there was a significant interaction between the two. Leaf extension rate was higher for the two September closing dates than for the October closing date. Leaf appearance rate (Table 1) followed a similar trend to that for LER. Between 48 and 70 days were required to produce a new leaf in mid-winter and this decreased to between 21 and 26 days by late January as LAR increased. Closing date and measurement period both had a significant effect ($P < 0.001$) on LAR. The earlier closing dates had lower LAR to mid-December, but LAR was similar on all treatments thereafter. Leaf senescence rate (Table 1) followed a similar trend to that for LER and LAR. Leaf senescence rate decreased from mid-October to early January and increased thereafter. As for LER and LAR, closing date and measurement period had a significant effect ($P < 0.001$) on LSR. The earlier closing treatments (1 Sept and 20 Sept) had higher LSR than the October closing treatment at all measurement periods.

Table 1. Effect of closing date (CD) and measurement period (MP) on LER (mm tilller^{-1}d^{-1}), LAR (leaves d^{-1}) and LSR (mm tiller^{-1}d^{-1}) averaged over the two sites.

		Closing Date		
	Measurement Period	1 Sept	20 Sept	10 Oct
LER	16 Oct – 5 Nov	9.605	8.361	6.955
	5 Nov – 26 Nov	7.125	5.935	4.773
	26 Nov – 17 Dec	4.498	4.396	3.398
	17 Dec – 7 Jan	2.363	2.838	1.989
	7 Jan – 28 Jan	5.812	5.921	4.676
			s.e. = 0.268	
			CD = ** MP =*** CD x MP =**	
LAR	16 Oct – 5 Nov	0.046	0.051	0.069
	5 Nov – 26 Nov	0.036	0.037	0.047
	26 Nov – 17 Dec	0.028	0.030	0.031
	17 Dec – 7 Jan	0.016	0.020	0.019
	7 Jan – 28 Jan	0.044	0.045	0.047
			s.e. = 0.016	
			CD = *** MP =*** CD x MP =***	
LSR	16 Oct – 5 Nov	11.896	6.188	2.829
	5 Nov – 26 Nov	9.341	3.807	2.297
	26 Nov – 17 Dec	8.040	5.852	3.839
	17 Dec – 7 Jan	5.367	3.856	1.622
	7 Jan – 28 Jan	9.597	10.672	2.325
			s.e. = 0.832	
			CD = *** MP =*** CD x MP =***	

Dry matter yield (Table 2) decreased over the winter in all but the 10 October closing treatment, with rate of decline being related to earliness of closing date. By January, differences between yields of contrasting closing treatments were small. The greater herbage yields in early winter in early closing treatments is not only a function of longer regrowth period but also faster leaf extension rates at this time. However, although LER and LAR were lower in the later closing date treatments, the rate of decline with advance into winter was slower and senescence rates were consistently low resulting in only small differences in herbage yield in late winter between closing treatments.

Table 2. Effect of closing date (CD) and grazing date (GD) on DM yield (kg DM ha^{-1}) averaged over the two sites.

	Closing Date			
Grazing Date	10 Aug	1 Sept	20 Sept	10 Oct
20 Nov	3326	2665	1752	1696
20 Dec	2726	2261	1506	1000
20 Jan	2293	2163	1535	1355
20 Feb	1326	1789	1335	1612
	s.e. = 146			
	CD = *** GD = *** CD x GD = ***			

Conclusions

This study demonstrates that there is potential to defer grass grown in the autumn for grazing in the winter. However, there are limits to the length of regrowth period between closing and utilisation. While the earlier closing dates increase DM yield in autumn, delaying grazing beyond an optimum date reduces DM yield. So while earlier closing in the autumn increases LER and LAR, these decline more rapidly and LSR continues at a higher level throughout winter than in later closed swards. In addition, although not considered in this study, heavy herbage masses carried into winter will reduce tiller density resulting in further increases in senescence rate in the canopy.

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Vegetation typology as a management tool for intra-alpine summer pastures

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Abstract

The ecological and management features are quite homogeneous in the summer pastures of the intra-alpine zone including mid to upper Maurienne and Tarentaise in France, and Valle d'Aosta, in Italy. The alpine level shows its maximum development in the inner Alps and is characterised by a wider variety of plant communities because of the bio-geographic conditions. In these regions, the economical and ecological role of upland pastures is of primary importance for farming systems and for preservation of the environment. A classification of plant communities in alpine pastures on both sides of the north-western Alps is proposed within a common research framework. This typology, based on multivariate analysis of the abundance of species in about 600 vegetation relevés, is for use by technicians and is presented with a simplified dichotomous key. Physiognomy, vegetation composition and phytosociological features are presented for each type, as well as the detailed environmental conditions and the utilisation value of the pastures. The characterisation of the vegetation, from a floristic and an agronomic point of view, provide the basic knowledge to define appropriate management schemes.

Keywords: NW Alps, botanical composition, potential stocking rate, diversity, diagnosis

Introduction

Summer pastures represent a key resource in the forage systems on dairy farms on both sides of the north-western Alps (Tarello *et al*., 2000). Since their floristic composition is influenced by the combined effects of physical environment and management practices, it is necessary to apply a management scheme adapted to their production potential, precocity and fragility if these grasslands, with their economic and ecological value, are to be preserved. For these reasons, different studies have been carried out over the last few years in order to provide field technicians with practical diagnostic tools for recognizing the main vegetation types and evaluating the correct stocking rate and the best period for grazing (Bornard and Dubost, 1992; Jouglet, 1999). Since any typology has only limited geographical application potential, those types identified in the outer valleys of the French Alps were difficult to apply to the inner Alps, where the bio-geographic conditions are particular. Because the high mountain massifs isolate these regions from Atlantic and Mediterranean influences, they receive relatively low precipitation: the annual rainfall, at 2000 m asl, ranges between 1000 and 1500 mm. The absence of summer mist, the wide temperature range and the accelerated snow melting due to the foehn wind lead to a lengthening of the growing season and to the raising of the altitudinal limits of the vegetation belts: the alpine level is at its maximal development and a wider variety of plant communities is observed.

Materials and methods

This work was carried out in the intra-alpine zone of the north-western Alps: Valle d'Aosta (I) and Vanoise (F). The floristic database was made up of 578 linear relevés carried out according to the Daget and Poissonet method in 83 mountain pastures (380 in 38 mountain pastures on the Italian side and 198 in 45 mountain pastures on the French side), thus embracing the regional variation in geological, topographical and management features. To follow grass production trends, phytomass samples were taken weekly in 33 sites during several summers, from 1987 to 1998, and another 76 samples were cut to evaluate herbage production in different pastures. Vegetation relevés were analysed by Factorial Correspondence Analysis followed by Hierarchical Cluster Analysis.

Results and discussion

All the floristic relevés were clustered into 23 types of vegetation: 19 grasslands, 3 heaths and one community on stony slopes. The initial hypothesis that the plant communities in the Italian and French inner Alps were substantially similar was confirmed: only one type (S6, dominated by *Festuca paniculata*, *Carex sempervirens* and *F. rubra*) was not common to both regions, due to the absence of *F. paniculata* in the Valle d'Aosta. Grassland types consisted of 6 subalpine, 3 transitional and 10 alpine plant communities (Table 1).

Table 1. Main species of the plant communities in the summer pastures of the study area.

Subalpine grasslands	
S1	*Nardus stricta*, *Festuca rubra*, *Plantago alpina*
S2	*Festuca rubra*, *Alchemilla xanthochlora*, *Agrostis capillaris*
S3	*Dactylis glomerata*, *Festuca rubra*, *Agrostis capillaris*
S4	*Onobrychis montana*, *Festuca ovina*, *Sesleria albicans*
S5	*Brachypodium pinnatum*, *Carex sempervirens*, *Festuca ovina*
S6	*Festuca paniculata*, *Carex sempervirens*, *Festuca. rubra*
Subalpine-alpine grasslands	
SA1	*Sesleria albicans*, *Carex sempervirens*
SA2	*Helianthemum nummularium*, *Carex sempervirens*
SA3	*Dryas octopetala*, *Carex sempervirens*, *Sesleria albicans*
Alpine grasslands	
A1	*Plantago alpina*, *Festuca ovina*, *Potentilla grandiflora*
A2	*Festuca violacea*, *Carex sempervirens*, *Festuca. rubra*, *Potentilla grandiflora*
A3	*Helictotrichon parlatorei*, *Helianthemum nummularium*, *Festuca violacea*
A4	*Festuca halleri*, *Potentilla aurea*, *Avenula versicolor*
A5	*Carex curvula*, *Trifolium alpinum*, *Avenula versicolor*
A6	*Kobresia myosuroides*, *Avenula versicolor*, *Festuca quadriflora*, *Carex rosae*
A7	*Trifolium alpinum*, *Festuca halleri*
A8	*Nardus stricta*, *Carex sempervirens*, *Trifolium alpinum*, *Festuca rubra*
A9	*Alchemilla pentaphyllea*, *Salix herbacea*, *Carex foetida*, *Plantago alpina*
A10	*Alopecurus gerardii*, *Plantago alpina*
Heaths	
L1	*Loiseleuria procumbens*, *Vaccinium uliginosum*, *Avenula versicolor*
L2	*Juniperus nana*, *Vaccinium uliginosum*, *Arctostaphylos uva-ursi*, *Vaccinium. myrtillus*
L3	*Rhododendron ferrugineum*, *Vaccinium uliginosum*
Stony slopes	
E	*Achillea nana*, *Salix retusa*

The results have been summarized in a field guide, published both in Italian and in French (Bornard and Bassignana, 2001), intended for technicians and advisors in the extension services. In the field, the identification of types follows a dichotomous key relying upon locality and topography of the site, sward appearance and, lastly, identification of the main species. Overall physiognomy, dominant and indicative species and phytosociological classification are presented for each type, as well as sub-communities, if they occur. The presentation of the agro-environmental features takes into account the altitudinal limits, prevailing aspect, topography, geological substratum and soil type, as well as usual management practices. The utilisation value of pastures includes: palatability evaluation, average dry matter yield and Pastoral Value index, potential forage resource expressed in Feed Units for Milk (UFL) per hectare (Figure 1), sustainable stocking rate for cows, heifers or sheep, aptitude to regrow after grazing and best grazing period(s).

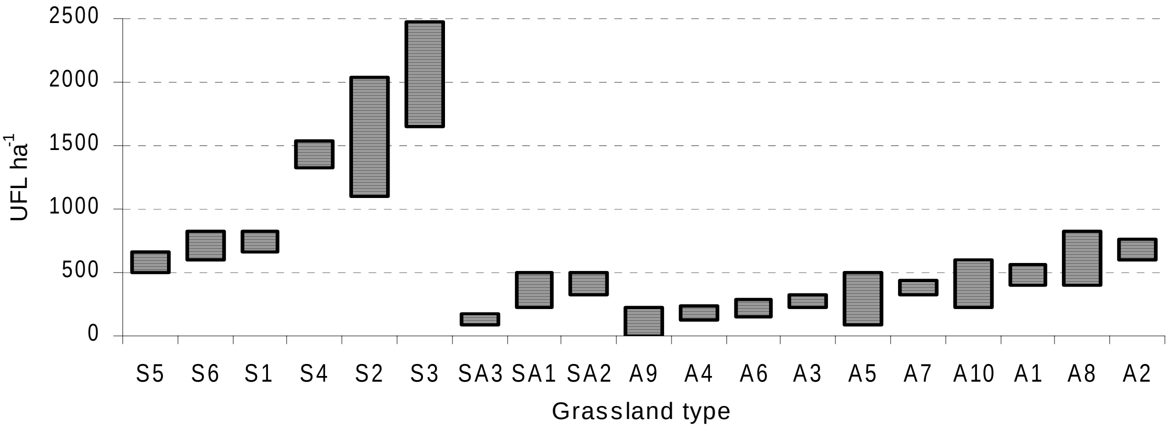

Figure 1. Ranges of potential forage resource (UFL ha^{-1}) in grassland types (code explanation in Table 1).

Conclusions

To complete the field guide, more detailed information will be required for each vegetation type concerning its classification according to Corine Biotope and to Natura 2000, its floristic diversity, different life forms, importance for wildlife, changes in management over the last decades, fodder potential, possible development and, finally, management suggestions to ensure sustainable utilisation of pastures, preserving both pastoral resources and diversity.

Acknowledgements

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Life Cycle Assessment of roughage production

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Abstract

Sustainable grassland management aims to produce high quality forage while limiting pressures on the environment and preserving landscape and biodiversity. An analysis of the environmental performances of roughage production and conservation is a prerequisite to designing environmentally sound grassland systems. Differences in environmental pressures among the processes of roughage production and conservation were identified and evaluated comprehensively for their effects on the environment by using the Life Cycle Assessment method. Roughage is produced under a wide range of environmental and management conditions. We investigated the effect of management intensity, yield, pasture, conservation technique and climatic conditions relevant for Switzerland. Large differences in the environmental impacts were found among the production processes in terms of the energy content of the fodder or of the cultivated area (so-called functional units). Roughage conservation accounts for a large part of these differences, such as the use of fossil energy resources and global warming potential. Management intensity strongly influences the eutrophication and acidification potential. A low input management has a positive effect on the environmental pressures per cultivated area unit but can be negative when considering the net energy for lactation produced. Differences between permanent grassland and temporary leys are also discussed.

Keywords: Life Cycle Assessment, environmental impact, roughage production, roughage conservation

Introduction

Methods of comprehensively assessing the environmental impacts of agricultural activities are needed to design sustainable production systems. Life Cycle Assessment (LCA) analyses a product's entire life cycle, including the production, transport and disposal of all means of production required and aims to evaluate all relevant impacts of the activity under study. We compared, at the plot level, the environmental impacts of different roughage production and conservation processes with the aim of identifying potentials to improve the environmental performance of roughage production.

Method

We used SALCA, the Swiss Agricultural Life Cycle Assessment Method (Nemecek *et al.*, 2003) to estimate potential emission rates at the plot level. All production processes taking place on the plot, as well as transportation to the barn, conservation and removal for feeding were included in the study. Emissions from the storage of farmyard manure were included but not the direct emissions from animal digestion. The impacts assessed were the use of non-renewable energy, aquatic and terrestrial eutrophication, global warming potential, ozone formation potential, aquatic and terrestrial ecotoxicity and human toxicity. The functional units (units of reference) used were the cultivated area of the plot multiplied by the duration of cultivation (ha x year) and the produced quantity of net energy for lactation (MJ NEL).

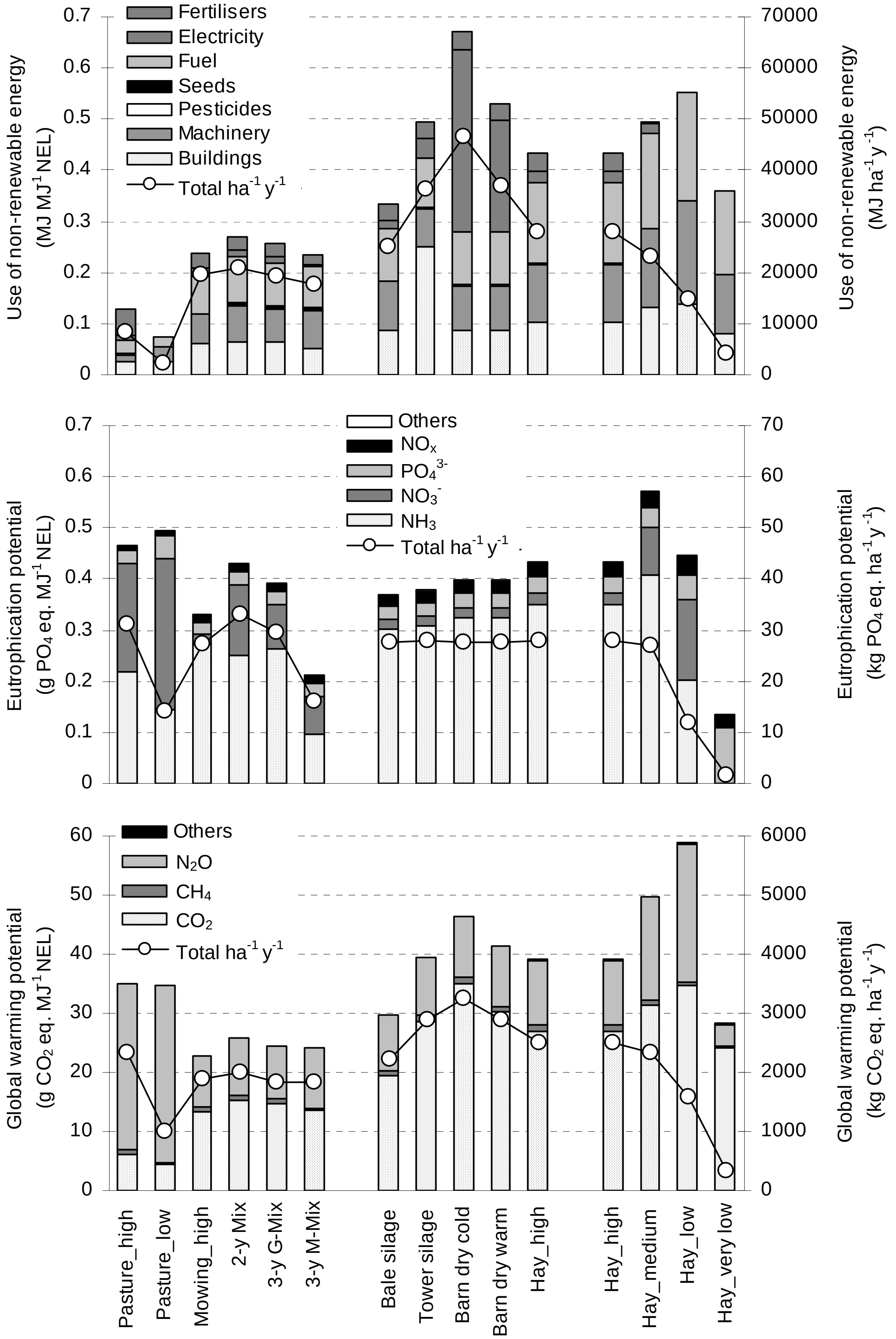

Figure 1. Use of non-renewable energy, potential for eutrophication and global warming potential of grazing pastures, permanent meadows and temporary leys, and for different roughage conservation processes and intensities of management for hay production. The characteristics of the production processes are presented in table 1. The bars represent loads per produced net energy for lactation (MJ NEL) and the line, per cultivated unit of area. eq. = equivalent.

Results

Differences in environmental impacts are large between the different processes of production and the ranking for environmental performance differs with the impact considered and the functional unit used (Figure 1). Mowing for daily feeding in the barn consumes significantly more energy than grazing pastures. The quantity of non-renewable energy used to establish leys is small compared to the energy used for total production. Solar heat collectors for barn drying can reduce the consumption of energy to the same level as ensiling in a tower silo, the construction of which contributes about half the energy used. The loads per hectare are lower at a low intensity of utilisation. Because the yield and the NEL concentration in the roughage decrease as the intensity of utilisation decreases, low intensity production generates more load per MJ NEL. This does not apply for very low intensity production where no fertiliser is applied. The main emission contributing to acidification is ammonia, followed by sulphur oxides and nitrogen oxides. Because less ammonia is produced by grazing pastures, this is favourable in regard to acidification. On the other hand, more nitrate and nitrous oxide are produced on pasture, which therefore appears negative for eutrophication and greenhouse effects. Red clover-grass leys that need much less nitrogen fertilisation to produce good yields are rated favourably for eutrophication and acidification.

Table 1. Description of the production processes presented in figure 1 for 1 ha and 1 year.

Variant	Description	N Input[a] kg N	Net yield t DM	MJ NEL kg^{-1} DM
Pasture_high	Stocking rate during pasture season: 3.40 cows ha^{-1}	290	10.1	6.6
Pasture_low	Stocking rate during pasture season: 1.65 cows ha^{-1}	100	4.9	5.8
Mowing_high	Daily mowing and transport to the barn, 5 cuts per year	196	12.7	6.5
2-y Mix	Ryegrass-clover ley, sowing year + 1 year, 5x mowing	224[b]	14.5[b]	6.5
3-y G-Mix	Grass-white clover ley, sowing year + 2 years, 5x mowing	199[b]	12.8[b]	6.5
3-y M-Mix	Red clover-grass ley, sowing year + 2 years, 4x mowing	43[b]	13.8[b]	6.1
Bale silage	5x ensiling in round bales	196	11.7	6.4
Tower silage	5x ensiling in a tower silo	196	11.5	6.4
Barn dry cold	5x barn drying, air not preheated	196	11.6	6.0
Barn dry warm	5x barn drying, solar heat collector	196	11.6	6.0
Hay_high	5x drying on the ground	196	11.1	5.8
Hay_medium	4x drying on the ground	147	9.0	5.2
Hay_low	3x drying on the ground	74	5.6	4.8
Hay_very low	1x drying on the ground	0	2.7	4.2

[a] Total nitrogen input in form of farmyard manure, mineral fertiliser, faeces and urine.
[b] Data for the years after the sowing year.

Conclusions

These results stress the importance of considering many environmental impacts when assessing the environmental performance of an agricultural production process. When the roughage is to be conserved, production of bale silage seems to have a better environmental performance. Without prejudice to the impact on biodiversity, which was not analysed in the present study and to the results of an analysis at farm level, it appears that a combination of plots managed at high and at very low intensity might be more promising from the environmental point of view than management at a medium intensity on the whole cultivated area.

References

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Energy efficiency in forage production

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Abstract

Based on experimental data gathered in the 'Karkendamm' project in Northern Germany, energy balances were drawn up for forage production systems with permanent grassland and silage maize. Both experiments comprised different cropping practices (defoliation regime in grassland; ryegrass under-storey in maize) and different rates of mineral N fertiliser and slurry application. In permanent grassland, each change from grazing to cutting decreased the energy efficiency. In both grassland and maize energy efficiency declined significantly with increasing rates of mineral N application. Net energy yields of silage maize were much higher than those of grassland when compared at the same level of fossil energy and nitrogen fertiliser input. It is suggested that a high proportion of silage maize in combination with N-unfertilised grass / clover swards can improve the efficiency of fossil energy use in forage production.

Keywords: defoliation system, grassland, maize, nitrogen, fossil energy

Introduction

Studies on the environmental impacts of intensive dairy farming have mostly addressed nitrogen (N) losses. This aspect, however, represents only one area of negative environmental impact. Energy balances provide a more integrative approach, since all inputs and outputs of the farming system and those at the site of production of external inputs (fertilisers, concentrates, etc.) are accounted for. In intensive dairy farming, most of the input of fossil energy is related to the acquisition of feedstuffs (e.g., concentrates, home-grown roughage). Thus, a less energy-intensive production/acquisition of feedstuffs is a key factor for improved energy efficiency and, at the same time, can reduce N surpluses in dairy farming. The objective of the present study was to quantify and analyse the input of fossil energy in forage production, as affected by management factors such as N input or defoliation regime, and the relationship between fossil energy input and productivity (i.e., the energy efficiency). Together with companion studies on N fluxes and N losses in forage production at the same site, it was hoped to outline environmentally sound management systems which would account for both N efficiency and energy efficiency.

Materials and methods

The present analysis is based on experimental data obtained in the 'Karkendamm' project in Northern Germany (Taube and Wachendorf, 2000). The grassland experiment was carried out with white clover / grass swards. Four defoliation regimes were analysed: grazing-only (GO), mixed systems with one (MS I) and two (MS II) silage cuts, and cutting-only (CO). Mineral N application rates were 0, 100, 200 and 300 kg N ha^{-1}. Slurry application was 0 and 20 m³ slurry per hectare, which corresponds to 0 and 70 kg N ha^{-1}, respectively (Trott *et al*., 2002).
Silage maize was grown in monoculture with and without undersown perennial ryegrass. Mineral N application rates were 0, 50, 100 and 150 kg N ha^{-1}. Cattle slurry was applied at three different rates (0, 20 and 40 m³ per hectare, corresponding to 0, 50 and 100 kg N ha^{-1}) (Jovanovic *et al*., 2000). 2000-2001 yield data was provided by K. Volkers (unpublished).
Energy input in forage production was calculated at the field scale, assuming management conditions (farm machinery, cropping practices, etc.) typical for Northern German dairy farms

on sandy soils. The required data for direct (diesel) and indirect (manufacturing and distribution of fertilisers, pesticides, seeds, machinery, lubricants) inputs was taken from the most up-to-date literature. In some cases, our own calculations were applied. In the following text 'total energy input' (E_t) refers to the sum of direct and indirect energy input related to forage production and conservation per hectare and year. The energy efficiency is the net energy yield [GJ NEL] obtained per GJ total energy input.

Results and discussion

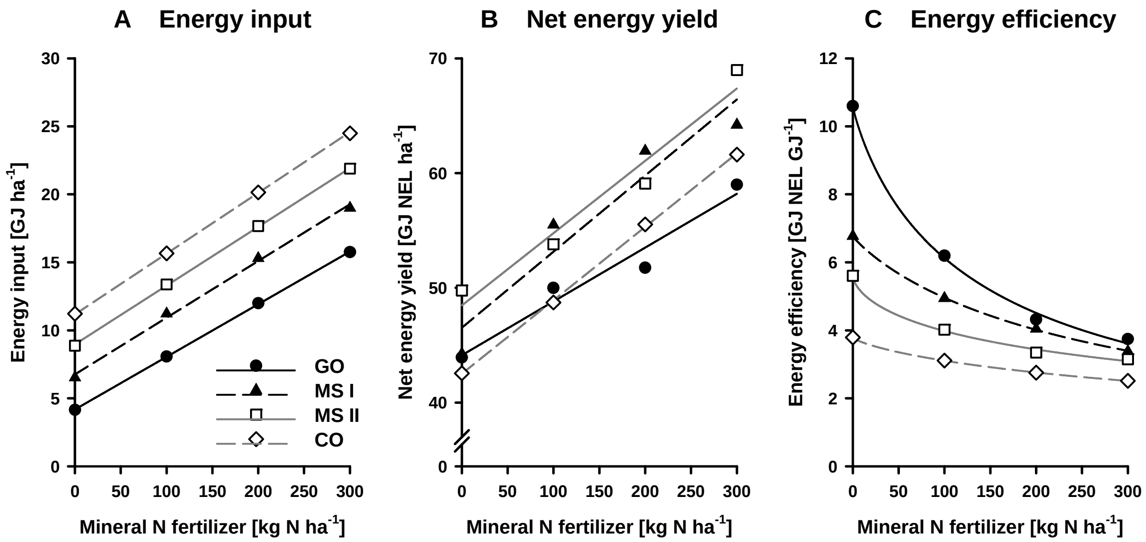

Figure 1. Fossil energy input (A), net energy yields (B) (means of 1997-2001; Trott *et al.*, 2002), and energy efficiency (C) in permanent grassland as affected by mineral N fertilisation and defoliation regime (GO: grazed-only pasture, MS I: mixed system I, MS II: mixed system II, CO: cutting-only) (all graphs for the treatment with 20 m^3 slurry per hectare).

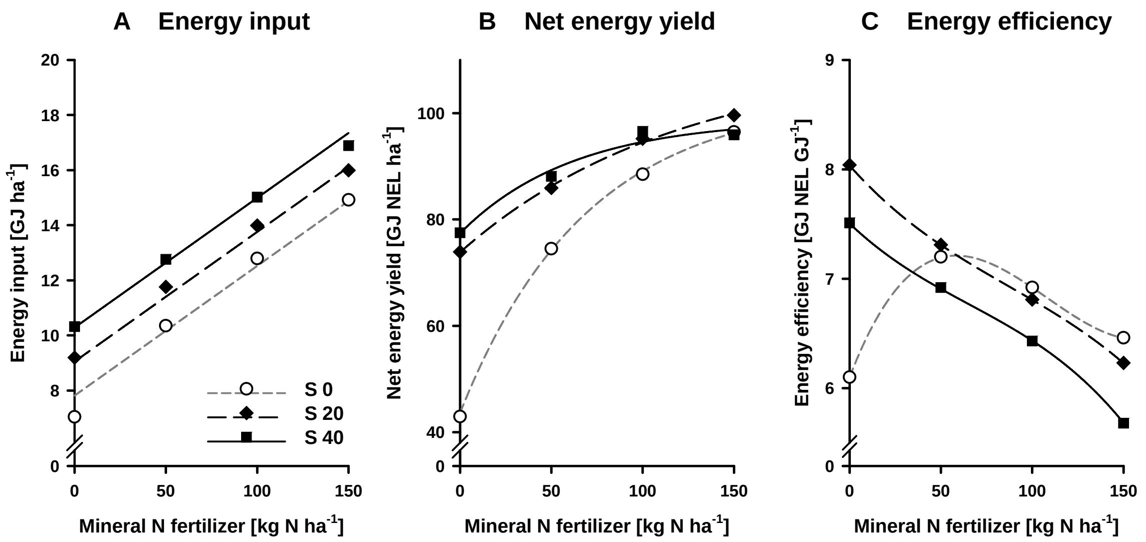

Figure 2. Fossil energy input (A), net energy yields (B) (means of 1998-2001; Jovanovic *et al.*, 2000; Volkers (unpublished)), and energy efficiency (C) in silage maize as affected by mineral N fertilisation and slurry application (S 0: without slurry, S 20: 20 m^3 slurry per hectare, S 40: 40 m^3 slurry per hectare) (all graphs for the treatment without undersown ryegrass).

The total input of fossil energy E_t consistently increased with increasing rates of mineral N application (Figures 1A, 2A). In grassland, each change from grazing to cutting increased E_t due to the use of direct energy for harvest operations and silage making. Slurry application increased E_t in both grassland and maize. A significant yield response, however, could be observed only in silage maize at low levels of mineral N fertilisation (Figure 2B). As net energy yields did not differ markedly between defoliation systems on grassland (Figure 1B), energy efficiency was highest on grazed-only pasture (Figure 1C). In silage maize, energy efficiency was highest when N supply was 50 kg N ha^{-1} from slurry without additional mineral N fertilisation. As the production of synthetic N fertiliser requires high amounts of fossil energy, energy efficiency consistently declined with increasing rates of fertiliser-N application, except for silage maize grown without slurry (Figures 1C, 2C). In the case of grassland this can be explained by the linear and relatively weak response of the white clover / grass swards to increased N fertilisation (Figure 1B). Maize showed a high efficiency of N utilisation at low levels of N supply, but a weak response to additional N at high levels of N supply (Figure 2B). Undersown ryegrass in maize decreased energy efficiency because a higher N input was necessary to obtain a given yield level (data not shown). Comparing grassland and maize, silage maize produced much higher net energy yields than grassland at a given level of N fertiliser and fossil energy input.

Taking into account the leaching of nitrates, which is an important environmental aspect on sandy soils in Northern Germany, grassland was always more 'leaky' than silage maize. In grassland, nitrate concentrations in the drainage water always exceeded 50 mg NO_3 l^{-1} on grazed plots, even if no additional N was applied (Büchter *et al*., 2002). In contrast, leaching losses were only low to moderate in silage maize (Büchter *et al*., 2003).

Conclusions

A high proportion of silage maize can be regarded positively with respect to efficient resource use, in terms of both nitrogen and fossil energy, in intensive dairy farming. In grassland, mixed cutting / grazing systems can represent a good trade-off between nitrate leaching and energy efficiency. Reduced N fertilisation, e.g., through the inclusion of white clover into grassland swards, helps to reduce both nitrate leaching and fossil energy use.

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A comparison of nitrate reductase activities in leaves of various grassland species

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Abstract

The actual nitrate reductase activity (NRA) in leaves of 19 different grassland species within the same habitat was measured in order to detect differences in their ability to utilise nitrate. This facilitates the classification of grassland species in respect of nitrate nutrition and the creation of NO_3-N indicator values. High levels of NRA in leaves were observed in *Rumex obtusifolius, Heracleum sphondylium* ssp. *sphondylium, Lamium album, Dactylis glomerata* and *Anthriscus sylvestris*. These grassland species are able to utilise large amounts of NO_3-N. Medium levels of NRA in leaves were observed in *Taraxacum officinale* agg., *Pimpinella major* ssp. *major, Trisetum flavescens, Rumex acetosa, Elymus repens, Achillea millefolium* agg., *Chaerophyllum hirsutum, Trifolium repens, Plantago lanceolata* and *Aegopodium podagraria*. Very low levels of NRA in leaves were found in *Crepis biennis, Trifolium pratense* ssp. *pratense, Ranunculus acris* ssp. *acris* and *Ranunculus repens*. These grassland species have a restricted ability to utilise NO_3-N in their leaves. Results are discussed in respect of individual species abundance in grasslands.

Keywords: nitrate reductase activity, utilisation of nitrate, NO_3-N indicator values

Introduction

In well-drained fertilised grassland soils NO_3-N is the most important source of inorganic N (Whitehead, 1995). Therefore grassland species take up most of their nitrogen in the form of nitrate. Before NO_3-N can be utilised by plants it must be reduced to NH_3. The reduction of nitrate to ammonia is mediated by two enzymes, nitrate reductase and nitrite reductase. Both enzymes are substrate-induced, but the more important is nitrate reductase, since it controls the level of nitrite, the substrate for nitrite reductase (Marschner, 1998). Nitrate reductase activity (NRA) can give an indication of the potential of a species to utilise nitrate. NRA is therefore a bioindicator for the nitrate nutrition of plants (Gebauer *et al*., 1988).
The aim of this study was to compare actual NRA measured in the leaves of 19 different grassland species within the same habitat in order to detect differences in their ability to utilise nitrate. This facilitates the classification of grassland species in respect of nitrate nutrition and the creation of NO_3-N indicator values.

Materials and methods

The investigation area was located in Irdning (Styria, Austria) at an altitude of 700 m. The climate is relatively cool and damp, with a mean annual temperature of 7.4 °C and annual precipitation of 1056 mm, of which 65 % falls during the growing season (April - September). The mean monthly temperature varies from –3.4 °C in January to 16.6 °C in July. The soil is a deep, well-drained Cambisol with a loamy sand texture and medium nutrient supply. Selected chemical properties of the soil are presented in table 1.
Leaves of healthy plants were collected only between 7 and 8 a.m., immediately before harvest in a meadow (*Trisetetum flavescentis* s.l.) managed by three cuts followed by autumn grazing. Nine collections per plant species were made at nearly the same stage of plant development. The meadow was fertilised regularly with slurry and mineral fertiliser. Only leaves were used for the determination of NRA, because leaves are the most important sites

for nitrate reduction (Oaks, 1992). For example, in *Rumex obtusifolius* the NRA in roots has been measured as only 1.6 % of that in the leaves (Bohner *et al*., in prep.). Actual NRA was assayed *in vivo* by the method described by Srinivasan and Naik (1982). Analyses were carried out immediately after collecting the leaves. Data (arithmetic mean of nine individual values per plant species) were treated by cluster analysis (SPSS 10.1). There are no clear rules in cluster analysis for either the number of objects or for the number of variables (Backhaus *et al*., 1989). A classification is neither 'correct' nor 'incorrect', but 'useful' or 'useless'. A classification is 'useful', if the clusters can be interpreted well (Kaufmann and Pape, 1984).

Table 1. Soil chemical properties of the Cambisol (0-10 cm soil depth)

						mg kg^{-1}				
$CaCl_2$	µS cm^{-1}	%	%		mg kg^{-1} $7d^{-1}$	CAL	H_2O	CAL	mEq 100 g^{-1}	% base
pH	EC	C_{org}	N_{tot}	C_{org} / N_{tot}	N_{pot}	P	P	K	CEC_{eff}	saturation
6.3	254	3.8	0.4	9.5	268	56	6.0	151	20.7	99

EC = electrical conductivity; N_{pot} = potentially mineralisable N; CAL = Ca-acetate-lactate solution; P_{H2O} = water soluble P; CEC_{eff} = effective cation exchange capacity ($BaCl_2$-extract).

Results and discussion

Table 2 shows the NRA of 19 different grassland species.

Table 2. Mean nitrate reductase activity in different grassland species, variation coefficient (V %) and NO_3-N indicator values (nomenclature of grassland species from Adler *et al*., 1994).

NO_3-N indicator value	Grassland species	µmol NO_2^- $h^{-1}g^{-1}$ (fresh weight)	V (%)
1	*Rumex obtusifolius*	3.81	39
2	*Heracleum sphondylium ssp. sphondylium*	2.55	46
	Lamium album	2.04	40
	Dactylis glomerata	1.98	60
	Anthriscus sylvestris	1.83	45
3	*Taraxacum officinale agg.*	1.42	32
	Pimpinella major ssp. major	1.36	58
	Trisetum flavescens	1.29	68
	Rumex acetosa	1.17	92
	Elymus repens	1.14	73
4	*Achillea millefolium agg.*	0.94	25
	Chaerophyllum hirsutum	0.79	63
	Trifolium repens	0.64	78
	Plantago lanceolata	0.62	92
	Aegopodium podagraria	0.54	56
5	*Crepis biennis*	0.22	34
	Trifolium pratense ssp. pratense	0.17	42
	Ranunculus acris ssp. acris	0.10	61
	Ranunculus repens	0.07	47

Five NO_3-N indicator values could be created by cluster analysis (Ward method). The variation in NRA measured within each grassland species was large. It must be taken into consideration that NRA is influenced by many site factors, such as temperature, light intensity, water supply and NO_3-N availability in the soil (Runge, 1983). Nevertheless, the grassland species examined showed either permanently high, medium or low levels of NRA within the same habitat; and the ranking order was similar in the different assays. Therefore a classification of grassland species on the basis of NRA seems to be valid. The grassland species examined can be divided into five groups representing different NO_3-N indicator values. The highest mean level of NRA in leaves was observed in *Rumex obtusifolius*. *Rumex obtusifolius* is a nitrophilic species with the ability to utilise large amounts of NO_3^-. *Rumex obtusifolius* is restricted to nutrient-rich grassland soils of high nitrate and potassium availability (Bohner *et al*., in prep.). *Heracleum sphondylium* ssp. *sphondylium*, *Lamium album*, *Dactylis glomerata* and *Anthriscus sylvestris* also had comparatively high mean levels of NRA in their leaves. These grassland species are able to utilise large amounts of NO_3^- from the soil and they possess a high capacity for NO_3^- reduction in their leaves. Therefore they are abundant in grassland soils of high nitrate availability. In contrast, very low levels of NRA have been found consistently in leaves of *Crepis biennis*, *Trifolium pratense* ssp. *pratense*, *Ranunculus acris* ssp. *acris* and *Ranunculus repens*. These grassland species evidently have a restricted ability to utilise NO_3^- in their leaves. Low leaf NRA may indicate either predominantly root nitrate reduction, or an ammonium-based nutrition, or may result from N_2 fixation. *Fabaceae*, such as *Trifolium pratense* ssp. *pratense*, take up only small amounts of soil NO_3-N, because of their symbiosis with N_2 fixing bacteria. Therefore they have a comparatively low mean level of NRA in their leaves. However, other species, such as *Trifolium repens*, use appreciable amounts of NO_3-N from the soil in addition to fixing N_2. *Ranunculus acris* ssp. *acris* and *Ranunculus repens* consistently exhibited a very low level of NRA in their leaves. *Ranunculus repens* is an indicator of compacted, periodically wet topsoils and is abundant in fertilised wet meadows and pastures. Both *Ranunculaceae* profit from a high available K^+/NO_3^- ratio in the soil. The same seems to be the case in *Aegopodium podagraria*. *Aegopodium podagraria* is abundant on sandy or silty nutrient-rich grassland soils at cooler sites. *Crepis biennis* and *Plantago lanceolata* are other grassland species with comparatively low potential to utilise NO_3^- in their leaves. They are often abundant in meadows with low proportion of grasses, presumably due to a lack of plant-available NO_3-N.

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Stability of leaf traits and species ranking across seasons and nitrogen availability.

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Abstract

Leaf dry matter content (LDMC), specific leaf area (SLA) and the leaf life span (LLS) of 24 native grassland species from the Pyrenean mountains were studied at two different levels of nitrogen supply during three growth seasons at the INRA Centre of Toulouse. The aim of this study was to analyse the stability of leaf traits in order to propose it as a tool for diagnosing the fertility conditions of the pasture. LDMC values make it possible to separate all the species ($P < 0.001$) into three life forms, grasses, rosette forbs and upright forbs. The variations of SLA and LDMC between seasons, and of SLA, LDMC and LLS between species, life forms and nitrogen availability, were highly significant ($P < 0.001$). Despite these variations, the different traits ranked the species in a consistent way as indicated by the Spearman rank correlation test for all the species, as well as for the different growth forms. LDMC proved to be more stable than SLA across the seasons and more stable than SLA and LLS across nitrogen availability. Taking into account the ease of trait measurement and the stability of species ranking, we conclude that it is possible to envisage using LDMC as an indicator to describe the fertility gradients in native vegetation on condition they are used on populations of grasses.

Keywords: leaf dry matter content, specific leaf area, leaf life span, nitrogen availability 'plasticity', ranking grassland species and season variability

Introduction

The management of grasslands needs tools for diagnosing the state of the vegetation in order to design, evaluate, and apply management practices to attain one or other of these aims. Each grassland species is characterised by a range of habitats representing their specific ecological preferences. These preferences are the result of the response of the physiological, morphological and phenological characteristics of the species to environmental factors (Duru *et al*., 1998). The ecology of grassland communities aims at predicting the response of species, plant communities and the ecosystem to the competition for resources, to climatic changes and to changes in the use of soil resources (Lavorel *et al*., 1999). This objective requires characterising and classifying the species from a functional point of view (McIntyre *et al*., 1999). These predictions can be made by studying the functional traits of the species, variables measured on plants that are directly linked to the growth and development functions, or are strongly correlated to other variables which can explain these functions (Weiher *et al*., 1999). The development of a tool for diagnosing the agronomic value of grassland vegetation based on the measurement of leaf traits presupposes a good knowledge of the trait variations and factors which act upon them. The aims of the present study were to analyse the stability of the values of LDMC, SLA and LLS for native herbaceous species across seasons and nitrogen availability, and to evaluate the consequences that these variations can have on the ranking of species for leaf trait values.

Materials and methods

Seeds of 15 grasses and 9 dicotyledons collected in their native habitat were sown separately according to a random block design with three replicates in Auzeville, France (latitude 48° 70' N, longitude 1.2 °E, altitude 200 m asl). The list of species is: *Agrostis capillaris* L., *Anthoxanthum odoratum* L., *Arrhenatherum elatius* (L.) Beauv., *Avenula pubescens* (Huds.) Dumort, *Brachypodium pinnatum* (L.) P. Beauv., *Brachypodium sylvaticum* (Huds.) Beauv., *Briza media* L., *Lolium perenne* L. (cv) clerpin, *Dactylis glomerata* L., *Festuca ovina* L., *Festuca rubra* L., *Phleum pratense* L., *Holcus lanatus* L., *Lolium perenne* L., *Trisetum flavescens* (L.) Beauv., *Centaurea nigra* L., *Crepis biennis* L., *Picris hieracioides* L., *Plantago lanceolata* L., *Rumex ac*etosa L., *Taraxacum officinalis* L., *Chaerophyllum aureum* L., *Heraclum spondylium* L. *subsp pyrenaicum* (Larn.) Bonnier and Layens, *Ranunculus acris* L. Each species was cultivated with two levels of nitrogen supply, limiting and non-limiting for growth (noted N+ and N-, respectively). Water, potassium and phosphorus were supplied in sufficient quantity to avoid limitations of species growth. LDMC (leaf dry mass to saturated fresh mass ratio in mg g^{-1}) and SLA (ratio of surface area / dry weight of the blade in m^2 kg^{-1}) were measured during three growth cycles corresponding to three different seasons, summer 2001 and spring and autumn 2002. For each level of nitrogen and each species, four individuals were sampled per replicate in 2001 and five per replicate for the two cycles in 2002. LDMC and SLA measurements were done following the protocol proposed by Garnier *et al*. (2001b). The LLS was determined by two series of measurements. The first series was carried out during spring 2002 on the 24 species. The second series of LLS measurements was carried out only on grasses and began on the 6 May 2002. The plasticity of leaf traits in response to nitrogen availability is quantified by the ratio between the smallest and the largest value of each trait which varies between 0 and 1 (Cheplick, 1991). The further this ratio is from 1, the more plastic the trait will be. Seasons variations of leaf trait is illustrated by the coefficient of variation as proposed by Garnier *et al*. (2001a). Variance analysis (General linear model) and comparison of means values (LSD, Least Significant Difference) were used to analyse the different effects of species, nitrogen and season on trait values.

Results and discussion

The first analysis of the LDMC values shows that, whatever the level of nitrogen nutrition, this trait makes it possible to separate the set of species studied into three groups: grasses, rosette forbs and upright forbs. These groups correspond to significantly different LDMC mean values ($\alpha = 0.001$), the highest value being that of the grasses and the lowest that of the rosettes.

Table 1. Inter-seasonal variations of leaf traits (LDMC, leaf dry mass to saturated fresh mass ratio in and the SLA, ratio of surface area / dry weight of the blade in) for the whole list of species and for each growth form under non N limitation conditions. Different letters in a line correspond to significant differences in the LSD test (Least Significant Difference, $\alpha = 0.001$). CV is the average coefficient of variation of the trait calculated among species.

	LDMC (mg g^{-1})			C.V	SLA (m^2 kg^{-1})			C.V
	spring	summer	autumn	(%)	spring	summer	autumn	(%)
All species	225 ^{a}	222 ^{a}	195 ^{b}	13.4	22.9 ^{c}	26.6 ^{b}	27.9 ^{a}	19.9
Grasses	258 ^{a}	248 ^{b}	216 ^{c}	13.7	23.8 ^{c}	26.6 ^{b}	29.6 ^{a}	21.0
Upright forbs	215 ^{ab}	227 ^{a}	205 ^{b}	9.5	21.6 ^{b}	23.6 ^{a}	23.2 ^{ab}	13.1
Rosette forbs	148 ^{a}	154 ^{a}	137 ^{b}	14.4	21.2 ^{b}	27.9 ^{a}	26.0 ^{a}	20.5

This differentiation by the LDMC was observed in the three seasons and was not obtained for the other leaf traits (SLA and LLS). LDMC and SLA in the N+ treatment showed significantly different values between the seasons. Specially, SLA had lowest values in spring and highest values in autumn, and the order was the reverse for LDMC for which the highest values were obtained in spring and summer (Table 1). Temporal variations were higher for SLA_{SAT} than for $LDMC_{SAT}$ considering all the species together as well as for every growth form separately. LLS plasticity was higher than the $LDMC_{SAT}$ one (LSD, α = 0.001) (Table 2). This observation was maintained for all species as well for each life form, except in *grasses* where LLS and $LDMC_{SAT}$ plasticity were not different. When the analysis was made on all species together and on the *grasses* form life, SLA showed a plasticity close to that of the LLS but higher than that of $LDMC_{SAT}$. These results were reversed when the analysis was conduced on *rosette* and *Upright forbs*.

Table 2. Comparison of the plasticity of traits, as regards nitrogen for the whole list of species and for each growth form. $LDMC_{SAT}$: leaf dry mass to saturated fresh mass ratio in mg g^{-1}, SLA_{SAT}: ratio of surface area / dry weight of the blade in m^2 kg^{-1}, and the LLS, leaf life span. Different letters on a same line correspond to the significant differences of the LSD (Least Significant Difference, α = 0.001) test.

	$LDMC_{SAT}$	SLA_{SAT}	LLS
All species	0.85^a	0.81^b	0.78^b
Grasses	0.84^a	0.78^b	0.81^{ab}
Rosette forbs	0.85^a	0.84^a	0.76^b
Upright forbs	0.92^a	0.87^a	0.71^b

LDMC proved to be a more stable trait across the seasons and nitrogen levels than SLA or LLS, as was shown by the coefficient of variation between seasons and the value of plasticity in response to nitrogen. For developing trait-based tools for diagnosing the agronomic value of vegetation, more than the inter-seasonal variability and the plasticity in response to nitrogen availability, it is the conservation of the species ranking between the different seasons and nitrogen levels which is important. In spite of the plasticity in response to nitrogen and season shown by LDMC, SLA and LLS, the ranking of species (Spearman rank test) was similar ($P < 0.001$) between the two levels of nitrogen nutrition and the three periods studied. The same trend could be observed among species within grasses.

Conclusions

LDMC proved to be the most relevant trait to ranks species across seasons and for their response to the nitrogen availability. It was shown that the choice of the growth form grasses for any use of LDMC as an indicator of vegetation properties seems to be the most appropriate option.

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Validation of a model simulating grassland vegetation dynamics using plant traits measured along a gradient of disturbance

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Abstract

To improve our understanding of grassland dynamics under different levels of exploitation, a functional description of the vegetation was introduced into a deterministic model. The selected traits and their parameterization were based on the results of a long-term experiment in which temperate grasslands were managed for 12 years with three levels of herbage use: high, medium and low. The model fits experimental data well for high levels of exploitation but was poorly adjusted at medium and low levels of herbage use. We believe this is due to a better simulation of green biomass fluxes than in senescence or reproductive fluxes. Some possible improvements of the model are discussed.

Keywords: model, grassland, vegetation dynamic, extensification, simulation

Introduction

In a context where grasslands are subjected to modification of grazing regimes, a major issue is identifying and qualifying the processes that drive the vegetation community. Under grazing, these processes involve spatial and temporal aspects of the interactions between herbivores and vegetation. A model was developed (Carrère *et al.*, 2002) to analyse the relationships and the dynamics of this complex system. A functional approach assumes that the plant species that develop in response to a given factor (e.g., herbage use efficiency, nutrient availability) display some converging traits, which in turn condition their performance in the community. The aim of this work was to integrate a functional description of the vegetation community in a deterministic model that simulates vegetation dynamics, and to test this model by comparison between simulated and experimental data. The selection of the traits and their parameterization was carried out using the results of a long-term experiment comparing contrasting levels of management (Louault *et al.*, 2002).

Materials and methods

Model description: The above-ground vegetation is described by four compartments: green leaves (gv), dry leaves (dv), green stems and ears (gr) and dry stems and ears (dr). Each compartment is described by state variables (biomass, height), herbage quality variables (fibre content, digestibility) and by the relationships between state variables (e.g., the vertical distribution of biomass). Six functions using 43 parameters simulate the biology of the vegetation (Carrère *et al.*, 2002). Growth is calculated in the gv compartment, using a light interception and light utilisation efficiency approach. The biomass income is then distributed between the compartments, using flowering or senescence functions. Time is managed through an environment input file, using a thermal calendar based on the sum of average temperatures, which turns on or turns off the growth, flowering and senescence functions. These processes follow continuous functions, which are specified in the sub-model using a daily iteration. Outputs of the vegetation sub-model are specified in the state and qualitative variables of each compartment and weighted averages of the compartments for each cell are computed.

Experimental data: We used a long term experiment (12 years) on upland permanent grasslands located in Theix (Auvergne, France). It was a factorial field trial with two blocks and three levels of herbage use: one spring cut (high) and four (medium, high) or one (low) sheep grazing period. There was no fertilisation supply. Sward height and biomass measurement along the year, including before and after cutting or grazing events, were made every two years throughout the experiment. In the 12th year, plant traits were measured on the most abundant species (i.e., those accounting for at least 85 % of the vegetation biomass). A list of 17 traits, including leaf traits, plant digestibility, plant height and phenology were studied with a method adapted from Weiher *et al.* (1999). The mean value for each trait was calculated at the community level for the three levels of herbage use, and significant differences between treatments were found for most of the traits (Louault *et al.*, 2002).
Simulation protocol: Simulations were performed to describe the dynamics of the total biomass and of its four compartments for a one-year period, starting from the first of January. Input parameters describe plant communities under the three levels of herbage use. The environmental file corresponds to climatic (temperature, light) data of the year 1998. A set of simulations were conducted including disturbance, i.e., biomass removal at each cutting or grazing event. Model outputs consider the above ground biomass at the end of winter, or corresponding to the re-growth after biomass removal.

Results and discussion

Among the 43 parameters of the vegetation sub-model, some are predominantly functional and were considered as traits of the plant community, and some describe vegetation structure. The former are related to the life cycle of the plant community (earliness and duration of flowering) and to growth ability (SLA), and the latter inform us about vegetation state at the beginning of the simulation (beginning of the year) and concern the quantity, quality and vertical distribution of the biomass. For 17 parameters, values are given at the community level for the three levels of herbage use (Table 1), values of the remaining 26 staying the same for all three plant communities.

Table 1. Values of parameters of the growth model for the three plant communities under the three levels of herbage use (High, Medium and Low).

Parameters (units)	High	Medium	Low
Plant traits			
Specific leaf area (m^2 kg^{-1} DM)	0.0297	0.0298	0.0247
Reproductive activation (day degree, °C)	883	992	1180
Reproductive de-activation (day degree)	1274	1443	1833
Vegetation state			
Height (1) (m)	0.043	0.128	0.088
Biomass (2) (g DM m^{-2})	**T** **gv** **dv** **gr** **dr**	**T** **gv** **dv** **gr** **dr**	**T** **gv** **dv** **gr** **dr**
	56 37 4 0 5	345 46 134 0 165	438 40 242 0 157
Volumetric mass (2) (g DM m^{-3})	**gv** **dv** **gr** **dr**	**gv** **dv** **gr** **dr**	**gv** **dv** **gr** **dr**
	926 291 253 207	732 192 1269 1002	404 72 2979 1652
*NDF (1) (g DM kg^{-1})	617	736	723
*NDF digestibility (1) (%)	62	46	45
Minimal % of laminae in biomass of **gv**	68	33	55
Maximal % of laminae in biomass of **gv**	72	77	67

*NDF = neutral detergent fibre, (1) for total cell, (2) Total (T), green leaves (gv), dry leaves (dv), green stems and ears (gr) and dry stems and ears (dr).

To estimate the accuracy of the model prediction, we compared the model outputs with the experimental results, considering the above-ground biomass of the sward (Figure 1).

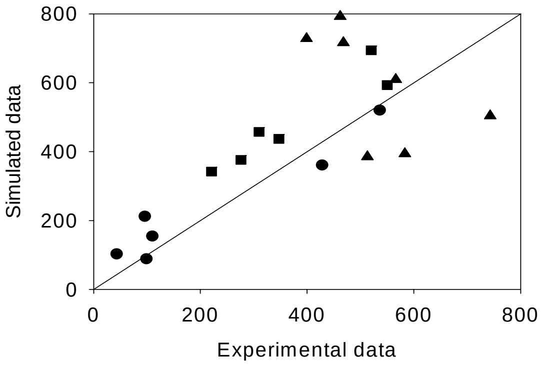

Figure 1. Comparison of simulated with experimental data for above-ground biomass (g m^{-2}) for three plant communities under three levels of herbage use (● High, ■ Medium, ▲ Low).

Under a high level of herbage use, the model outputs fit the experimental data well. High levels of biomass before cut, and lower level for spring or summer re-growths, are well simulated. Lower accuracy was observed for the low level of above-ground biomass at the end and beginning of winter. Under the medium level of herbage use, the model correctly simulates a greater accumulation of biomass, but tends to over-estimate it compared with experimental values. Under the low level of herbage use, the amount of biomass is highest, and remains high throughout the year. Under this treatment, the largest discrepancies were recorded between estimated and measured data (Figure 1), with both strong over-estimation and strong under-estimation. We suggest that the lack of agreement between observed and simulated results is due to a poor estimation of senescence and abscission fluxes. The largest discrepancies were shown for the winter period under high herbage use treatment. Under medium and low treatments, the large amounts of biomass were for long re-growth periods without disturbance, during which the tissues become old and start their senescence. Under high level of herbage use, the structure of the sward is more homogeneous than under low level of exploitation (Parsons *et al.*, 2000). We believe that the discrepancies registered in our study partly arose because the errors of prediction were lower for a homogeneous structure than for a heterogeneous structure. One way to improve the model would be to use a stochastic and spatial approach, specifically combining plant and animal models.

Conclusions

According to the changes of trait values observed in the vegetation at different levels of herbage use, the modification of the values of few parameters of the growth model (designated as traits), enable us to simulate contrasted biomass dynamics.
Increases in the prediction performance of the model could be achieved through a better description of senescence mechanisms and also by integrating a spatial approach.

Acknowledgements

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Herbage mass estimates with an improved electronic capacitance meter

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Abstract

Non-destructive estimates of dry herbage mass (DM) with capacitance meters could possibly replace time-consuming and laborious cutting and weighing on grassland. A new capacitance meter has been tested and its capability in different sward types (meadows, pastures and turf grass) has been evaluated. The instrument needs proper calibration before use, mainly depending on sward type. Considerable variations of capacitance readings (C_r) were found within plots. However, means from multiple (3 to 4) replicates (plots) of the same treatment were more precise (higher r^2) than plot-wise comparisons of C_r with the actual DM.

Keywords: capacitance meter, DM estimation, grassland

Introduction

The determination of above ground dry matter (DM) yield in grassland swards is one of the most measured attributes in field trials but is not yet established on farms. Usually, DM yield is determined by hand cutting, drying and weighing. However, this procedure is laborious, costly and time-consuming. Common non-destructive biomass estimations rely on capacitance measurements which are based on the relatively high dielectric constant ($\varepsilon_r = 80$) of pure water. Electronic capacitance meters have been documented in detail (Fletcher and Robinson, 1956; Neal and Neal, 1973; Vickery *et al.*, 1980; Michell and Large, 1983; Stockdale and Kelly, 1984). In recent times, a capacitance meter is available on the market which is weatherproof, lightweight, easy to handle and equipped with a microcontroller including a datalogger and a PC interface. The intention of the present study was (i) to examine the precision of the instrument in comparison with the cutting technique, (ii) to create calibration equations for differently managed swards and (iii) to evaluate the future application of this technique in precision farming.

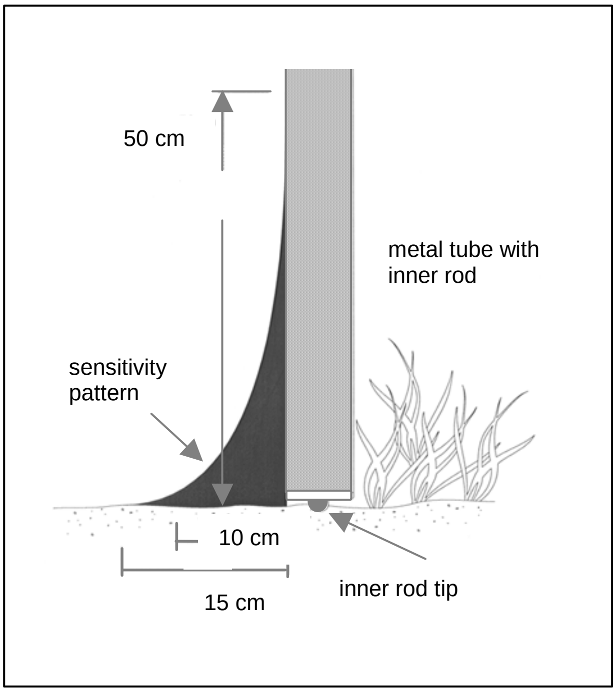

Figure 1. View of the pasture probe (TruTest, NZ).

Materials and methods

The pasture probe (GrassMaster, TruTest, NZ) consists of two conductors, an inner thin rod which is surrounded by a metal tube (Figure 1). When the probe contacts the ground the inner rod becomes grounded and the electric generator is triggered to build up a capacitance field between the two poles. The electric field strength depends on the amount of water bound in fresh biomass surrounding the pasture probe. Consequently, a theoretical relationship exists between the reading of the electric field strength and the biomass at that location. Readings are given as the weight of dry matter per unit area (kg DM ha^{-1}) calculated from equations relating the capacitance reading (C_r) to dry biomass. We tested the instrument on experimental plots on Rengen grassland farm (Eifel mountains) and on the experimental farm at Dikopshof near Bonn. The treatments included different mowing dates, fertiliser levels, grazing dates and turf grass varieties. Before applying the instrument in the field, repeated readings were registered on some plots and successive means of C_r were calculated to identify the required number of replicates which varied between 30 and 150 per plot for a given 5 % confidence interval of less than 200. Immediately after taking the readings, the swards were cut and the biomass was oven dried and weighed. The application of the pasture probe requires dry weather conditions and is limited to sward heights of not more than 35 to 45 cm (see sensitivity pattern in figure 1), corresponding to about 4500 kg DM ha^{-1}.

Results and discussion

We experienced an extreme variation of C_r-readings in grazed swards from one spot to the next, which may reflect real changes in sward density on a small scale but which demands a higher number of replicates compared to cut swards. When comparing C_r-values with the DM yield of individual plots (150 measurements), correlation coefficients were unsatisfactory.

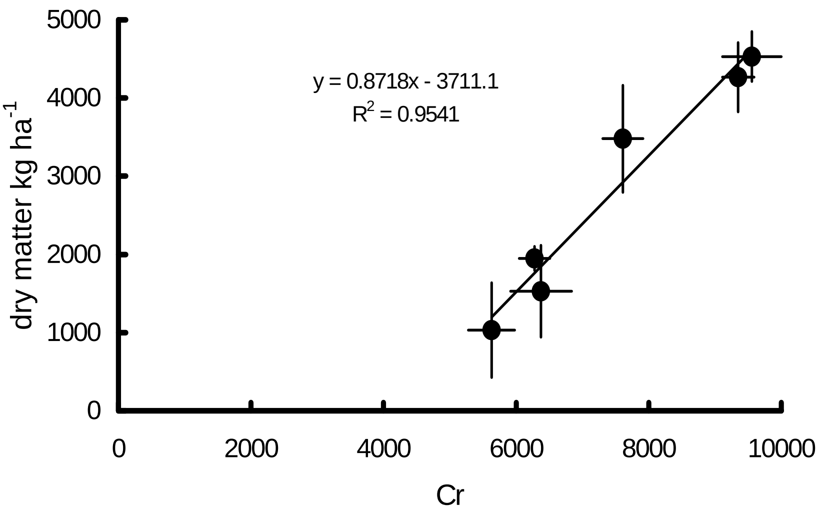

Figure 2. Relation between capacitance readings (C_r) and DM yield on a pasture (means of 4 plot replicates) (Rengen, Eifel mountains, Germany). Bars indicate SE.

Hence, we calculated means of treatment replicates and found an adequate relationship between C_r and DM yield (Figure 2). The point of intersection on the abscissa (3,711.1 / 0.8718 = 4256.7) gives the C_r value of the cut sward. This value indicates a considerable remaining biomass underneath the cutting level in this case. In cut grassland swards, the quality of the linear fit was the same as in grazed swards, especially when considering treatment means and not the values of each replicate (Table 1). On turf grass plots, the derived coefficient of determination of DM to C_r means was weak (not shown) due to considerable amounts of fresh and dry biomass remaining after the grass was cut and due to dead organic matter on the soil surface. Therefore, we repeated the measurements immediately after the cut and calculated a regression for the difference in both C_r values and the removed biomass (Figure 3). In contrast to figure 2, the regression was forced through the origin, as residual biomass remained unconsidered.

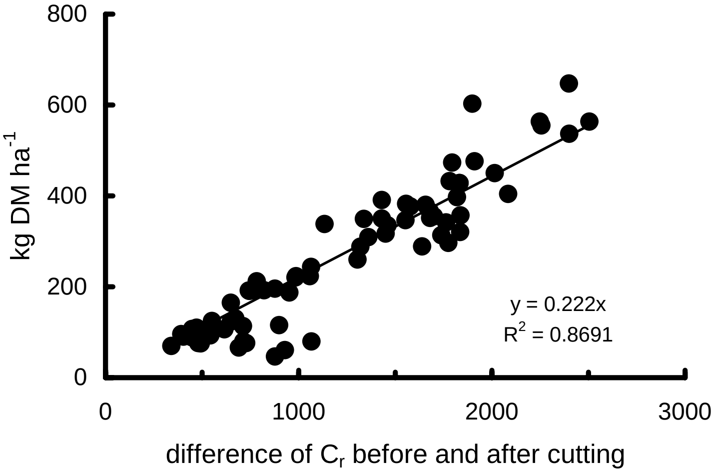

Figure 3. Relation between capacitance readings (C_r) – difference before and after cutting and removed DM yield on turf grass (Dikopshof, Bonn, Germany).

Table 1. Linear regression parameters (y = a × x-b) of pairwise DM yield to C_r comparisons on grassland and turf grass plots. Lines with indices (1) and (2) refer to figure 2 and 3, respectively.

Sward type	Plot comparison				Treatment comparison			
	n	a	b	r^2	n	a	b	r^2
Intensive cutting (Rengen)	32	0.293	670.8	0.567	8	0.409	1768	0.924
Intensive grazing (Rengen)	44	0.423	384.9	0.465	6 (1)	0.872	3711	0.954
Turf grass (Dikopshof)	288	0.217	0	0.769	72 (2)	0.222	0	0.869

Conclusions

The pasture probe potentially is a useful piece of equipment to obtain non-destructive DM yield estimates on grassland swards. However, only a high number of replicates provides adequate DM yield estimates. Non-homogeneous grassland plots must be divided into subplots and measured separately, thus offering the opportunity to match fertilisation to the yield potential within these separate areas. Such techniques may lead to a precision grassland management adapted to local conditions. Once farmers gain reliable yield estimates on pastures and hay meadows, the grazing rotation, stocking density, harvest date and nutrient supply can be organised in an appropriate manner. For research purposes, a combination with a global position system would enable yield mapping in combination with other sward characteristics.

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Methods of digital image processing to quantify ground cover of turf grass

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Abstract

Percent ground cover is a significant characteristic of turf grass quality and currently evaluated by subjective ratings. However, ratings are subject to significant variation and therefore difficult to reproduce. The rapid development in digital camera techniques offers the possibility to substitute ratings by quantitative measurements. Since modern digital still cameras provide images with high spatial resolution and high colour depth, results of image processing strongly depend on the software algorithms used. In the present study different specific algorithms for digital image processing have been investigated on images obtained from a field experiment. The experiment was conducted in 2002 using turf grass plots with artificially established gaps of different size and shape representing 5 %, 10 %, and 15 % of plot area. Images of the canopy were taken using a digital still camera. Image processing was done using soil colour and additionally geometric classifiers to improve the accuracy. Results show high accuracy and in particular the robustness of the used classifiers.

Keywords: digital image processing, turf grass evaluation, rating, classifier

Introduction

The most commonly used technique for estimating turf grass cover involves frequent, but subjective ratings by trained evaluators. Although these measurements give relevant information on management studies or cultivar evaluation trials, the data are often highly variable and difficult to reproduce. The reason for moderate results is the difficulty of the human eye to quantify the area with sufficient precision, a task that is easily solved by counting pixels when digital image analysis is used. However, the difficulty in image processing is to detect and distinguish different objects within a single image. Obviously colour is a proper classifier to detect soil (brown) and leaves (green) in a turf grass sward. Using a couple of classifiers like the colours and geometric traits of the objects has been shown to improve precision and robustness in image processing software tools. In this study we focus on the analysis of gap area in turf with special respect to the geometric features of gaps.

Materials and methods

A field trial with sodded turf grass (*Lolium perenne* L. and *Poa pratensis* L.) was established in 2002. The trial was subdivided in two blocks each consisting of six variants representing gaps of different shape (rectangle, 10 × 15 cm, circle d = 8.5 cm) and gap area portion (5 %, 10 %, 15 %). The gaps were punched with special tools and filled up with soil. The turf grass was mowed to a mowing height of 5.5 cm prior to imaging. Images were captured with a Nikon Coolpix 995 still camera, mounted in a light-tight box with artificial light provided by 4 bulbs (Sylvania Mini-Lynx, 15 Watt). Detection of gaps within the turf grass sward was based on colour discrimination between soil (brown) and turf grass (green) similar to procedures Richardson *et al*. (2001) have used. The colour of each pixel was given as an RGB triple value and was transformed into the HSL (hue, saturation, lightness) colour space. One image was used for a teach-in procedure where colour samples were taken from bare soil to define a parallelepiped classifier in the HSL colour space. To improve the result additional geometric characteristics of gaps and turf grass such as size thresholds and contour filters were applied. All algorithms were written in Visual C++ 6.0.

Results and discussion

Figure 1 displays the contour line of a gap, as an assessor would see it. The task for the image processing software was to detect a very similar contour. The subsequent measuring of the area inside the contour line by pixel counting was a standard task for the computer. Colour is a major classifier to distinguish between green leaves and brown soil. The advantage of HSL versus RGB colour space is the de-coupling of brightness (grey scale) from colour. Thus the classification is more robust against fluctuations of illumination or influences that are caused by shadows. Figure 2 shows the result of an image processing procedure using HSL-colour as the only classifier. The classified area (black) differs significantly from the outlined area in figure 1.

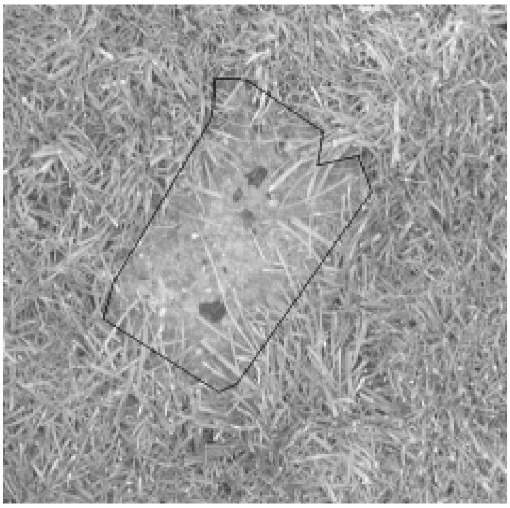

Figure 1 (left). A gap in turf grass marked by a contour line that an assessor would draw to evaluate ground cover.

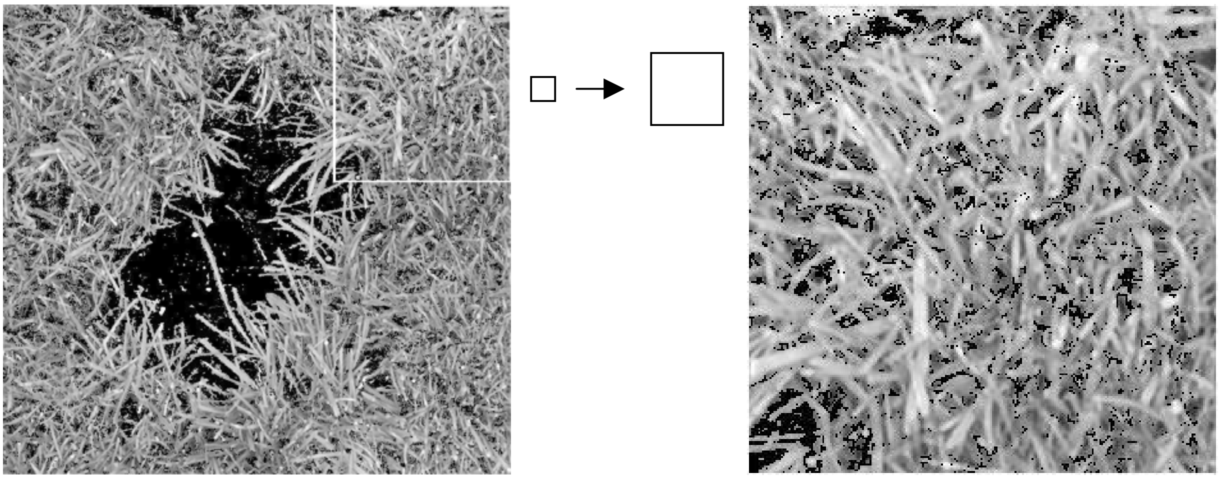

Figure 2. Result of an image processing procedure using only the HSL-colour-classifier (left image). Magnification of a detail (top right of image) to demonstrate the appearance of small objects that are mainly caused by shadows from leaves (right image).

Comparing figure 2 with figure 1 demonstrates some reasons for inaccuracy. Many small objects classified as soil are in fact shadows from leaves (Figure 2, right image). Larger objects are correctly detected as soil (gap) but within these objects some pixels of different colour are not classified correctly and cause areas of false classification within the gap (holes). Finally, some leaves also protrude into the gap indicating ground cover, however, beneath these leaves is soil.

Image processing procedures were improved by 1) removing objects < 10 mm^2 (considered to be grass leave shadows) with the use of a size threshold, 2) filling up the remaining object space (correctly classified as gaps) by adding pixels to areas where pixels are absent and 3) by using a contour filter to smooth contours, essentially ‘clipping’ the leaves which protruded into the gaps.

The result of using both colour and geometric classifiers in combination is shown in figure 3. Small spots were removed and leaves reaching into the gap were eliminated to detect the real size of the gap (black contour line). Figure 4 displays the measuring error, i.e., the percent deviation from the nominal gap area. When using only the HSL-colour as classifier the error is relatively small because increases in gap size due to small spots is offset by leaves reaching into the gap. However, results are subject to significant variation.

If colour and geometric classifiers were used the variation of the measuring error is much lower due to the removal of individual error sources. Therefore the use of these combined classifiers provides results with high accuracy and high robustness.

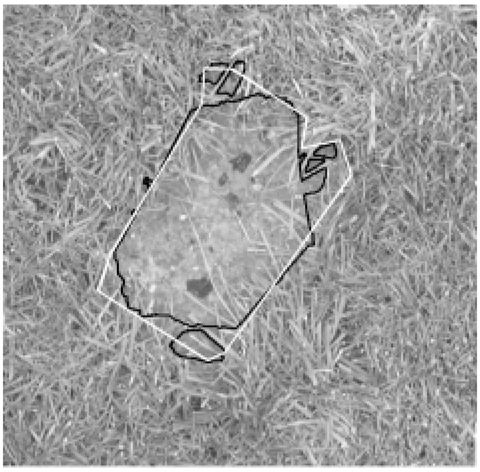

Figure 3 (left). Gap detection by image analysis using multiple classifiers (black line) in comparison to visual assessment (white line).

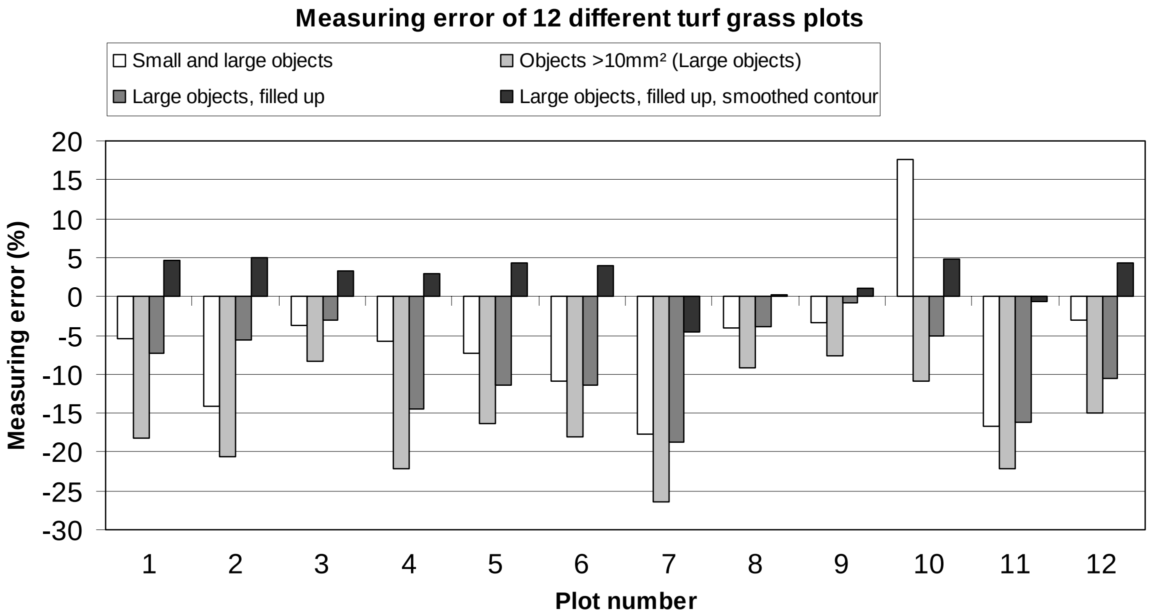

Figure 4. Measuring error of the 12 different plots representing different shapes and area portions of gaps (APG). (Plot 1, 2 and 3 – rectangle with 5 %, 10 % and 15 % APG; Plot 4, 5 and 6 – circle with 5 %, 10 % and 15% APG; plot 7-12 – second block).

Conclusions

Geometric classifiers in addition to HSL-colour classifier have increased the robustness of image processing procedures. This is a prerequisite to applying image analysis as an accurate and dependable tool for quantifying turf grass cover.

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Modeling leaf area index of perennial ryegrass according to nitrogen status and temperature

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Abstract

The aim of this article is to present a simple model of leaf area index (LAI) extension of a perennial ryegrass crop in spring, on the basis of temperature and nitrogen availability.
A function has been developed in which the LAI extension rate is modelled in relation to a nitrogen nutrition index calculated from dry matter yield and grass nitrogen content. When nitrogen nutrition is not restrictive, the LAI extension rate is 0.023 (degree-days)$^{-1}$.

Keywords: LAI, temperature, nitrogen, perennial ryegrass

Introduction

The extension of the canopy in grasses is mainly stimulated by temperature and nitrogen. Mineralisation of soil nitrogen is very variable from site to site and from year to year, making trial comparisons difficult. So, in order to establish a more general comparison basis, nitrogen availability can be estimated by the nitrogen nutrition index (Lemaire *et al*., 1989).
In the course of this article, we examine the effect of nitrogen on the leaf area index (LAI) expansion rate of perennial ryegrass in relation to temperature. Determining the relationships between these parameters will allow the development of a model of the changes occurring in LAI of a perennial ryegrass sward during spring.

Materials and methods

The location of trial sites and their characteristics are indicated in table 1. Soil organic matter content and annual temperature varied widely between sites.
Average daily temperatures (average of hourly air temperatures at 1.5 m) were summed above a base of 0 °C for each regrowth from the date of the cut or from the start of growth at the end of winter.

Table 1. Location, altitude and average annual temperature of the experimental sites.

Sites	Latitude	Longitude	Altitude (m)	Mean annual temperature (°C)	Humus content (%)	pH of soil
Louvain-la-Neuve	50°40'	4°37'	120	10.1	1.8	7.3
Michamps	50°01'	5°50'	510	7.6	4.2	6.5
Elsenborn	50°27'	6°13'	635	6.9	8.8	5.4

On each site, the data were recorded on plots of *Lolium perenne* cv. Meltra, sown with a space of 12 cm between rows. Phosphorus and potassium fertilisers were applied at the end of the winter according to the results of soil analysis. The experiment included four replicates in complete randomised blocks. Each plot measured 12 m^2. The plots were managed according to the methodology of Corrall and Fenlon (1978). Early in spring, when growth started, four plots were cut at weekly intervals. Each plot was then cut repeatedly after 4-weeks growth. The results presented here relate to spring growth before heading.
The LAI of each regrowth was calculated on a weekly basis at each site from the interception efficiency of solar radiation (Ei), measured with a SunScan canopy analysis System

(Delta-T Devices), on the basis of the following equation: LAI = -(1/0.674) x 1n(1-(Ei/0.89)) (Lambert *et al.*, 1998).
The extension rate of LAI was given by the regression coefficient of the linear relationship between LAI and the sum of positive daily average temperatures. It was calculated for each site-year-nitrogen fertiliser level combination.
Different levels of nitrogen fertilisation were applied approximately one month before the first cut and then each month just after cutting. The dry matter yields and the grass nitrogen contents were measured after 4 weeks of growth.
The nitrogen nutrition index (I_N) was calculated from the dry matter yield and the nitrogen content according to the formula: $I_N = 100(N/(4.8Y^{-0.32}))$ (Lemaire *et al*., 1989).
With N = N content (% DM) in the biomass
Y = dry matter yield (ton ha^{-1})
An I_N value of 100 or more was taken to indicate non limiting nitrogen nutrition.

Results and discussion

The extension rate of LAI was found to increase with nitrogen fertilisation. Table 2 indicates the characteristics of the linear relationships between LAI and the sums of daily average temperatures determined for the different site-year-fertilisation combinations. The average nitrogen nutrition index (I_N) is also indicated.

Table 2. Characteristics of linear relations determined between LAI and the sums of daily average temperatures for the different combinations between site, year and fertiliser level.

Year	Site	Fertiliser rate (kg N ha^{-1} $month^{-1}$)	Nutrition index mean ± sd	n	LAI extension rate	r^2
1996	Michamps	0	42 ± 5	16	0.0061	0.8813
		15	49 ± 6	13	0.0180	0.8837
		30	61 ± 7	10	0.0212	0.7688
		60	83 ± 12	9	0.0196	0.8494
1996	Louvain-la-Neuve	0	31 ± 1	16	0.0038	0.8458
		60	92 ± 5	12	0.0241	0.7934
1997	Michamps	0	43 ± 7	24	0.0069	0.8216
		80	93 ± 9	14	0.0228	0.7678
1997	Louvain-la-neuve	80	103 ± 9	12	0.0179	0.6854
1997	Elsenborn	80	86 ± 8	7	0.0200	0.8261
1998	Michamps	0	40 ± 2	16	0.0039	0.9281
		20	49 ± 3	13	0.0113	0.9601
		40	62 ± 5	11	0.0158	0.7237
		80	87 ± 9	11	0.0201	0.8355
1998	Louvain-la-Neuve	80	105 ± 10	10	0.0241	0.8465
1998	Elsenborn	80	97 ± 4	9	0.0203	0.8725

n = number of LAI value used to establish the regression. Each LAI value is the average of LAI measured on 3 plots (15 measures / plot).
sd = standard deviation

The relationships between LAI extension rate and nitrogen nutrition index were described by a monomolecular function (Figure 1).

The equation was: $\frac{LAI}{°C.days} = 0.023 * (1 - 3.343 * \exp(-0.04 * IN))$. The determination coefficient (r^2) was 0.84. In this case the estimated maximum value of the LAI extension rate was 0.023.

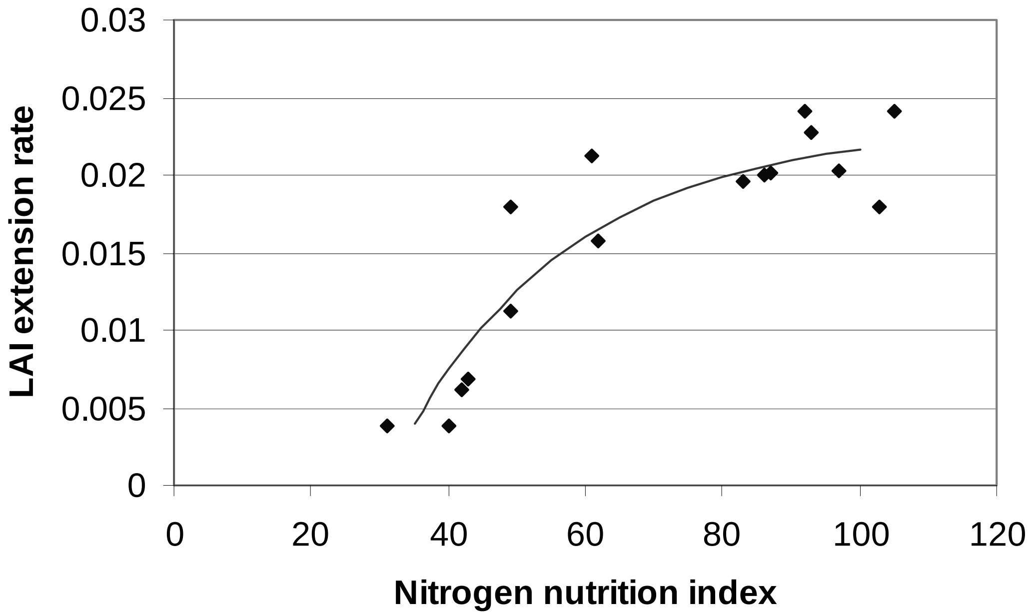

Figure 1. Effect of nitrogen nutrition index on LAI extension rate.

Conclusions

LAI extension rate, expressed in terms of temperature sum, increased with nitrogen fertilisation. A relationship between LAI extension rate and nitrogen nutrition index was defined. This relationship allowed the increase in LAI of a perennial ryegrass sward during spring to be modeled in accordance with the daily average temperature. The maximal extension index when nitrogen was not limiting was estimated as 0.023 LAI units degree-day^{-1}. Consequently, a sum of daily average temperatures of 43 °C day would be required to increase LAI by 1 unit.

Acknowledgments

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Improving the management of native pastures: a phenology-based tool

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Abstract

In order to support changing technology imposed by new agri-environmental trends, it is necessary to understand farmers' practises when developing technical innovations. The aim of this work is to propose a technique to represent fodder practices based on the phenology of meadow species. Intervals between defoliations are expressed as cumulative degree days to allow the comparison of different ways of using meadows situated at various altitudes for the same dairy farm or between farms. These values are compared with phenological thresholds which give information about mown grass quality and quantity and about grazing practices (i.e., whether or not the stem apex is removed). This easy to use method was tested in a project involving cheese production ('tomme des pyrénées au lait cru') with 11 farmers. It allows a better analysis of fodder systems whilst describing pasture and hay quality. Most dairy farm meadows are grazed or mowed too late to obtain good quality forage. This could be improved by more effective organisation of grazing and mowing of meadows.

Keywords: grassland management, grazing, mowing, diagnostic tools, phenology

Introduction

In order to provide support for technical changes, advisors rely on field records which enable successive use of fields over time to be planned whilst specifying whether they are to be used for hay or grazing. Although essential for understanding the forage production of the farm, this information is nevertheless purely descriptive. Knowledge of the grazing dates and intervals alone does not provide information about the characteristics of the pasture being grazed. To do so, it is necessary to have models which define phenological thresholds beyond which there is a change in the state of the vegetation. We propose a method to represent these thresholds to estimate the difference between what a livestock farmer does and what he intended to do in relation to these objectives. In the first part we define these thresholds from work carried out on a model plant (*Dactylis glomerata* L.) for which we have validated the parameters for natural populations. We then illustrate their application in making a diagnosis of forage practices on dairy farms.

Materials and methods

In comparing different sites and seasons, the timing of stem elongation, expressed in degree-days (dd) can be used to determine whether or not the first use of a field in spring will result in the removal of the reproductive apices of grasses. The degree-day sum (base 0 °C) at which the ear reaches 10 cm has been estimated at 600 dd (Duru *et al*., 2000). Grazing after this date will remove the apex, or meristem ('étêtage'), and the following regrowth will be vegetative and less productive. This threshold agrees with the observations of Theau *et al.* (2001) for three forage grasses observed in natural pastures (*Dactylis glomerata, Lolium perenne, Holcus lanatus*). The degree-day sum at which the decline in digestibility accelerates during stem elongation can be used to determine a threshold beyond which pasture quality falls rapidly, especially for dairy cows. This threshold has been estimated at around 800 dd by Duru *et al*. (2000). Expressing time as day-degrees also allows the haymaking date to be determined in relation to the biomass accumulation of the pasture. When growing conditions are constant during a regrowth, net biomass accumulation rate of the leaf laminae approaches zero after a period corresponding to the leaf lifespan (Parsons *et al*., 2000). For cocksfoot, this period has been estimated to be 800 dd (Duru and Ducrocq, 2000), but because of the growth of the stems, the net accumulation of total biomass becomes zero at around 1200 dd (Calvière and Duru, 1999) until 1500 dd. This methodology was applied to dairy farms which belong to a group whose approach involves a specific management system known as 'IGP Tomme des Pyrenées'. According to their nature, the current forage systems (feeding maize silage throughout the year, maize silage in winter and grazing in spring, or hay in winter and grazing in spring) are rather different from the systems which require three months of grazing in summer and 25 % of the winter ration comprising hay. The great majority of pastures in the region are dominated by grasses representative of fertile environments, of which the typical species is *Dactylis glomerata.* The diagnoses were made on 11 farms, using about a hundred grazed fields and 62 hay meadows.

Results and discussion

During spring grazing (Figure 1a), 70 % of fields are grazed above meristem level ('déprimage') (< 600 dd), indicating good quality of offered herbage and a regrowth yield potential for hay which is hardly affected by grazing. 70-80 % of these pastures are either on primarily grassland farms (hay and grazing) or on farms which cease using maize silage during spring grazing. Farms which feed maize silage in addition to grazing practise a late (below-meristem level) grazing on 37 % of their fields. This practice is the consequence of late turnout and of overestimating the grazed area needed for the first grazing rotation. When this happens, there is considerable opportunity for those who wish to improve the contribution of their grazing management. Apart from the decline in quality of the grass and the 50 % reduction in hay yield potential (Theau *et al*., 2000), there is a risk of selective grazing by the animals, which increases when the stocking rate is low.

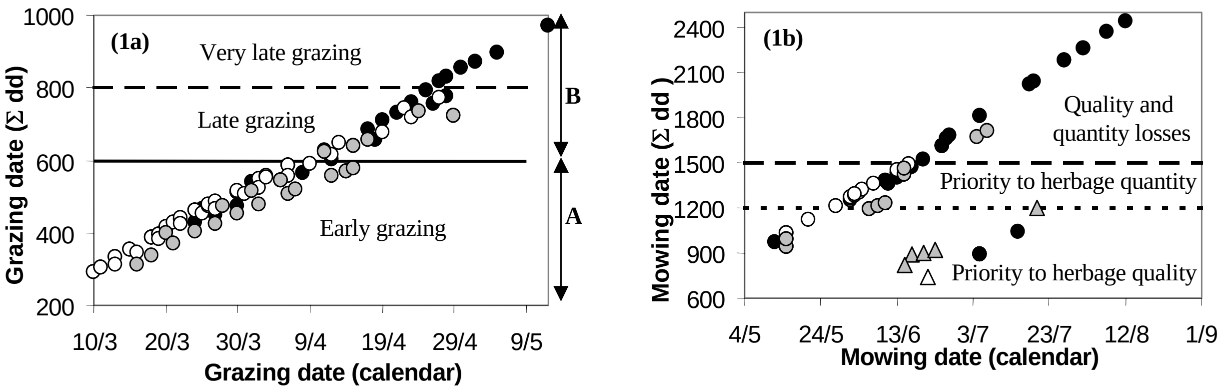

Figure 1. Determination of: (1a) spring grazing parameters for each field. Farms supplementing grazing with maize silage (black); Farms stopping silage feeding when grazing (white); Grassland farms; hay and grazing (grey). A: Conservation of meristem 'déprimage'; B: Destruction of meristem 'étêtage'. The variation in degree-days (dd) for a given date on the Y axes is explained by differences in altitude. (1b) hay quality according to mowing practices. Fields not grazed in spring (circles); fields grazed above meristem level (triangles).

For fields grazed above meristem level in spring (Figure 1b), mowing takes place after a regrowth period of less than 1200 dd, providing good quality grass even at late mowing. On the other hand, for fields which are mown but not grazed in spring (n = 54), only 20 % were mown to benefit quality (< 1200 dd), 43 % were mown to favour high yield at the expense of quality, while 37 % were mown very late, after the 1500 dd threshold, reducing herbage growth over the following period.

After identifying the fields in which management could be improved, these forms of representation also enable pasture utilisation to be replanned to suit various feeding strategies. Farmers who feed their cattle on maize silage throughout the year have limited interest in quality hay. The scope for improvement is considerable for them if they want to increase the quality of their forage. For those wanting to introduce more hay into the winter diet to supplement the maize, mowing is earlier, although improvements are still needed to obtain quality forage. The practice of grazing above meristem level is common for grassland farmers producing milk exclusively from grazed grass or hay. This technique, which guarantees quality hay despite late mowing, is essential in this region where, due to the climate, haymaking is rarely possible before June 1st. The thresholds used in the present procedure do not take account of the diversity of pastures. This diversity, characterised by dominant functional groups of species, can be defined by functional traits such as leaf lifespan (Cruz *et al.*, 2002). The definition of thresholds for each group will enable the diagnosis to be improved.

Figures 1a and 1b show ways of representing forage practices which are meant to be shared between the farmer and the technician. Each can analyse the practices from his own knowledge. The farmer, with his empiricism of the land will schedule his practices by calendar dates, while the technician can adjust them to phenological stages by using temperature sums.

Conclusions

This method of diagnosis could be used to evaluate the management of the forage systems on the basis of an analysis of cutting and grazing practices, both at the level of the whole forage area or a single field. Knowing key leaf and phenological traits of dominant grassland species allows the effects of practices to be interpreted much more precisely than from information purely from field records. It has the advantage of being able to compare farms from different geographical zones, and also to facilitate dialogue between farmers and technicians (group analysis), each contributing from his own experience and knowledge.

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Phenological development in timothy and meadow fescue as related to daily mean temperature and day length

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Abstract

Equations for daily advance in phenological development of timothy and meadow fescue were developed on the basis of field observations, recorded daily mean temperatures and day lengths. The deviations in days between observed and predicted phenophase tended to be smaller for meadow fescue than for timothy ($P < 0.01$).

Keywords: growth stage, meadow fescue, model, temperature, timothy, photoperiod

Introduction

Increasingly use is nowadays being made of grassland simulation models in order to gain insight into complex interactions between grass growth and changes in nutritive value, and as a base for decisions support in forage production. Phenological development is often a state variable in such models (*e.g.*, Gustavsson *et al.*, 1995; Höglind *et al.*, 2001; Baadshaug and Lantinga, 2002), since both growth and nutritive value are strongly related to it (Homb, 1953; Langer, 1958). Robertson (1968) introduced a model that allowed easy incorporation of functional relationships between developmental rate and environmental factors. The objective of the current work was to estimate daily phenological development in timothy (*Phleum pratense* L.) and meadow fescue (*Festuca pratensis* Huds.) by a multiplicative function of linear responses to daily mean temperature and day length, a simplification of Robertson's (1968) model.

Materials and methods

Observations were done in first year ley at four sites under various temperature and day length conditions (Table 1). The phenological stages were defined as: leaf stage (leaves only), jointing (the first nodes have appeared), early heading (the top of the inflorescence has appeared on at least 10 tillers m^{-2}), full heading (when 50 per cent of the elongated tillers have heads fully emerged from the flag leaf sheath) and anthesis (visible stamens).

The phenological development was divided into two distinct phenophases, the first from onset of growth to full heading and the second from heading to anthesis. This division was done according to Bleken and Skjelvåg (1986) who found that photoperiod no longer affected the progress in phenological development in oats after heading:

$$\begin{aligned} P < 1, \quad dP &= \alpha(T - T_{b1})(\min(Dl, Dl_m) - Dl_b) \\ P > 1, \quad dP &= \beta(T - T_{b2}) \end{aligned} \qquad (1)$$

where P is the current phenological stage (dimensionless), dP is the daily rate of phenological development (d^{-1}), α is the rate coefficient until full heading (°C^{-1} h^{-1} d^{-1}), β is the rate coefficient from full heading (°C^{-1} d^{-1}), T is the daily mean temperature (°C), T_{b1} is the base temperature until full heading (°C), T_{b2} is the base temperature from full heading (°C), Dl is the day length (h), Dl_b is the base day length (h), and Dl_m is the maximum effective day length (h). The progress toward full heading is complete when P = 1. Thereafter and until anthesis the temperature sum concept was applied. The progress towards anthesis is completed when P reached 2. The start of the phenological development was assumed to be at the first passage of a five-day diurnal mean air temperature of 5 ^{o}C on the prerequisite of snowless ground.

Results

Equations for daily advance in phenological development from start to full heading of the two species, were found to be:

Timothy:
$$dP = 0.000144(T - 0.01)(Dl - 5.76)$$
$$Dl_m = 17.80 \qquad (2)$$

Meadow fescue:
$$dP = 0.000163(T - 1.19)(Dl - 4.09)$$
$$Dl_m = 17.72 \qquad (3)$$

Deviations, in days, between times of observed and predicted heading were mostly small (Table 1). However, the larger deviations for timothy indicate a better fit to data for meadow fescue than for timothy (P < 0.01), also shown by their standard deviations of 3.6 days and 1.0 day, respectively.

Table 1. Observed day for snowless ground, growth start at first passage of five days diurnal mean air temperature of 5 ^{o}C, and predicted days of full heading and anthesis for two species at seven fields.

Species	Location (N, E)	Year	Snowless ground	Start of growth	Pred. Full heading	Earlier (-), later (+) than obs.	Pred. Anthesis	Earlier (-), later (+) than obs.
Timothy	Vågønes	1993	30 Apr	2 May	9 Jul	1	25 Jul	3
	(67°18', 14°29')	1994	24 Apr	29 Apr	12 Jul	0	1 Aug	3
	Sæter	1993	7 May	13 May	20 Jul	6	17 Aug	15
	(62°35', 10°17')	1994	26 Apr	30 Apr	13 Jul	-5	31 Jul	-2
	Fureneset	1993	24 Mar	7 Apr	17 Jun	-4	15 Jul	-4
	(61°18', 5°03')	1994	25 Mar	4 Apr	22 Jun	-2	13 Jul	-9
	Ås (59°40', 10°53')	1995	28 Mar	26 Apr	25 Jun	3	14 Jul	-3
Meadow fescue	Vågønes	1993	30 Apr	2 May	5 Jul	-1	16 Jul	1
		1994	24 Apr	29 Apr	8 Jul	0	24 Jul	5
	Sæter	1993	7 May	13 May	16 Jul	2	5 Aug	8
		1994	26 Apr	30 Apr	10 Jul	1	23 Jul	-2
	Fureneset	1993	24 Mar	7 Apr	8 Jun	0	29 Jun	-3
		1994	25 Mar	4 Apr	16 Jun	-1	6 Jul	-9
	Ås	1995	28 Mar	26 Apr	22 Jun	0	3 Jul	-2

The daily advance in phenological development from full heading toward anthesis was for timothy and meadow fescue estimated as:

Timothy:
$$dP = 0.003773(T - 0.64) \qquad (4)$$

Meadow fescue:
$$dP = 0.007155(T - 3.85) \qquad (5)$$

The coefficient of determination (r^2) was low, 0.30 and 0.33, for timothy and meadow fescue, respectively. For the deviations between observed and predicted day of flowering, standard deviations of 6.9 days for timothy and 5.2 days for meadow fescue were greater than those at heading. There was no significant difference among the experimental fields.

Discussion

A base temperature for the first phenological phase close to 0 °C for both timothy and meadow fescue (eqn 2 and 3) is in agreement with findings of Angus *et al.*, (1980) and Landström (1990). When comparing parameter values of the two species for the period from the start of growth to full heading, it should be recognised that both base temperature and base day length were extrapolations of linear functions. Thus, the differences of 1.18 °C in base temperature and 1.6 h in base day length between the two species is of minor importance. Furthermore, a simple assessment of the influence of the various parameters showed that the difference between estimated α-coefficients, 1.44×10^{-4} and 1.63×10^{-4} for timothy and meadow fescue, respectively, accounted for the larger part of the difference in earliness of heading. A minor part was due to the differences in base temperature and base day length between the species. Deviations between predicted and observed duration of the two phenophases were greater for the two to three week phase from full heading to anthesis than for the preceding phase of approximately two months duration (Table 1). As demonstrated by Robertson (1968) a model accounting for day and night temperatures separately might have been more appropriate than the simple heat unit concept. Implementation of the current equations for advance in phenologcial development in a grass growth model has already been demonstrated by Bonesmo (1999). These equations are also central in the development of a web tool for decision support on cutting time under Norwegian conditions (Gustavsson *et al.*, 2003).

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Temporal differentiation in exhibition of maxima among growth and nutrient accumulation rates in *Rumex acetosella* L.

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Abstract

A method based on growth analysis model was used to calculate and compare the timing of exhibition of absolute rates of above- and below- ground and total parameters (biomass and N, P, and K accumulation) of perennial *Rumex acetosella* L. The peaks of absolute growth rates (AGR) were observed for roots at the end of April, for total plant at 10 May, and for shoots at 20 May. The maxima for N accumulation rates were observed for shoots at 10 April and for total plant and roots at the end of April. For P and K maxima, the accumulation rates were observed for total plant and roots in late April and for shoots at 10 May. The phenological pattern in the field provides indication of differentiation of above- and below-ground parameters with respect to the time of the nutrient peak of perennial *Rumex*.

Keywords: absolute growth rate, growth analysis, *Rumex*, temporal differences

Introduction

Parameters of plant growth analysis such as relative growth rate, net assimilation rate and rate of nutrient uptake are important in the structure and dynamics of vegetation (Tilman, 1982). Researchers interested in plant growth often have to estimate plant growth parameters from experimental data (Hunt, 1978). Perennial herbs in temperate regions keep fresh material almost exclusively in the root and below-ground storage organs. Consequently, below-ground biomass, in the first stages of growth, is greater than above-ground biomass. However, the root to shoot ratio of biomass is progressively reduced during the growth period up to the stage of seed production (Mamolos *et al.*, 1995). The same trend is evident for N, P, and K total content. Furthermore, Veresoglou and Fitter (1984) and Vasilikos *et al.* (unpublished data) found that, for various herbs grown in the field, the maxima on the rates of nutrient accumulation were proceeded by that of productivity. The objectives of this study were to calculate the timing of maxima exhibition for the rates of root, shoot and total absolute biomass growth and of N, P, and K accumulation in root, shoot and total biomass for the perennial herb *Rumex acetosella* L. by using equations proposed by Hunt and Parsons (1974).

Materials and methods

This study was carried out in a moderately acid lowland grassland 70 km north of Thessaloniki (40°56′N, 22°53′E) during 1991 which was a relatively wet year (Mamolos *et al.*, 1995). The soil was classified as a Typic Xeralf type. Eight plots (6 x 1.9 m) used as replicates were arranged in a 30 x 20 m fenced area. Seven harvests were carried out during the growing season (mid March to early June). The harvest dates were 27 March, 11 and 24 April, 8 and 29 May, and 5 and 19 June. On each occasion two samples per plot were selected at random (each of 25 x 25 cm) and cut. The above-ground material of each sample was sorted into component species, dried at 72 °C for 48 h and weighed. At the same time *Rumex* plants, with their underlying roots, were taken from outside the experimental area, using aluminium cylinders (25 cm internal diameter and 50 cm long) to extract undisturbed cores. The roots of *Rumex* could be easily separated and thus, roots and shoots of *Rumex* were sorted out and dried at 72 °C for 48 h and weighed. The dried plant material was weighed, ground and stored in airtight containers at room temperature (20 °C). Nitrogen was determined by the Kjeldahl method. Sub-samples were digested with triple acid reagent HNO_3:H_2SO_4:$HClO_4$; 10:1:1 (Allen, 1989). Phosphorus in the solution was determined by a spectrophotometer at 882 nm and K by flame photometry (Allen, 1989).

Growth analysis

Data for above and below-ground and total plant weight as well as N, P, and K accumulation were log-transformed to render their variability more homogenous over time. The order of polynomial fitted to the parameters was best represented by the general formula (Hunt and Parsons, 1974):

$$f(T) = \ln (W) = \sum_{i=0}^{n} a_i T^i$$

Where W is the above- below-ground and total plant biomass or N, P and K accumulation in above- below-ground and total plant biomass, n is the order of polynomial ($0 \le n \le 3$), a_i is the coefficient and T the time in days.

For every harvest the mean of the root:shoot ratio of *Rumex* was used to estimate the root biomass of *Rumex* from above-ground biomass data in the experimental plot. As Elias and Causton (1976) suggested, regressions were fitted by using harvest mean values and polynomials of varying degree were used. When the *F*-test was not significant, then the sum of squares corresponding to that degree of fit was pooled with the residual sum of squares and a new residual mean square was calculated (Hunt and Parsons, 1974). The degree of polynomial was calculated with mean values and this order of polynomial was simulated separately for the data of every plot. The first derivative of $W = e^{f(T)}$ gives the absolute growth rate or the rates of change of N, P and K accumulation with time. When the second derivative d^2W / dt^2 was 0 the rates of parameters were maximum at timing (T). The solutions (timing of maximum values) from all plots for all parameters were analysed as a split-plot design with the parameters of above- below-ground and total plant as main plot treatments and the timing of maximum values as sub-plot treatments.

Results and discussion

We used the mean ratio of root:shoot for every harvest during the growing period of *Rumex* to calculate the corresponding root in each plot and harvest because the interaction replication × harvest were very small (unpublished data). For above- below- ground and total parameters of *Rumex* the cubic polynomials were found to be significant (unpublished data). Figure 1 shows the time and the maxima of above- below- ground parameters of *Rumex* with the respective maxima of absolute rates. The timing of below-ground and total parameters were found to be significantly earlier than that above-ground parameters except N (Figure 1). Maximum absolute growth rates were observed significantly earlier for below- ground biomass at the end of April, for total plant at 10 May, and for above-ground biomass at 20 May (Figure 1). The maxima of accumulation rates for N were observed significantly earlier for above-ground at 10 April in relation to the total plant and for below-ground at the end of April. The maxima of accumulation rates for P and K content were found significantly earlier for total plant and below-ground in late April in relation to above-ground at 10 May (Figure 1). The seasonal order could possibly be explained by differences in response to seasonal variables of soil such as soil water content. There are several reasons why the absolute growth rates of plants decrease over time, including reduction in resource per unit tissue with increasing size, and allocation increase to structural and reproductive rather than photosynthetic tissues. The evidence of differentiation of nutrient accumulation rates over time is important for co-existence with other plant species. These differences do not arise directly from inherent differences in nutrient uptake; it is rather the response of plants to environmental factors (soil moisture, nutrients), which permit them to partition this resource (Hunt and Lloyd, 1987). Differentiation in the optimal ratio of nutrients required by plants can account for stability and richness in plant communities (Tilman, 1982). High diversity has been attributed to spatial and temporal differences in growth and nutrient uptake among plant species (Veresoglou and Fitter, 1984). The conclusions of this work are that for perennial species the calculations of maxima of AGR and the uptake rates of nutrients are of use as total plant parameters.

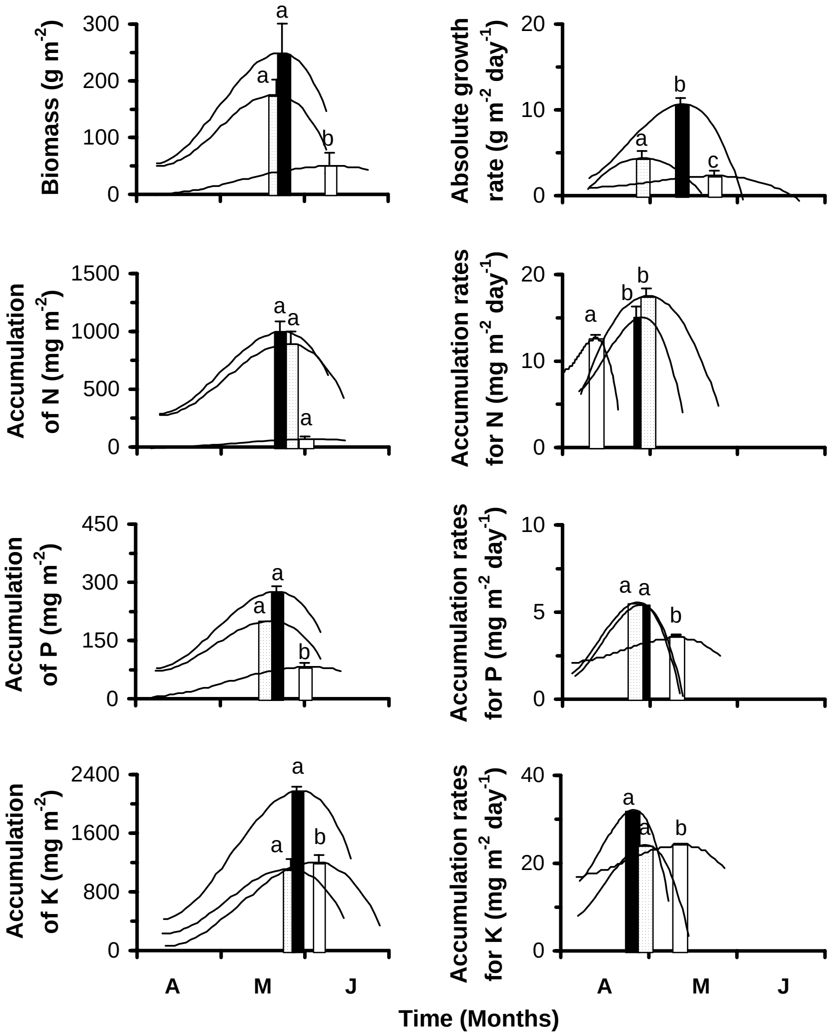

Figure 1. Mean values of maxima ± 1 S.E. (n = 8) of (□) above- and (▨) below-ground and (■) total plant biomass, and N, P and K accumulation with corresponding absolute rates for *Rumex*. Different letters show significant differences between timing of maximum values.

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Responses of perennial ryegrass seedlings to mycorrhiza development and leaf removal – leaf morphology and carbohydrate contents

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Abstract

In grassland the symbiotic association between fungi and plant roots (mycorrhiza) is a widespread phenomenon. The mycorrhiza supports plant growth in return for photosynthetic C from the host plant. Plants in grassland are subject to periodic removal of leaf tissue by cutting or herbivores, which may strongly decrease C availability for plant growth. How the additional C requirement by the arbuscular mycorrhizal fungi (AMF) *Glomus mosseae* and *Acaulospora longula* affect plant growth of repeatedly defoliated plants was studied in potted ryegrass seedlings. Development of mycorrhiza did not affect total plant dry mass, but induced significant changes in leaf morphology of seedlings. The presence of mycorrhiza resulted in a higher specific leaf area and an increased leaf area ratio. Fructan contents in plants were significantly decreased by mycorrhiza, indicating that C requirement by fungi was appreciable. The morphological changes resulted in an increase in the light intercepting area per g of photosynthate, which would increase the C gain of seedlings and thus counterbalance part of the fungal C requirements.

Keywords: *Glomus mosseae*, *Acaulospora longula*, cut, reserves, allocation

Introduction

Specific fungi, named arbuscular mycorrhizal fungi (AMF), form symbiotic associations with roots of the majority of plant species. Amongst other effects, this symbiosis facilitates nutrient uptake (mainly P and N) and increases the plants' tolerance of various kinds of stress (Smith and Read, 1997) in return for photosynthate supply from the host plant to the fungi.

In grassland, periodic removal of leaf tissue (defoliation) by cutting or herbivores decreases C availability (i) directly by removal of carbohydrates present in the removed tissues and (ii) by decreasing the light intercepting area for photosynthesis.

It is estimated that up to 20 % of photosynthetic C gain can be consumed by symbiotic fungi. Thus, the presence of mycorrhiza is a quantitatively important component of the plants' C metabolism. It is widely accepted that under conditions of low soil fertility, the higher photosynthetic productivity associated with the better nutrient status due to the increased nutrient supply by the fungus might compensate a part of the additional C cost attributable to the symbiosis. But when soil phosphorus availability is sufficient the presence of mycorrhiza has been found to decrease the growth of citrus (Graham and Eissenstat, 1998), which indicates that mycorrhizal colonisation is not always beneficial for the host plant (Johnson *et al*., 1997).

In white clover, at similar phosphorus and nitrogen concentrations in mycorrhizal and non-mycorrhizal plants, mycorrhizal colonization enhanced photosynthesis (Wright *et al*., 1998). In that study it was suggested that the stimulation of photosynthesis was attributable to the additional sink activity of the fungus, which counterbalanced part of the symbiotic costs.

The amount of photosynthate available to the plant is not only dependent on the photosynthetic rate but also on the light intercepting area. Thus, the relative growth rate of a plant can be separated into the assimilation rate and the leaf area ratio (here: leaf area per g of above-ground biomass; LAR; cf. Poorter, 1990). The latter quantity is composed of the specific leaf area (SLA) and the fraction of plant mass present in leaves (LMR).

In this study, morphological responses of defoliated ryegrass seedlings to mycorrhizal development were investigated. To estimate the C availability within the symbiosis we also studied the fructan contents in plants. We assumed that the amount of fructan present in the plant reflects the 'internal' carbohydrate status of the plant. A low fructan content may indicate a low availability of photosynthate for plant growth due to the additional C requirement by the fungi.

Materials and methods

Seeds of ryegrass (*Lolium perenne* L. cv. Stratos) were sterilised and placed in 1.1 l pots. Pots (n = 40) were filled with a 1:1 (v:v) mixture of quartz sand and granulated clay. All pots were fertilised using slow-release fertilisers without phosphorus and soft rock phosphate as a phosphorus source of low availability for plants. To half of the pots, an inoculum was given containing roots colonised with the AMF *Glomus mosseae* and *Acaulospora longula* (+AMF). When seedlings emerged, the temperature in the growth chamber was controlled at 24 °C during the 14 hours light period and at 16 °C during the dark. The relative humidity was kept between 65 and 75 % and the photosynthetic photon flux density at the plant level was 250 µmol m^{-2} s^{-1}. Plants were watered daily by adding de-ionised water.

Half of the +AMF and half of the –AMF plants were defoliated four times at weekly intervals at 3 cm height (DEF). After each of the first three cuts the –AMF plants received an additional P fertilisation to account for the relatively low P availability of the soft rock phosphate. After the fourth cut, plants were allowed a three week long re-growth period.

At final harvest, plants were separated into roots and shoots. Blades of fully expanded leaves were dissected from tillers, counted and their leaf area determined (Li-Cor 3100, Lincoln, NE, USA). The remaining parts of the tiller, mostly leaf sheaths, remained together as a single compartment, subsequently called stem. Stems and leaf blades were oven-dried at 70 °C for determination of dry weight. Mean leaf size was estimated as leaf area divided by leaf number, and SLA (cm^2 g^{-1}) as leaf area divided by dry mass of leaf blades.

Roots were freed from the soil substrate by washing with tap water and used for detection of AMF colonisation to prove the absence of fungal material in the roots of the –AMF plants (data not shown). The WSC contents of dried leaf sheaths were determined using procedures described previously (cf. Thome and Kühbauch, 1985; Gebbing *et al.*, 1998).

Results and discussion

As expected, the defoliation treatment significantly decreased the above-ground biomass of ryegrass seedlings (Table 1). Interestingly, there was no statistically significant effect of mycorrhiza development on total biomass. Leaf area at the final harvest was lower in the defoliation treatments. On average, defoliation reduced leaf area by 23 %. The highest leaf area (288 cm^2 pot^{-1}) was found in the undefoliated plants which had formed mycorrhiza. The higher leaf area in this treatment was mainly attributable to a significantly higher mean leaf size (data not shown). In undefoliated and non-mycorrhizal plants, fructan content in the stem was 343 mg pot^{-1}. The combination of both defoliation and mycorrhizal colonisation resulted in the lowest fructan content (28 mg pot^{-1}). In both defoliation treatments, the presence of AMF decreased the fructan content approximately by half. Thus, the C costs associated with mycorrhiza were not obvious from the biomass development of plants, but the reduced fructan content indicated that less C was available for plant growth (Morvan-Bertrand *et al.*, 1999). The SLA ranged between 105 and 209 cm^2 g^{-1}. When plants had no mycorrhiza defoliation caused a 66 % increase in SLA. The development of mycorrhiza resulted in an increase of SLA in both defoliation treatments.

Table 1. Biomass, leaf area, fructan contents, specific leaf area and leaf area ratio of undefoliated and defoliated ryegrass seedlings without (-AMF) and with (+AMF) arbuscular mycorrhizal fungi. Values represent means ± SE of five replicates.

	Undefoliated		Defoliated	
	-AMF	+AMF	-AMF	+AMF
Above ground biomass (g pot^{-1})	3.1 ± 0.2	2.6 ± 0.2	1.6 ± 0.1	1.4 ± 0.2
Leaf area (cm^2 pot^{-1})	225 ± 29	288 ± 9	191 ± 16	205 ± 28
Fructan content (mg pot^{-1})	343 ± 48	182 ± 15	63 ± 7	28 ± 9
Specific leaf area (cm^2 g^{-1})	105 ± 7	159 ± 8	175 ± 11	209 ± 16
Leaf area ratio (cm^2 g^{-1})	72 ± 5	114 ± 7	121 ± 10	148 ± 10

The leaf area ratio was 72 cm^2 g^{-1} in undefoliated, non-mycorrhizal plants. Both defoliation and the presence of mycorrhiza increased this quantity in our experiment and it was almost doubled when plants had formed mycorrhiza and were also defoliated. Thus, when photosynthate availability was low, morphological changes resulted in an increase in the light intercepting area at a given C investment.

Conclusions

The additional C drain associated with mycorrhiza caused significant morphological changes, so as to decrease the amount of C required for establishing the light intercepting leaf area. Despite these morphological changes, low plant fructan contents indicated that the C demand by the fungi could not be counterbalanced completely. One may ask whether this C demand decreases the persistence of ryegrass seedlings under field conditions, when the plants do not benefit from mycorrhiza due to a high soil phosphate status.

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Effect of canopy structure on the incident radiation profiles of mountain permanent meadows managed with different intensities

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Abstract

Canopy structure and PAR profile of a NE Italy mountain meadow (1000 m asl) managed extensively (1 cut per year and no fertilisation), medium intensively (2 cuts per year, fertilisation with mineral P and K) and intensively (3 cuts per year, fertilisation with mineral NPK) were studied. As a consequence of their effects on phytomass amount and distribution in the canopy, the different meadow treatments determined specific PAR absorption profiles, which are, probably also affected by the different efficiencies of PAR absorption of the various canopy layers.

Keywords: canopy structure, management intensity, mountain meadows, PAR.

Introduction

Canopy structure is highly affected by management intensity. It also considerably influences the microclimate inside the plant stand and in the soil, especially with reference to light penetration, and all the connected physical exchange processes (CO_2, water vapour and heat) and physiological activities (transpirations and photosynthesis). In order to contribute to knowledge of these relations, the results of some analyses of the effects of canopy structure on the PAR profile of a mountain meadow managed with different intensities are presented .

Materials and methods

The research was carried out in a plot trial established on a permanent meadow located near Asiago (Vicenza province, NE Italy) at about 1000 m asl on soils of calcareous origin and medium texture. Mean annual precipitation and temperature are 1444 mm and 7.5 °C. The meadow was managed according to eight treatments (Tr.) set in a randomised complete block design with three replicates. Of the eight Tr., only the following three were considered in this study: 1) extensive (one cut per year around 10 July and no fertilisation), 2) medium intensive (two cuts per year, around 20 June and 30 September and mineral fertilisation with 50 and 250 kg ha^{-1} y^{-1} of P_2O_5 and K_2O, respectively), 3) intensive (three cuts per year, around 1 June, 31 July and 30 September and mineral fertilisation with 250, 50 and 250 kg ha^{-1} y^{-1} of N, P_2O_5 and K_2O, respectively). In the meadow, which can be referred to by the association *Centaureo dubiae - Arrhenatheretum elatius* Oberd. 64, the main species at the first cut were *Arrhenatherum elatius* (45, 46 and 15 % of the phytomass in Tr. 1, 2 and 3, respectively), *Dactylis glomerata* (17, 12 and 26 %), *Agropyron repens* (8, 2 and 4 %) and *Lolium perenne* (2, 3 and 7 %). Shortly before the first cut of each Tr. from 1998 to 2000, on 50 × 50 cm subplots (two per Tr. in 1998 and one per Tr. in 1999 and 2000), the following characteristics were studied: i) PAR profile, obtained measuring PAR every 10 cm from the soil surface to the top of the canopy according to Fliervoet (1984), using a portable PAR meter (SS1 model, Delta T Device, UK) and ii) canopy structure, assessed according to the stratified clipping method proposed by Monsi and Saeki (1953). Briefly, from each subplot the above-ground phytomass of the canopy was divided into 10 cm layers, harvested, separated into stems, leaves, inflorescences or fruits of grasses, other species and dead plant material, dried and then weighed.

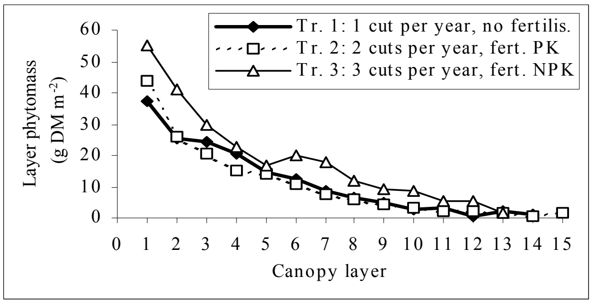

Figure 1. Distribution of phytomass in the canopy layers (0-10 cm (1) and 10-20 cm (2) etc.) above the soil.

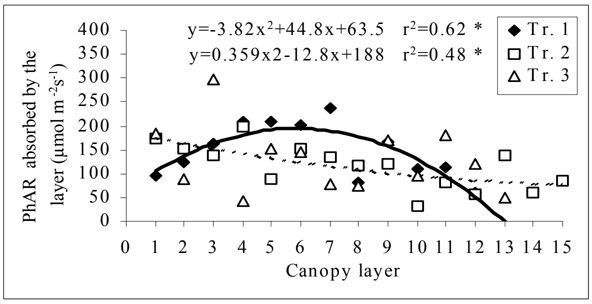

Figure 2. Distribution of absorbed PAR in the canopy layers (* = significant at $P \leq 0.05$).

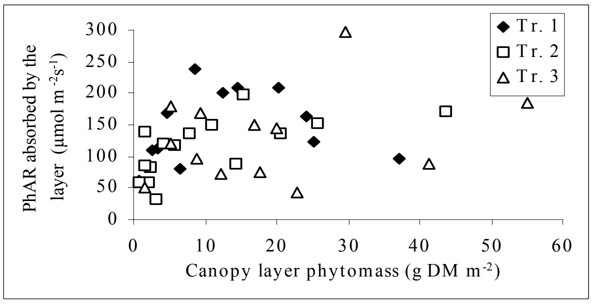

Figure 3. PAR absorbed by the layer and canopy layer phytomass.

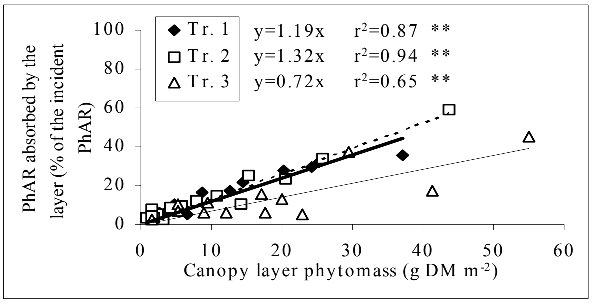

Figure 4. Relation between % PAR absorbed by the layer and layer phytomass (intercepts at origin, lines differ at $P < 0.01$, ** = significant at $P \leq 0.01$).

Regressions between radiation absorption and phytomass dry matter (DM) or layer height were studied through the GLM procedure of SAS (1985). Identification of the best regressions and comparison of those fitted for the three Tr. were carried out according to Donatelli and Annichiarico (1997). The results are presented as means of the four surveys per Tr. and for total phytomass (biomass + necromass) which showed very similar regressions compared to those based on biomass data but was statistically more accurate.

Results and discussion

In Tr. 1, 2 and 3, above ground phytomass was 164, 159 and 246 g DM m^{-2}, respectively and distributed in the 10 cm layers according to figure 1. In the same Tr., a PAR varying between 160 and 310 µmol m^{-2} s^{-1}, equal to 9-16 % of the incident radiation (on average 1880 µmol m^{-2} s^{-1}) arrived at the soil level. In Tr. 1, PAR was absorbed mostly in the canopy layers 4-7 while in Tr. 2 and 3 a lot of radiation was also absorbed in the lower layers (Figure 2). Except for a high value of Tr. 3, the maximum PAR quantity absorbed in a 10 cm canopy layer was around 200 µmol m^{-2} s^{-1} for all the Tr. A linear relationship between PAR absorbed and phytomass of the layers was not observed (Figure 3). This is understandable, as on the upper layers there is a lot of radiation that can be absorbed, whereas less radiation is available at the lower layers. A linear relationship occurred, instead, when PAR absorbed by the layers was expressed as % of the incident PAR (Figure 4). The absorbed PAR g^{-1} phytomass DM in the canopy layers increased with the canopy height, according to a function of x^3 (Figure 5). Maximum values were around 30 in Tr. 3 and 90 in Tr. 1 and 2, despite the fact that in these last Tr. the majority of values were below 30. In all Tr., the % absorbed PAR (PAR absorbed by the layer expressed as percentage of the PAR incident on the layer per g phytomass DM) increased with the layer height (Figure 6) according to a function of x^4. This increase derives

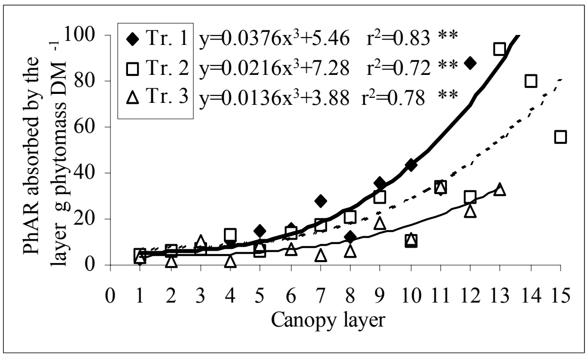

Figure 5. Relation between PAR absorbed by the layer (µmol m^{-2} s^{-1} g^{-1} phytomass DM) and canopy height (line intercepts and slopes differ at $P < 0.01$, ** = significant at $P \leq 0.01$).

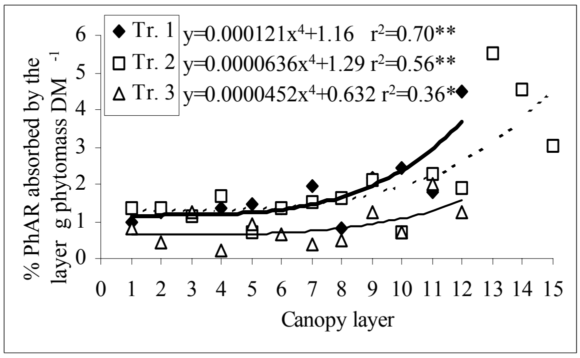

Figure 6. Relation between PAR absorbed by the layer (% of incident PAR) g^{-1} phytomass DM and canopy height (* and ** = significant at $P \leq 0.05$ and $P \leq 0.01$, respectively).

from the fact that the points with lower x values located above the line in figure 4 come from the higher canopy layers. The diversity of the % PAR absorbed by the layer g^{-1} phytomass DM, between upper and lower layers tends to be less pronounced when passing from Tr. 1 to 2 and 3, even if no statistically significant difference was found among the slopes of the three lines. The higher values of % PAR absorbed by the layer g^{-1} phytomass DM of the upper canopy layers and of the Tr. 1 and 2 could derive from the fact that in such situations the phytomass amount sharing out the available radiation is less (Figure 1). Indeed, the first variable increases when the second decreases (Figure 7). Nevertheless, this increase does not fit a straight line: in upper canopy layers of Tr. 1 and 2 (low values of phytomass), % absorbed PAR g^{-1} phytomass DM increases more than phytomass decreases. As the same result is obtained when considering only the biomass, we can suppose that the absorption power in the upper layers of the canopy is greater than in the lower ones.

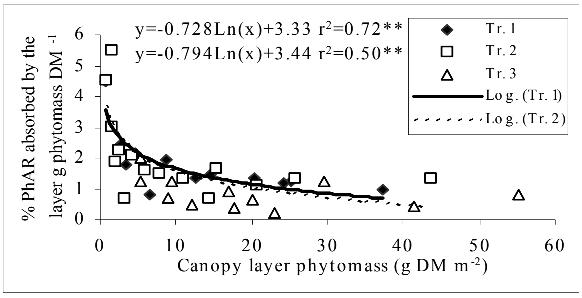

Figure 7. Relation between PAR absorbed by the layer (% of incident PAR g^{-1} phytomass DM and layer phytomass (Tr. 1 and 2 lines not significantly different, ** = significant at $P \leq 0.01$).

Conclusions

As a consequence of their effects on phytomass amount and distribution in the canopy, the different meadow treatments determine specific PAR absorption profiles, which are, probably, affected also by a different power of PAR absorption of the various canopy layers.

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Use of vegetation indexes to predict biomass and LAI of Trentino grasslands

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Abstract

Within the EU Carbomont project (5^{th} framework), detailed studies of primary production collected at ten different grassland sites at Viote del Monte Bondone (Trento, Italy) have been complemented by proximal and remote sensing measurements. Measurements have been made at different levels from ground truth (through ASD hand-held spectroradiometer using different foreoptics) and aerial remote sensing (ASPIS sensor), in order to allow comparisons with satellite data. Biomass, necromass and leaf area index (LAI) were determined, providing comprehensive ground truth reflectance data for comparison with some vegetation indexes. A good relationship was found between measured canopy parameters and Vegetation Indexes such as NDVI. Indexes calculated from ground-collected data produced good correlations with canopy biomass and LAI, particularly regarding the indexes calculated from the 170° cosin diffusor measurements data. Saturation of NDVI, however, is strong and seems to occur, in both cases, above 150 g m^2 of dry biomass and 2 of eLAI, confirming that it is one of a major issue in grassland remote sensing research.

Keywords: Remote sensing, grassland biomass, LAI, vegetation indexes

Introduction

Spatial and temporal resolution of satellite multi-spectral images has dramatically improved in the last few years. Vegetation indexes may provide an indication of biophysical parameters of vegetation through their relationship to light reflectance (Clevers and van Leeuween, 1996, Myneni *et al*., 1997). Many studies have been carried out in order to find a relationship between measured grassland parameters and Vegetation Indexes (such as SR, NDVI, Green NDVI, ARVI, GARI, etc.). Results obtained from correlation analysis between field spectral indexes supports the hypothesis that biophysical parameters can be derived from remote sensing data. These results, in fact, can be applied to validate models of productivity and carbon cycling, from ecosystem to regional level, based on aerial and satellite image data interpretation. On the other hand, the limitation of predicting power of these indexes is saturation, which occurs above a certain biomass rate and LAI (Borfecchia *et al*., 2001). Spectral ground truth measurements allow the comparison of both airborne sensor data and satellite data. Aerial remote sensing could provide a key tool to scale up the measured ground data due to the high spatial resolution available and the possibility of planning the flight in the best phenological moment. At present, there are no extensive dataset of canopy reflectance collected on natural alpine grasslands. In this work we present the preliminary results of and investigation on canopy reflectance made at different levels from ground truth and aerial remote sensing. The predictive power of the two approaches on different canopy parameters such as phytomass and LAI, has been compared.

Materials and methods

At biomass peak (8^{th} of July), during the cutting period, an intensive field campaign was conducted on the grassland study area of Viote of Monte Bondone, Trento, Italy (1550 m a.s.l). Ground radiometric measurements were acquired using both ASD Hand-Held spectroradiometer (170° diffusor foreoptics) and ASD Field Spec Pro (10° foreoptics) in

10 different 100 m^2 wide square plots characterised by different vegetation and biomass rates. Investigation plots were selected in differently managed meadows, pastures, peat bogs and abandoned or just cut areas.

Dry biomass and necromass were determined at each site by cutting two long cross-stripes (1 m^2) and effective Leaf Area Index (eLAI, LAI obtained by inverting the gap fraction data) was indirectly measured by means of a Sunscan Canopy Analyser ceptometer. At the same time, aerial images of the whole grassland area of Monte Bondone, including the 10 measurement plots, were taken by the University of Tuscia team by means of an ASPIS sensor (Advanced Spectroscopic Imaging System) with an average spatial resolution of 60 cm. Aircraft measurements have been made at 2400 m a.s.l (850 m above ground level). Acquired spectral bands were: 550, 680, 700, 699.8, 719.3, 733.5, 748.5 and 780 nm. Radiometric data have been elaborated and NDVI has been calculated from both at the ground level and at the airborne sensor level.

Results and discussion

The investigated plots were very different regarding their canopy parameters such as phytomass, biomass, necromass and vegetation composition. Dry biomass values of the 10 different areas varied between 23 and 540 g m^{-1}, while eLAI range was included between 0.3 and 7 (Figure 1).

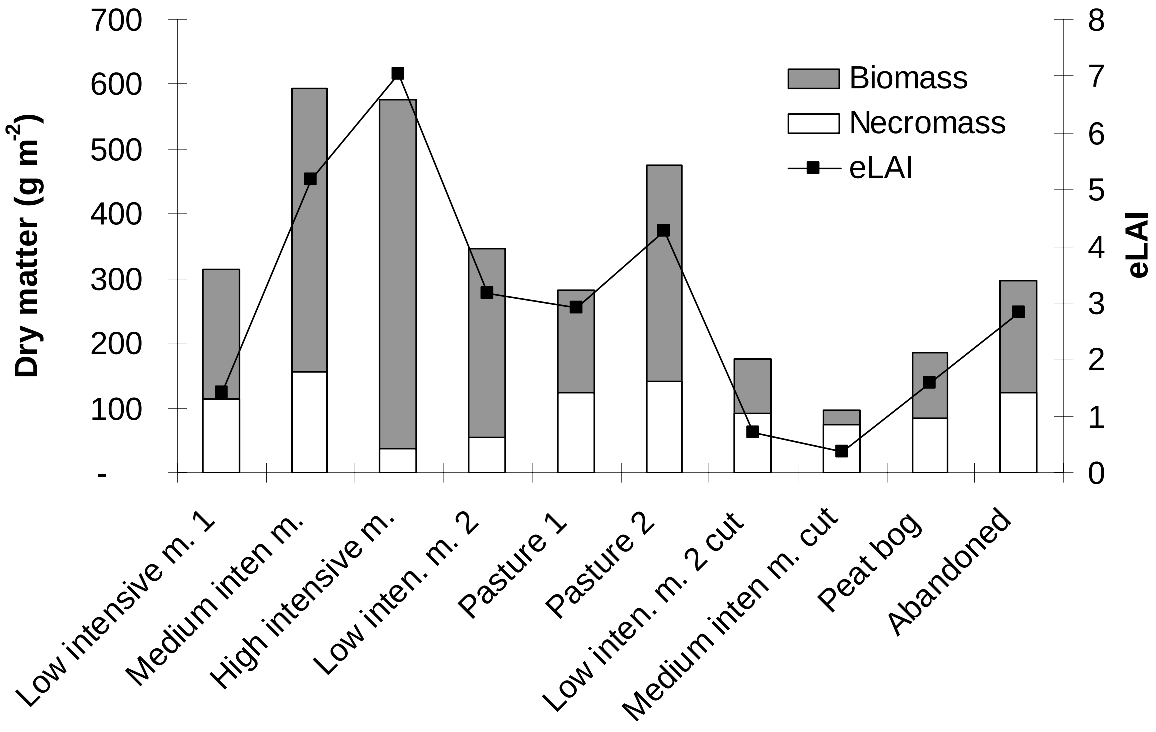

Figure 1. Biomass, necromass and effective Leaf Area Index of the 10 plot areas of Viote del Monte Bondone.

NDVI values calculated from ASPIS data and those calculated from ground truth measurements (ASPIS NDVI = 1.24*ground NDVI-0.28; R^2 = 0.94; P < 0.00) showed a good correlation. In this paper, data calculated with 170° diffuser foreoptics, which produced better correlations than the 10° ones, are considered. 170° reflectance data seem to be independent from errors related with vegetation structure, giving a hemispheric view of a wide area under the spectroradiometer. NDVI demonstrated significant correlations with biophysical parameters such as dry biomass (Figure 2A) and effective Leaf Area Index (Figure 2B).

NDVI calculated from ground reflectance data showed correlations with dry biomass and LAI similar to those calculated from ASPIS sensor data; trends were similar but aircraft values were lower than ground ones in all cases (Figures 2A and 2B).

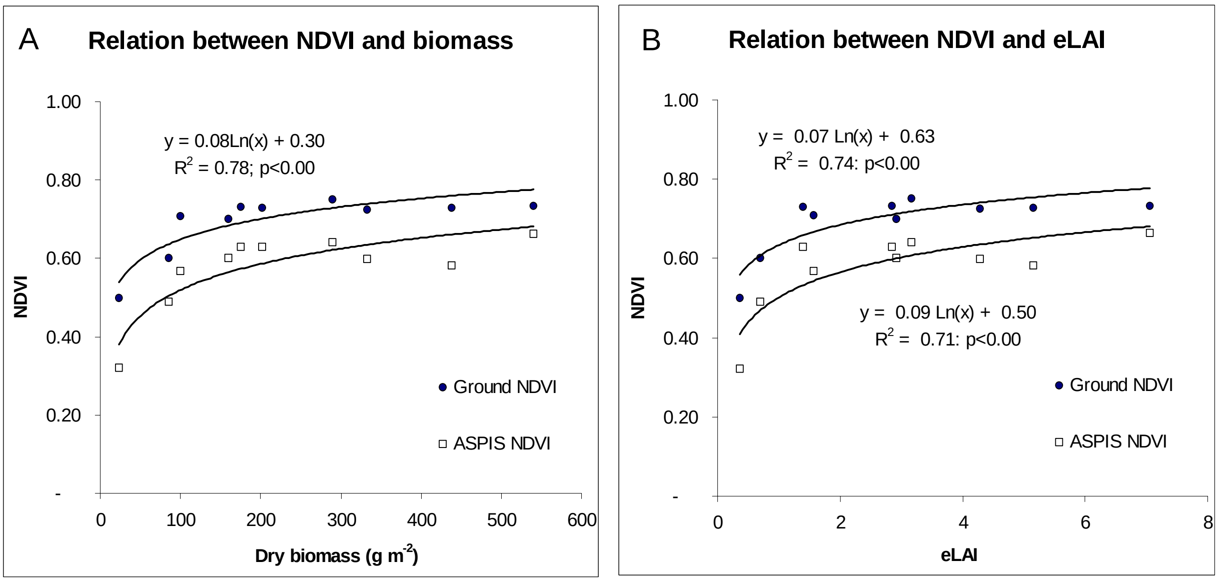

Figure 2. Relation between calculated NDVI and dry biomass. Ground NDVI has been calculated with 170° diffusor foreoptics.

NDVI showed the same predictive power both in regards to the airborne sensor and the ground spectroradiometer data. Saturation of NDVI, however, is strong and seems to occur, in both cases, above 150 g m^2 of dry biomass and 2 of eLAI, confirming that it is one of a major issue in grassland remote sensing research.

Conclusions

Based on the strong correlation between the results of airborne and ground data, it can be concluded that it is possible to obtain a similar predictive power both from airborne multi-spectral data and from diffuser foreoptics ground spectroradiometric measurements. Considering the strong saturation which occurred both at aircraft and at ground levels, other indexes have to be tested and a wider data base collection is needed.

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Diversity in European dairy farming systems and its environmental consequences

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Abstract

Even after several decades of a Common Agricultural Policy in Europe, there still exists a wide range of diversity in dairy farming systems, linked to regional natural conditions and with consequences for the quality of the environment. This paper divides Europe in five regions, each characterised by typical dairy farming systems. Next, attention is focused on regions with rather intensive systems, for an assessment of performance in relation to European environmental regulations, especially the Nitrates Directive. Finally, issues are highlighted which need more attention to adjust dairy farming in these regions to societal demands. The paper is mainly based on the results of a meeting of European scientists in France (Quimper, 2003), who propose to continue collaboration by establishing a permanent EGF-working group on ‘Dairy farming systems’.

Keywords: dairy farming systems, diversity, sustainability, environmental regulations

Diversity in dairy farming systems in Europe

Despite of 35 years of a Common Agricultural Policy (CAP) there is still much diversity in European dairy farming systems. Diversity survives because ruminant-based farming systems are more linked to natural than to socio-economic conditions. Physically, Europe is shaped by a virtually continuous mountain backbone from the Sierra Nevada in the South of Spain to the Carpathians in Romania, with two offshoots: the Apennines and the Balkans. The southern slope of this spine descends very rapidly to the Mediterranean and the Adriatic, whilst the slope to the north-west is rather flat, creating more or less fertile plains. The climate adds to the north-south division, contrasting Mediterranean Europe and its long summer drought with the rest of Europe, which is temperate. As a result, European dairy farming can be divided in five regions (Pflimlin and Todorov, 2003): 1) a wet mountain area extending from the Cantabrian mountains to the Pyrenees then to the Massif Central, continuing as far as the Jura, the mountains of the Rhineland and above all to the chain of the Alps that extend right to central Europe. Permanent pasture dominates here. Grazing is often the only way to use extensive areas that cannot be reached by machines; 2) a dry Mediterranean area of mountains and foothills which includes the high plateaux of the Centre of Spain, the French Mediterranean foothills, the centre and south of Italy and the south-west of the Balkans. In these areas of more or less wooded land, extensive dairy farming is mainly carried out with ewes and goats. However, very fertile wide valleys with intensive dairy farms are also to be found in this area, for example in the Po valley in Italy; 3) north of the wet mountains of Continental Europe there are vast plateaux of grassland, which are difficult to plough. These grassland areas are used by dairy and suckler herds in France, Wallonia, west of England and Ireland; 4) in the north-west of the continent there is a strip of originally very poor sandy soils, extending from Flanders to the north of Jutland via the south- east of the Netherlands and Brittany in France. On these light soils livestock systems have developed, with forage crops and high purchases of feed, also for pig and poultry farming. It is in this very sensitive to leaching area that the most intensive dairy systems in Europe are to be found; 5) another specific region is the north of Scandinavia with Norway, Finland and Sweden, where forest alternates with wide clearings of quite intensive forage crops for dairy production. Climatically, this area is similar to the wet mountain area, with latitude compensating for altitude.

Performance in relation to European environmental policy

For the mountainous, Mediterranean and Nordic regions, it is unlikely that nutrient losses exceed environmental standards on a large scale. As the agronomic potentialities are reduced by unfavourable soil and climate conditions, farmers practice low nutrient input systems, with a high rate of acceptance of agri-environment programs and organic farming. Due to the natural conditions, the cost of milk production is high and therefore economic viability depends on additional payments for landscape and wildlife, and on the possibility to make products that are relatively valuable (e.g., regional cheese). However, there are some specific problems linked to slopes and manure: bacteria and phosphorus in surface water.

In the other regions, with better production potential, intensification of dairy farms by increased inputs of fertilisers and feeds has led to high nutrient surpluses, especially of nitrogen and phosphorus. The nitrogen surplus can be lost as nitrate to ground- and surface waters or as ammonia or nitrogen oxides to the atmosphere. European directives aim at protecting the environment against such harmful losses, among them the important Nitrates Directive. In order to reduce water pollution caused by nitrates from agricultural sources, it includes rules for the use of fertilisers, particularly of animal manure, for which application rates are restricted to 170 kg N ha^{-1}. However, derogation can be allowed for specific situations, provided the objectives of the Nitrates Directive will still be realised and the higher rate can be justified on the basis of objective criteria. To avoid sanction for non-respect of environmental standards through cuts in direct payments (CAP review in Luxembourg, 2003), farmers have to adapt their farm management to environmental standards.

How to attain environmental policy objectives in regions with intensive dairy farming?

This question gathered 35 researchers from 8 European countries with intensive dairy farming during a workshop held in June 2003 in France (Quimper). They compared characteristics and performances of farming systems and discussed the way they could be improved to comply with national and European legislation (Bos *et al*., 2003). Differences between regions were large (Table 1), even within the more intensive areas. As a result, in many regions manure-N production is above the 170 kg ha^{-1} threshold. The most extreme situations can be found in the south and east of the Netherlands, but also in Belgian Flanders, where milk production is above 10,000 kg ha^{-1}. Related high stocking rates create organic-N loads of 250 kg ha^{-1}, and N-surpluses over 200 kg ha^{-1}. Farms in such regions need to improve nutrient management and probably should reduce stocking rates or export manure.

Table 1. Characteristics of intensive dairy farms in some European regions (Bos *et al*, 2003).

	Belgique Flanders	Denmark Jutland	Germany Schlesw.H	NL South	UK England	Italy Po vally	Ireland Southw.	France Brittany
tons milk	320	450	470	475	560	260	180	260
tons milk ha^{-1}	10.0	7.0	5.2	13.4	7.4	11.0	7.2	6.5
% grassland	63	15	60	65	80	75	100	45
% fress grass in diet	30	15	35	30	45	0	75	40
kg organic N ha^{-1}	250	150	120	230	220	175	210	125
kg mineral N ha^{-1}	180	90	130	285	240	40	230	100
kg surplus N ha^{-1}	200	240	160	400	280	240	200	140
mg nitrate l^{-1} groundw.	>50	25-40	40-50	>50	20-50	20->50	25-40	30-40

Research projects at the farm scale are indispensable in the process of developing more sustainable dairy farming systems. The major challenge is to deal with the complex interactions between animal, soil and crop, and this calls for a systems approach. Several models are available in different countries to simulate farm nutrient flows and to predict nitrogen losses. Some countries have research experience with experimental and pilot farms, or will soon start experimenting. Combining experiences and knowledge from the different countries by collaboration can be very helpful. Indicators should be found to compare the performance of farming systems and to evaluate them from an environmental and socio-economic point of view. Generally, agri-environmental indicators should (i) be correlated with both environmental problems and farming practices, (ii) encourage farmers to improve their management practices, and (iii) fulfil the requirements of policy (low cost for data acquisition, efficient control, reliability). The relationship between technical solutions and their adoption by farmers is of particular interest: farm-economic data and 'sociological elements' are important to judge the validity of proposed solutions.
Some other methodological aspects need to be reconsidered when comparing nutrient surpluses, for instance, biological N_2 fixation by legumes. Livestock units should be expressed in terms of nutrient excretion. This also needs to be calculated in a uniform way, based on animal nutrition and production level.
The EGF working group 'Dairy Farming Systems' intends to contribute to these items. The scope of the working group is to improve environmental quality by designing effective, efficient and attractive farm-strategies to improve nutrient cycling, and to contribute to the dissemination of these strategies among European farmers.

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Comparison of extensive, organic and conventional grassland farming methods

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Abstract

The aim of our study is to compare extensive, organic and conventional grassland farming methods. Pasture of a low productivity was under-seeded with three plant species (*Lolium perenne*, *Bromus inermis*, *Phleum pratense*) in a larger plot experiment while the original sward was retained as the control. Treatment with liquid manure formed the basis of the organic system (30 m^3 ha^{-1} y^{-1} cattle liquid manure) while artificial fertiliser was used for the conventional one (50 kg ha^{-1} y^{-1} nitrogen). There was no nutrient input to the extensive system. The production of forage and the energy value of forage produced as well as other forage quality parameters were examined.
Our results are the followings:

1. There was no significant difference between the yields of plots treated with liquid manure and artificial fertiliser independent from the year or underseeded plant species.
2. Yield of extensive plots started to decrease significantly from the second year.
3. In the first and second year the yield of *Lolium perenne* was significantly higher. From the third year the more drought resistant *Bromus inermis* become first in terms of yield.
4. In the first year there was no significant difference among the sample's estimated energy density values. Estimates were based on Weender-analysis.
5. Crude fibre content was found significantly higher in the extensive treatment while crude protein content was found significantly higher in case of treatment with liquid manure or artificial fertiliser.

Keywords: extensive farming, organic farming, conventional farming, *Lolium perenne*, *Bromus inermis*

Introduction

In Hungary the extent of grasslands has been decreasing in the last few decades as agricultural areas of good-quality have been taken up by tillage farming (Barcsák and Kertész, 1986). Grasslands located on soils of lower productivity produce on average 1.5 t hay ha^{-1} y^{-1} (Szemán, 1994). Increases in yield have been realised by applying artificial fertiliser. Barcsák *et al*. (1981) determined that, in case of NPK rate of 1:0.4:0.4, one kg nitrogen will result in 20 kg increase in dry matter production. The appropriate quantity of nutrients required to raise the yield of different grasslands has been examined by many experts (Nagy, 1989; Szemán, 1991a and 1991b; Szemán, 1994). Overuse of artificial fertilisers has resulted in not just the increase in production but also in soil degradation (Cowling, 1981; Láng, 1983; Sipos and Patócs, 1975) and loss of biodiversity (Müller, 1994). Szemán (1998) has determined that there was a greater variety of species of Fabaceae and that their yield was higher on those grasslands that were not supplied with artificial fertiliser. The crude protein content of grasses also increases with nitrogen supply (Bánszky, 1988; Szemán, 2003). New, eco-friendly grassland management methods such as organic and extensive approaches appear to be interesting alternatives (Ángyán and Menyhért, 1997).

Materials and methods

The experimental site is located in Central-Hungary, 60 km to the east from Budapest at the elevation of 250 m. Average yearly rainfall is 600 mm. Plots were established in a pasture sown in 1994. This run down pasture was under-sown with three grass species (*Lolium perenne*, *Phleum pratense* and *Bromus inermis*) in October 2000 while original the sward was retained as the control. Four different plots were thereby established. In these plots different grassland farming methods were examined (extensive – no fertiliser or manure; organic – 30 m^3 ha^{-1} y^{-1} liquid manure; conventional – 50 kg N ha^{-1} y^{-1} artificial fertiliser). The sward was harvested in late May. Aspects of sward nutritive value were determined based on *Weender*-analysis after dehydration. Results were analysed using the *MINITAB* statistical method.

Table 1. Set up of the experiment.

Factor	Treatment
Underseeding	*Lolium perenne*
	Bromus inermis
	Phleum pratense
	Control
Fertilisation	Nil fertiliser
	Liquid manure (30 m^3 ha^{-1} y^{-1})
	Artificial fertiliser (50 kg ha^{-1} y^{-1} N)
Year	2001
	2002
	2003

Results and discussion

Table 2 shows the results of nutritive value analyses of samples harvested in 2001. According to these data it is apparent that there was no significant difference between the estimated energy values for liquid manure and artificial fertiliser treatments. Energy value estimates were based on the crude fibre content. Lower energy value of non-fertilised plots was due to the higher crude fibre and lower crude protein content.

Table 2. Internal parameters based on *Weender*-analysis and estimated energy values based on the crude fibre content in 2001.

Nutrient	Measure	Nil fertiliser	Liquid manure	Artificial fertiliser	Standard deviation
Dry material	g kg^{-1}	922	920	919	2.3
Crude protein	g kg^{-1} DM	70	107	122	28.9
Crude fat	g kg^{-1} DM	18	31	26	5.9
Crude fibre	g kg^{-1} DM	367	321	302	52.6
Crude ash	g kg^{-1} DM	67	75	83	110.9
N-free extract	g kg^{-1} DM	479	462	468	82.1
Energy value	MJ ME kg^{-1} DM	8.7	9.4	9.4	0.7

Table 3 shows the dry matter yield harvested in the experimental plots. There was no significant difference in yield between the liquid manure and artificial fertiliser treatments. Swards under-sown with *Lolium perenne*, *Bromus inermis* and *Phleum pratense* responded to artificial nitrogen supply (F3) in the same way as to liquid manure (F2).

According to the overall yield of the species, *Lolium perenne* (8.53 t ha^{-1}) and *Bromus inermis* (8.26 t ha^{-1}) provided significantly more forage than *Phleum pratense* (6.94 t ha^{-1}) or the non-under-sown control (5.98 t ha^{-1}). Increased production from *Lolium* was attributed to its aggressive growth characteristics while *Bromus inermis* could have significantly better results due to its drought tolerance. Yield of the moisture-loving *Phleum pratense* was less than expected because of the drought and the dry location of the pasture. Based on this experiment plots under-sown with *Lolium perenne* and *Bromus inermis* and treated with liquid manure seem to provide more forage of a better-quality.

The production from the extensive grassland management treatment method was lower, this approach seems to have a lower livestock-carrying capacity even when under-sown.

Table 3. The effect of under-sowing and fertilisation on dry matter production.

Treatment		Average yield		Extra yield		Equation of regression
Under-sowing	F	t DM ha^{-1}	%	t DM ha^{-1}	%	(y = yield; x = N-fertilisation)
Control	F1	4.5	100	-	-	y = -0.477x + 6.9417
	F2	8.0	179	3.6	79	r^2 = 0.0672
	F3	5.4	121	1.0	21	
Phleum pratense	F1	6.0	134	1.5	34	y = -0.843x + 8.6353
	F2	7.1	159	2.7	59	r^2 = 0.9638
	F3	7.7	172	3.2	72	
Bromus inermis	F1	6.7	149	2.2	49	y = -1.4355x + 11.136
	F2	8.6	191	4.1	91	r^2 = 0.9709
	F3	9.6	213	5.1	113	
Lolium perenne	F1	5.6	124	1.1	24	y = -1.7895x + 12.111
	F2	10.9	243	6.4	143	r^2 = 0.4343
	F3	9.1	204	4.7	104	

F = Fertilisation: F1 = Nil fertiliser, F2 = Liquid manure, F3 = Artificial fertilizer.

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Effects of cutting frequency and fertilisation on forage quality

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Abstract

Long-term small plot trials were established at five sites in the Czech Republic in 2003. There were four cutting systems (four, three, two and two cuts) and four fertiliser regimes (zero fertiliser, PK, N_{90}PK, N_{180}PK)The average dry matter production of grassland was 6.46 t ha^{-1} for all sites, and it was significantly (P < 0.01) reduced when subjected to four and three cut systems compared with a two-cut system. The number of botanical species present at the 5 geographically distinct sites fluctuated between 42 and 61, representing 130 species over all trial sites. The intensive cutting system significantly (P < 0.01) increased CP concentration (from 121.5 to 174.0 g kg^{-1} DM), CP production (from 692 to 961 kg ha^{-1}), NEL concentration (from 5.43 to 5.95 MJ kg^{-1} DM), NEV concentration (from 5.29 to 5.67 MJ kg^{-1} DM), PDIE concentration (from 74.2 to 86.0 MJ kg^{-1} DM), and PDIN concentration (from 74.7 to 105.9 MJ kg^{-1} DM) when compared with the extensive cutting system. The intensive system significantly (P < 0.01) decreased the fibre concentration from 297.0 to 218.4 g kg^{-1} DM. Increasing N fertiliser significantly (P < 0.01) increased DM production (from 5.49 to 7.96 t ha^{-1}), CP concentration (from 145.1 to 157.7 g kg^{-1} DM), CP production (from 682 to 1104 kg ha^{-1}) and the PDIN concentration (from 88.5 to 96.2 g kg^{-1} DM) when compared to the control treatment (zero fertiliser).

Keywords: grasslands, cutting frequency, forage quality, biodiversity

Introduction

Permanent grassland in the Czech Republic (CR) accounts for 950,000 ha, or 22.2 % of agricultural land (4,280,000 ha). The decrease in cattle numbers from 1,236 thousand in 1990 to 590 thousand in 2003 has had a negative effect on the management and utilisation of grassland (803 thousand ha were utilised in 2002). Fifty percent of cattle are located in the lowlands where forages on arable land, corn silage and concentrates form the basis of cattle diets (Kohoutek, 2002). The requirement to increase biodiversity and improve animal welfare have increased in importance (Pflimlin and Todorov, 2003). Gruber *et al.*, (2000) stated that increasing the cutting frequency of grassland distinctively improved the voluntary intake of bulky fodder at 2, 3 and 4 cuts (10.4, 13.0, 15.2 kg DM respectively), as well as daily feedstuffs intake (herbage + concentrates). Cutting systems of 2, 3 and 4 cuts in dairy systems resulted in milk yields of 11.4, 17.2 and 23.0 kg milk (FCM) respectively per cow per day.

Materials and methods

Long term small plot trials were undertaken on permanent grassland at 5 sites in 2003. The sites were located in Jevíčko, Liberec, Rapotín, Hladké Životice and Zubří. Plots were 10 m^2. The grassland vegetation on the experimental sites Jevíčko, Rapotín, Liberec and Zubří was classified as *Arrhenatherion*. The Hladké Životice site had been reseeded and *Alopecurus pratensis* was the dominant species. There were 16 treatments with four replications of each treatment at each site. There were four cutting treatments: 1) an intensive cutting system (1st cut May 15th followed by 4 cuts y^{-1} with 45 day intervals between cuts), 2) a medium intensive system (1st cut between 16th and 31st May followed by 3 cuts per year with 60 day intervals between cuts), 3) a low intensive system (1st cut between 1st and 15th June followed by 2 cuts y^{-1} with 90 day intervals between cuts) and 4) an extensive system (1st cut between 16th and 30th June followed by 1-2 cuts y^{-1} after 90 days). There were four levels of fertilisation: the control treatment had zero fertiliser (A), $P_{30}K_{60}$ (B), $N_{90}+P_{30}K_{60}$ (C), and $N_{180}+P_{30}K_{60}$ (D). P_{30} was 30 kg P ha^{-1} y^{-1} applied as superphosphate, K_{60} was 60 kg K ha^{-1} y^{-1} applied as potash salt, $N_{90,\ 180}$ were 90 and 180 kg N ha^{-1} y^{-1} respectively applied as calcium ammonium nitrate (CAN). Total annual DM production and sward botanical composition were recorded at all sites. Crude protein (CP), fibre, NEL (net energy for lactation), NEV (net energy for fattening), PDIE (protein digested in the small intestine when energy is limiting), PDIN (protein digested in the small intestine when nitrogen is limiting) were predicted using the NIR Systems 6500 instrument. Data were statistically analysed using two-factor analysis of variance with one observation in the subclass. The differences between the averages were tested with the Tuckey test.

Results and discussion

The average DM production for the 16 treatments and 5 sites was 6.46 t ha^{-1} (Table 1 and 2) in the extremely dry year that was 2003. Dry matter production significantly decreased ($P < 0.01$) from 6.86 to 6.06 t ha^{-1}when a four and three cut system were applied compared to the two-cut system. The use of N fertiliser (treatments C and D), even in the dry year of 2003, significantly increased ($P < 0.01$) DM production compared to the zero fertilisation treatment (A) and the PK only treatment (B). Similarly, based on the analysis of perennial trials in BAL Gumpenstein, Gruber *et al.* (2000) claimed that the yield of grassland decreased with increasing cutting frequency, especially when a four-cut system was applied (8,648, 8,054, and 6,509 kg DM ha^{-1}, at 2, 3 and 4 cuts respectively). The highest energy yield was acquired from a 3-cut system.

The number of plant species (Table 3) at the 5 sites varied from 42 to 61, of which there were 10 to 16 grass species, one to six legumes, and 25 to 39 other native species. The forage quality (Table 1 and 2) was significantly influenced by both cutting system and fertiliser regime for all evaluated parameters. The intensive cutting system (1) significantly ($P < 0.01$) increased CP concentration (from 121.5 to 174.0 g kg^{-1} DM), CP production (from 692 to 961 kg ha^{-1}), NEL concentration (from 5.43 to 5.95 MJ kg^{-1} DM), NEV concentration (from 5.29 to 5.67 MJ kg^{-1} DM), PDIE concentration (from 74.2 to 86.0 MJ kg^{-1} DM), and PDIN concentration (from 74.7 to 105.9 MJ kg^{-1} DM), when compared to the extensive system (4). The intensive cutting system significantly ($P < 0.01$) decreased the fibre content from 297.0 to 218.4 g kg^{-1} DM. The level of fertilisation, especially increasing N fertiliser, significantly ($P < 0.01$) increased DM production from 5.49 to 7.96 t ha^{-1}, the CP concentration from 145.1 to 157.7 g kg^{-1} DM, the CP production from 682 to 1104 kg ha^{-1} and the PDIN concentration from 88.5 to 96.2 g kg^{-1} DM when compared to the zero fertilised control. The average concentration of fibre, NEL, NEV and PDIE for all sites was not significantly influenced by fertilisation. The results reported here are in agreement with the conclusions of Gruber (2000) who reported that increasing the cutting frequency increases CP concentration and decreases fibre concentration (331, 291, and 246 g kg^{-1} DM). He also reported that digestibility and energy concentration were significantly lower with fewer cuts (4.53, 5.24, and 5.85 NEL MJ kg^{-1} DM). This corresponds to morphological changes in the plant, which result in an increased proportion of stalks and their continuing lignification. In accordance with Kühbauch and Anger (1999), a higher cutting frequency is a more favourable system because it requires fewer animals ha^{-1} and lowers consumption of grain feedstuffs (nutrient import to the farm).

Table 1. Average DM production and forage quality for four different cutting systems averaged over fertiliser treatments at 5 sites in 2003.

Cutting system	Evaluated feature							
	Dry matter	CP	CP production	Fibre	NEL	NEV	PDIE	PDIN
	($t\ ha^{-1}$)	($g\ kg^{-1}$ DM)	($kg\ ha^{-1}$)	($g\ kg^{-1}$ DM)	($MJ\ kg^{-1}$ DM)	($MJ\ kg^{-1}$ DM)	($g\ kg^{-1}$ DM)	($g\ kg^{-1}$ DM)
1 (intensive, 4 cuts)	6.06	174.0	961	218.4	5.95	5.67	86.0	105.9
2 (medium intensive, 3 cuts)	6.18	168.8	914	227.4	5.87	5.67	84.9	102.4
3 (low intensive, 2 cuts)	6.72	133.0	814	271.4	5.44	5.36	77.8	80.4
4 (extensive, 2 cuts)	6.86	121.5	692	297.0	5.43	5.29	74.2	74.7
Average	6.46	149.3	845	253.5	5.67	5.50	80.7	90.8
$DT_{0,05}$	0.35	4.2	53	5.6	0.06	0.19	0.7	2.7
$DT_{0,01}$	0.42	5.2	65	6.8	0.08	0.23	0.9	3.3

Table 2. Average DM production and forage quality for four different fertiliser treatments averaged over cutting systems at 5 sites in 2003.

Fertiliser treatment	Evaluated feature							
	Dry matter	CP	CP production	fibre	NEL	NEV	PDIE	PDIN
	($t\ ha^{-1}$)	($g\ kg^{-1}$ DM)	($kg\ ha^{-1}$)	($g\ kg^{-1}$ DM)	($MJ\ kg^{-1}$ DM)	($MJ\ kg^{-1}$ DM)	($g\ kg^{-1}$ DM)	($g\ kg^{-1}$ DM)
A (zero fertilisation)	5.49	145.1	682	246.2	5.74	5.44	80.5	88.5
B (PK)	5.50	145.8	700	253.0	5.67	5.38	80.3	88.4
C ($N_{90}PK$)	6.87	148.7	896	257.3	5.62	5.52	80.6	90.4
D ($N_{180}PK$)	7.96	157.7	1104	257.5	5.65	5.65	81.5	96.2
Average	6.46	149.3	846	253.5	5.67	5.50	80.7	90.8
$DT_{0,05}$	0.35	4.2	53	5.6	0.06	0.19	0.7	2.7
$DT_{0,01}$	0.42	5.2	65	6.8	0.08	0.23	0.9	3.3

Table 3. Number of grassland species present at 5 sites in 2003.

Botanical group	Site				
	Jevíčko	Vysoké nad Jizerou	Rapotín	Hladké Životice	Zubří
Grass species	13	15	16	10	16
Legumes	4	4	2	1	6
Other species	25	31	37	39	39
Total	42	50	55	50	61

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Improving productivity of grasslands in mountainous areas of Greece by 'conventional' or 'organic' farming practices

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Abstract

In order to assess the production potential of an acidic, high altitude, grassland in North-West Greece, the following six treatments were applied, in a completely randomized design (four replicates each): Control (indigenous vegetation), Fertilisation of indigenous vegetation (fertiliser type 11-15-15), Tillage and Reseeding (*Lolium perenne* + *Trifolium repens*), Tillage-Reseeding and Fertilisation (the same inputs as above), Tillage-Reseeding and Liming I (the above seed mixture + 2,320 kg $CaCO_3$ ha^{-1}), Tillage-Reseeding and Liming II (the above seed mixture + 4,640 kg $CaCO_3$ ha^{-1}).
One year after sward establishment under rain fed conditions, herbage was sampled during the growing period (April-October) at 45 days intervals, to evaluate herbage dry matter produced, botanical composition and chemical composition. Soil samples were also harvested for pH, N, P and K analyses.
Liming at the high level resulted in an increase in soil pH. Herbage production and chemical composition were similar between 'Tillage-Reseeding' treatments and significantly higher than that of indigenous vegetation. It was concluded that high altitude acidic fields in Greece, currently used as rough grazing lands, can successfully be converted into either 'conventional' or 'organic' improved pastures under rain fed conditions.

Keywords: sown pastures, management, grass-clover, Greece

Introduction

The extensive rough grazing lands in Greece, covering approximately 40 % of the total land area, are predominantly on mountainous (or semi-mountainous) areas, are publicly owned and are managed traditionally, receiving almost no inputs (Hadjigeorgiou *et al.*, 2002). Local soil and climatic conditions as well as the management practices which have been applied for decades often result in fields of low productivity, which together with access difficulties result in deterioration of these grazing lands. However, the need for sustainable dairy sheep farming systems, together with a market demand for certified products, make the improvement in local forage production very necessary.
'Grass / clover' swards have been extensively used in the temperate zone, as they produce forage with high dry matter yields, forage quality and protein content (Frame, 1992). Furthermore, it is well established that NPK fertilisation influences sward floristic composition and productivity (Marriot and Carrere, 1998).
The objective of this study was to evaluate under Greek conditions the effects of some 'classical' management practices for grassland improvement, including those compatible with 'organic farming'.

Materials and methods

The experimental sward was established on a mountain plateau (1,250 m asl) in Northwestern Greece (39°11'N and 21°17'E). Local climatic conditions are characterized by high annual rainfall (1,550 mm) (precipitation occurring mostly during winter, with 330 mm in December and only 32 mm in July, and cool temperatures (mean annual temperature 12.7 °C), where

January is the coldest month (mean daily temperature 2.5 °C) and July the warmest (mean daily temperature 23.0 °C).
The experimental field was divided into twenty four (16 m × 8 m) sub-plots and the following six treatments were applied, in a completely randomized design, with 4 replicates each: Control (undisturbed indigenous vegetation), Fertilisation of indigenous vegetation (1,000 kg ha^{-1} of fertiliser type 11-15-15), tillage and reseeding with 30 kg ha^{-1} of perennial ryegrass (*Lolium perenne* cv. Belinda) + 30 kg ha^{-1} of white clover (*Trifolium repens* cv. Huia), tillage-reseeding and fertilisation (the same as above), tillage-reseeding and liming I (the above seed mixture + 2,320 kg ha^{-1} $CaCO_3$), 6) tillage-reseeding and liming II (the above seed mixture + 4,640 kg ha^{-1} $CaCO_3$).
One year after sward establishment, under rain fed conditions, herbage was sampled four times during the growth period (April-October) at 45 days intervals by taking cuts. After each sampling the field was heavily stocked by sheep, until standing herbage was totally removed, after which the vegetation was allowed to recover.
Herbage samples were mixed and divided, so that one part was used for botanical analysis and the second dried overnight for dry matter determination and, after milling, for chemical composition analyses of organic matter (OM), crude protein (CP), ether extracts (EE) and crude fiber (CF) according to the procedure of Weende (AOAC, 1984).
Soil samples were collected to a depth of 10-20 cm during the middle of the sampling period and analysed for pH and total N, P and K.

Results and discussion

Soil analyses revealed an acidic soil moderate in N, P and K content, applying a high level of lime resulting in an increase in pH (Table 1). Other soil chemical characteristics investigated such as total P and K were also found to differ statistically between treatments.

Table 1. Soil characteristics of the study area (control) and the respective changes one year after the treatments application.

Treatments	pH	Total N (%)	P (µg g^{-1})	K (µg g^{-1})
Control	5.51 ^{a} *	0.525 ^{a}	5.19 ^{a}	887 ^{ab}
Fertilisation	5.49 ^{a}	0.556 ^{a}	5.51 ^{ab}	720 ^{a}
Reseeding	5.62 ^{a}	0.512 ^{a}	6.53 ^{d}	999 ^{b}
Reseeding and Fertilisation	5.52 ^{a}	0.525 ^{a}	6.30 ^{cd}	855 ^{ab}
Reseeding and Liming I	5.59 ^{a}	0.554 ^{a}	6.12 ^{cd}	831 ^{ab}
Reseeding and Liming II	6.14 ^{b}	0.529 ^{a}	5.87 ^{bc}	765 ^{a}

* Means within each column sharing different superscripts differ at the $P < 0.05$ level.

Although perennial ryegrass is a nitrophilous grass (Cookson *et al*., 2000), the treatments established with ‘grass-clover’ did not result in soil nitrogen depletion compared to the control. On the other hand P tended to rise in the ‘reseeding’ treatments, while K showed a variable response.
The cumulative production of herbage (Table 2) was higher for the reseeding and fertilisation treatment, while the control treatment produced the lowest quantity of herbage. Furthermore, the highest CP content was found in herbage from reseeding and fertilisation plots (175 g CP kg^{-1} OM), while the lowest was from the fertilisation treatment (143 g CP kg^{-1} OM). In all reseeding treatments broad-leaved plants made a high contribution to the total DM produced compared to the indigenous vegetation.

Table 2. Cumulative herbage dry matter produced over the growth period and average herbage chemical composition in the different treatments.

Treatments	Dry matter ($g\ m^{-2}$)	CP ($g\ kg^{-1}$ OM)	EE ($g\ kg^{-1}$ OM)	CF ($g\ kg^{-1}$ OM)
Control	534.4 ^{a}*	151 ^{ab}	2.6 ^{a}	326 ^{a}
Fertilisation	733.4 ^{ab}	143 ^{a}	2.6 ^{a}	321 ^{a}
Reseeding	1092.2 ^{bc}	157 ^{abc}	2.8 ^{a}	315 ^{a}
Reseeding and Fertilisation	1236.0 ^{c}	175 ^{c}	2.4 ^{a}	297 ^{a}
Reseeding and Liming I	1108.1 ^{bc}	156 ^{abc}	2.6 ^{a}	321 ^{a}
Reseeding and Liming II	1021.2 ^{bc}	170 ^{bc}	2.4 ^{a}	310 ^{a}

* Means within each column sharing different superscripts differ at the $P < 0.05$ level.

Conclusions

All treatments evaluated in this study had a positive effect on herbage productivity, but the replacement of indigenous vegetation by reseeding and the creation of 'grass-clover' swards had the strongest effects in terms of dry matter production. When a compound fertiliser was applied, herbage production was improved, but liming of the acidic soil did not increase dry matter production under the management used in this study. However, liming at a high level improved soil pH and herbage was richer in crude protein than that produced on the other reseeded plots.

It appears that rough grazing lands in Greece have an important potential for improved herbage production, both quantitatively and qualitatively. 'Conventional' or 'organic' farming practices appear equally productive for this purpose.

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Distribution of *Deschampsia caespitosa* (L.) Beauv. in the pastures of the Asiago and Vezzena uplands (North-Eastern Italy)

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Abstract

The Asiago and Vezzena uplands (Italian calcareous pre-Alps) represent a region where cattle-breeding has maintained great importance. Here *Deschampsia caespitosa*, a species with low palatability and great growing capacity, has spread widely in the last decades deteriorating many pasture surfaces. The problem was studied on 26 pastoral units of the 2 uplands. On the basis of the cartography of some important environmental characteristics, input into a GIS, it was determined that the abundance of the species, on average, 15.4 % is particularly enhanced by high soil depth and low slope.

Keywords: distribution, *Deschampsia caespitosa*, soil characteristics, weeds, pastures

Introduction

In the calcareous Italian Eastern pre-Alps, *Deschampsia caespitosa* (L.) Beauv. (DC) is a pasture species of low palatability for cattle because its leaves are very rough and rich in silica (Davy, 1980). Therefore, its progressive spread in the wide montane and subalpine pastures of the region is more and more worrying. The spread is mainly a result of a weed control program which is nowadays less careful than before, but site characteristics also have great importance. In order to quantify its extent and to identify the environmental situations where it is most common, the distribution of the species has been studied on two pre-Alpine uplands highly suited to grazing, Asiago and Vezzena.

Materials and methods

The two neighbouring uplands, located between 800 and 2,000 m asl, are characterised by high annual precipitation (1,250-1,450 mm) which is subequinoctially distributed but abundant in summer as well. Mean yearly temperature varies between 8.9 and 2.3 °C. Twenty six of the nearly 100 pastoral units present in these areas (covering 1,617 ha pasture) were studied. In Asiago, the study areas occupied the sides and tops of little mountains whereas in Vezzena they were located on the bottom and on the South or North facing sides of an East-to-West extended hollow. The animals, mainly dairy cows and heifers, stayed on the pastures for 93-111 days depending on elevation, grazed freely or were loosely controlled (1-2 daily driving interventions by the graziers) and were additionally fed with 0-8 kg concentrates day^{-1} (average 2.5). In surveys carried out during summer 1998, the pastoral units were divided into sub-areas with homogeneous pasture characteristics and DC abundance. For each sub-area, marked on 1:5000 maps, the pasture type was described according to Dietl *et al.* (1981), DC % abundance estimated by sight, soil depth measured, animal permanence time (expressed in Animal Unit Days, AUD) determined and soil samples collected. On the latter, texture, pH and carbonate content were analysed. With the obtained data a geographical information system was implemented which included all the above themes as well as elevation, aspect, slope (obtained from an already available digital elevation model) and geological substrate. The created themes were crossed to obtain many sub-sub-areas, each of which constituted an observation characterised by a specific combination of the considered variables. With the aim of studying the distribution of DC, these very numerous observations were analysed by single factor analysis of variance followed by the Duncan test, and by multiple linear regression (model stepwise) resulting in high F values but low levels of explained variability. In addition, single linear regression analysis was applied to the weighted means of the DC abundances and of the environmental characteristics, calculated for each pastoral unit.

Table 1. Mean values of some characteristics of the studied pastures.

Characteristic	Asiago	Vezzena	Mean
D. caespitosa abundance (%)	10.3 B	26.4 A	15.4
Elevation (m asl)	1443	1491	1458
Slope (%)	15.6	15.4	15.6
Soil depth (cm)	25.8	28.9	26.7
pH	5.6	5.4	5.5
Carbonates soil content (%)	1.0	1.7	1.2
Sand (%)	32.1 B	49.1 A	37.4
Silt (%)	32.1 A	22.3 B	29.0
Clay (%)	35.9	28.5	33.6
Permanence time (AUD ha^{-1})	107 b	161 a	124

(values with different small/capital letters are significantly different at $P \leq 0.05$ / $P \leq 0.01$).

Table 2. Parameters of the multiple linear regressions between *Deschampsia caespitosa* abundance (%) and environmental characteristics.

	Asiago	Vezzena	All pastures
Intercept	3.11	21.5	13.8
Soil depth (cm)	**0.438**	0.368	**0.398**
Slope (%)	-	**-0.0533**	*-0.329*
Permanence time (AUD ha^{-1})	*-0.00987*	0.018	0.00985
Model R^2 (%)	6.6	17.9	12

(bold, 1st variable; italic, 2nd variable; normal, 3rd variable).

Results and discussion

Excluding wooded areas, the mean % abundance of DC in the 26 pastoral units is 15.4 % (Table 1). The abundance of the species is greater in Vezzena (26.4 %: range 4-68) than in Asiago (10.3 %: range 7-25). Even in Asiago DC abundance is not limited by the higher animal permanence time which is clearly not sufficient to control it. The difference between the two uplands is probably mainly due to the differences in attention paid to the weed problem by shepherds and technicians in the recent past, rather than to the environmental conditions which are not very different (Table 1). The multiple linear regression shows that the characteristics that influence the abundance of the species are soil depth, slope and animal permanence time (Table 2). The overall regression R^2 is higher in Vezzena where, besides the mean abundance, the variability of the presence of the species is also greater. In this upland the slope is the most important variable. Low slope values increase the abundance of the species (Figure 1a), probably because they increase the soil humidity which is a condition

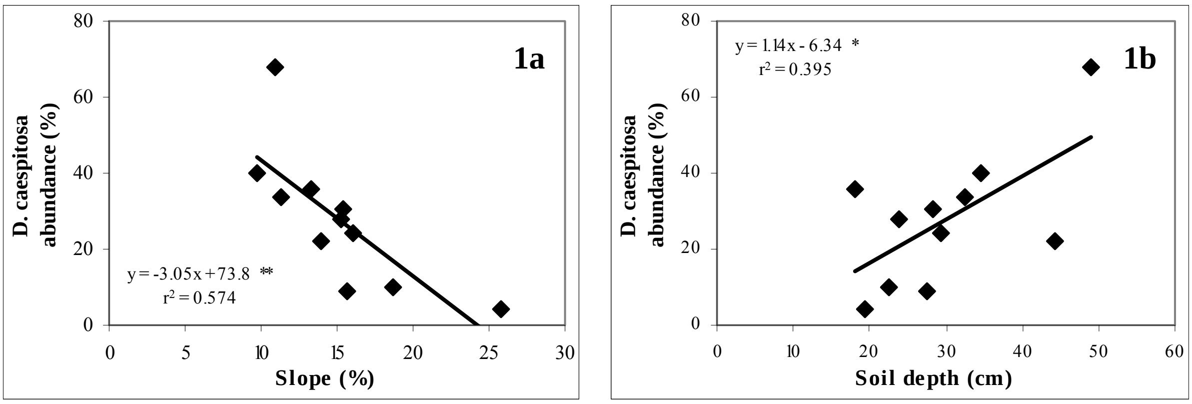

Figure 1. Relation between *Deschampsia caespitosa* abundance and slope (1a) or soil depth (1b). Mean values of the 11 Vezzena pastoral units. * and ** = significant at $P \leq 0.05$ or $P \leq 0.01$.

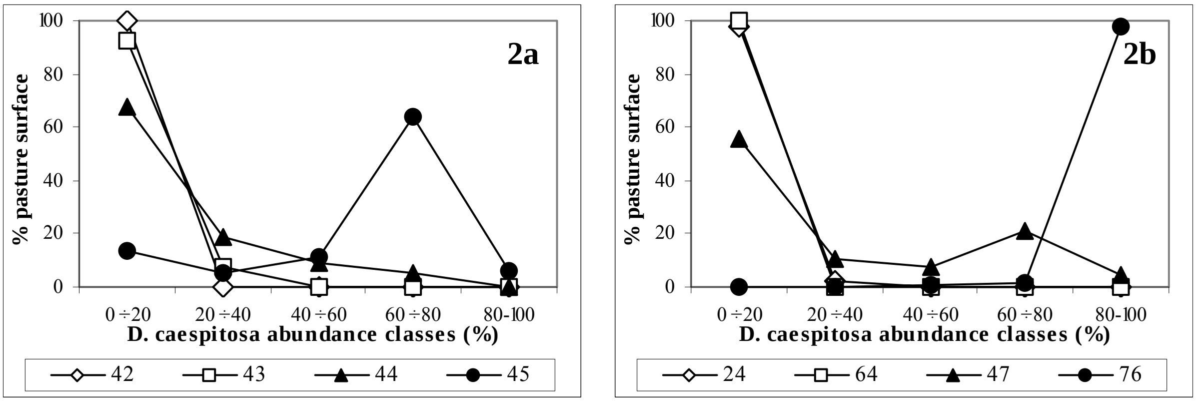

Figure 2. Presence of *Deschampsia caespitosa* in the different pasture types. Mean values of the 26 pastoral units. The codes 42-45, 24, 64, 47 and 76 indicate pasture types according to Dietl *et al.* (1981) (see text).

heavily favourable to the DC spreading (Davy, 1980). The second variable is the soil depth, which is positively correlated to the DC abundance (Figure 1b). The combined effect of the two variables leads to a particularly high presence of DC in the flat areas located on the bottom of the Vezzena hollow where the soils are deep and humid. These soils were derived from morainic substrates whereas the areas located at higher elevation on the two hollow sides have substrates which are on average less deep and were derived from compact rocks (limestone and clayey limestone). It is more difficult to identify environmental variables which are clearly related to the abundance of DC in Asiago. Therefore, the following indications were obtained by considering only the nine pastoral units where surfaces with DC abundances greater than 20 % were rather frequent. The most influential variable, also positively in this case, is the soil depth (Table 2). Moreover, some species reduction is caused by the increasing animal permanence time, which is on average lower in Asiago than in Vezzena. Indeed, on the latter, permanence time seems to have a low positive relation with DC abundance, maybe because the flat surfaces of the hollow bottom are also the most regularly frequented ones and, therefore, have more compacted soils where the DC spreading is heavily favoured (Davy, 1980). Of the examined environmental characteristics, pasture type explains a much greater quantity of the variability of DC distribution (F value in the analysis of variance equal to 545 against values of less than 291 for the environmental variables). As a matter of fact, the effects of all the environmental factors are combined in the vegetation characteristics. The species abundance is particularly strong in the fertilised pasture types which are characterised by good or high moisture (categories 44 and 45: Figure 2a), in the nitrophilous and humid vegetations (categories 47 and 76; Figure 2b). On the other side, the species is less abundant in the drier fertilised pasture types (categories 42 and 43), in the dry basophilous and in the acidophilous pasture types (categories 24 and 64; Figure 2b).

Conclusions

DC occupies on average 15.4 % of pasture in Asiago and Vezzena but in some particularly degraded pastoral units can reach mean abundances of 40-70 %. Its spread seems to be favoured particularly by low slope and by high depth of the soils derived from morainic substrates whereas other environmental variables do not seem to have an important effect.

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Cartography of pasture resources of Murcia region (Spain): calculation of stocking rates

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Abstract

The paper discuss a preliminary cartography of pasture resources of the Murcia region within the context of a national SEEP-INIA project 'Characterisation, cartography and evaluation of Spanish pastures'. Shrubland communities in natural pastures represent the largest contributors to animal feed resources, whereas in cultivated areas sub products from cereals and horticulture crops (both, herbaceous species and trees) are the main fodder resources. Proper integration and management of livestock, crops, and degraded natural resources, remains one of the major tasks to develop new agrosilvopastoral systems. A model at 1:200,000 scale was obtained to estimate livestock stocking rates in relation to the units mapped, its potential biomass and energy production and its bioclimatic conditions and fluctuations. The cartography obtained could be consulted in our web mapping service (*http://wsiam.carm.es/website/pastos/default.htm*).

Keywords: GIS, forest pastures, agriculture by-products, biomass production, metabolisable energy, feed resources management

Introduction

This paper falls within the context of the SEEP project 'Characterisation, cartography and evaluation of Spanish pastures', financed by INIA with the collaboration of Spanish Autonomous Communities. The intention is to map, on a national level, the pasturelands existing in Spain and to determine their production capacity, quality and seasonal fluctuations, in order to optimise the management of an extensive stock rearing activity in equilibrium with pasture resources.

Materials and methods

In carrying out this cartographic exercise, we have followed the general methodology described by Broca *et al*., (2001). To delimit the large surface units (unproductive, agricultural, wetland and water, pasture with a dense tree cover and pasture with sparse tree cover), we used the level 1 field of the Vegetation Cover Map from the III National Forest Inventory (1:200,000) drawn up by the Spanish Environment Agency .
To analyse the forest area without tree cover, which comprises scrub of various types and grazing land, we referred to the Actual Vegetation Map (Alcaraz *et al*., 2000) and to the National Habitat Map, while other units (esparto grass) were taken from the Map of Crops. All these were cross-referenced by aerial georeferenced photography covering the province of Murcia. In addition, bio geographical and bio climatic criteria were applied to obtain the precise delimitation of the main pasture in the province. The phytosociological associations and habitats included in Directive 42 / 93 were also included. The final denomination of the

units was made according to the nomenclature of Ferrer *et al*. (2001) for Spanish pasturelands. The potential production of metabolisable energy (ME) in each plot was calculated as a function of the bio climatic floor level, the plant community, mean rainfall and the equations determined by Passera *et al.* (2000). Given the large number of plots making up the basic map a spreadsheet was developed to make these calculations automatically. For the rainfall data, the historical data covering 30 years from weather stations belonging to the National Meteorological Institute were used in conjunction with the Spatial Analyst extension. The equations used for biomass production in forest pastures were of the multiple linear type ($y = a + bx + cz$), where y is the energy in MJ ha^{-1} y^{-1} of each unit in each bio-climatic level, a, b and c are constants obtained by regression techniques, x is the mean annual rainfall of the unit and z the mean cover of the unit (Passera *et al.*, 2000). For agricultural pastures, the metabolisable energy was estimated from the data concerning the agricultural by-products produced and their corresponding tables of nutritive value. Once the energy that can be generated in a sustainable way has been calculated, this can be expressed in terms of the potential ovine or caprine stocking capacity by taking into account that a sheep of the Segureña breed in production and with a live weight of approximately 45 kg needs about 5033 MJ ME y^{-1}, while a Serrana goat needs about 5189 MJ ME y^{-1}.
Assuming that low temperatures and the absence of rainfall (winter months with mean temperatures below 7.5 ºC and dry months with a water deficit greater than 20 %) interrupt growth, seasonal graphs of natural pasture production were drawn up, while, at the same time, we took into account the production calendar of the main agricultural by-products to obtain a similar seasonal production graph.

Results and discussion

Forest formations cover almost half (45 %) of the Region of Murcia (1,131,390 km^2). The main units are extensive pastures densely covered by trees (23.4 % of the province) and bushy pastures of a low evolutive level (14.2 %). The surface covered by climax vegetation in the province is less than one percent, which gives some idea of the general degradation which it has suffered. Agricultural crops cover 46 % of the province, with cereals (14.1 %), almond (12.0 %) and horticultural crops (11.6 %) being the most widespread.
The greatest potential stocking capacities are to be found in areas where there is an abundance of agricultural by-products, particularly those resulting from irrigated crops (2-5 sheep ha^{-1} under citrus and 1-2 sheep with horticultural crops) and dry land cereal (1-2 sheep ha^{-1}). In vineyards and almond plantations the corresponding load is very low (0.25 sheep ha^{-1}) due to the low production of forage resources (dry leaves and weeds during a short period of time). Forested zones present noticeably lower potentials (0.25-0.75 sheep ha^{-1}) since productivity is low. The highest potential stocking rates (0.50-0.75 sheep ha^{-1}) in forest areas are to be found in intermediate zones with a mild climate and rainfall of 350-400 mm y^{-1}. In semi-arid coastal areas (200-300 mm) stocking rates are lower (0.25-0.50 sheep ha^{-1}) because of the low rainfall, while in higher areas inland (> 1200 m) low temperatures in winter have a limiting effect and the same stocking capacities apply. There is a substantial area of Murcia that is badly eroded (badlands); this area has a very low stocking capacity and should be excluded from grazing.
Sheep grazing activity has increased greatly during recent years in the mild coastal areas of the province, where there are extensive areas dedicated to horticultural crops. For example, in the Campo de Cartagena area a mean stocking rate of 1.18 sheep ha^{-1} can be sustained with a mean flock size of 464 sheep. In contrast, other areas with a long history of grazing, (e.g., in the north-west of the province) support much lower stocking rates (0.52 sheep ha^{-1}) and smaller sized flocks (average of 265). In this area the resources are basically the by-products of cereal crops (straw, harrowing, fallow lands and poor harvests) and the shrub land

communities of forest areas. In short, the intensification of sheep grazing activity is evident in the region, as it is in many other parts of the EU.

The feed-deficits that occur at certain times in some areas mean that feed concentrates have to be provided, thus increasing final costs. In the north-west, for example, there are times during the coldest months without plant growth and with few resources, which may also occur during colder than usual autumns; however, during those cold periods, horticulture by-products from the Campo de Cartagena could be used. In this coastal area, on the other hand, there are feed-deficits at the end of winter and during early spring, when the land is in full agricultural production. At such times, the process can be reversed and feed can be provided from forested areas such as the north-west. There may also be periods of shortage during the summer, when the land is ploughed and prepared for autumn seeding.

The possibility of complementary feeding could be facilitated by the existence of a wide network of livestock tracks that link many areas in the province. These are publicly owned tracks that were set up to enable the transit of animals. Of great importance for many centuries, these tracks have fallen into disuse and are currently the subject of debate amongst conservationists who see them as potential green corridors.

Conclusions

Integration of vegetation mapping with biomass production models in GIS is of enormous value in the management of an extensive and sustainable livestock programme. It permits an understanding of resources distribution, which, combined with a knowledge of seasonal availability, facilitates the planning of animal feed distribution, the provision of feed representing almost half of the costs involved in bringing sheep / goats to market.

In Murcia Region as a whole, potential stocking rates are low, exceeding 1 sheep ha^{-1} only in those zones that generate a large quantity of agricultural by-products, whether resulting from cereals, fruit pulp or horticultural products. Densities only reach 0.25-0.75 sheep ha^{-1} in forest zones. Although there is a clear tendency towards feed intensification, grazing forest areas are still of importance and may contribute to the conservation of the environment and natural habitats, many of which are of priority interest for the EU. An alternative to the provision of supplementary feed during shortages might be to take advantage of the network of livestock transit tracks that still exist, which would facilitate the complementary provision of feed. Their recovery and use, furthermore, would contribute to the creation of biological corridors which connect different habitats.

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Web mapping site of Murcia cartography: *http://wsiam.carm.es/website/pastos/default.htm.*

Soil / vegetation relationship in Spanish Pyrenean summer pastures: the case of animal resting areas

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Abstract

Animal distribution on Spanish Pyrenean summer pastures is related closely to midday and night resting areas. In these sites, we find the coincidence of eutrophic and mesophyte plants and these can occur in both central and peripheral situations in the resting areas. Our objective is to understand the soil characteristics influencing these vegetation changes. A study was conducted (2002-2003) in the Sorrosal pastures (Broto Valley, Spain) at 1700 m asl. A transect from the central point of the resting area to the periphery was made and five vegetation types were considered. Floristic composition (6 cut plots of 0.50 x 0.50 m per vegetation type) and soil characteristics (6 samples at 20 cm depth, in every vegetation type) were sampled. All species were separated by hand, dried and weighed to calculate their individual dry matter contribution, the number of species and the grasses percentage. Plant (N, P and K) and soil (total N, nitrates, P, K, organic matter and pH) analyses were made. A Principal Components Analysis (PCA) was obtained with the 12 variables studied. A soil mineral gradient (N nitrates, P and K) was found separating the typical bed ground vegetation from the other pastures. Two other groups were identified considering the organic matter and total N content.

Keywords: resting area, vegetation types, mineral analysis, topographical situation, animal disturbance

Introduction

More than half of the Spanish Pyrenean surface is pasture which in several valleys constitutes the basis of the local economy (Montserrat and Fillat, 1990). The organization of a typical summer pasture day consists in two grazing periods, with a resting period in the middle of the day. Animals choose flat and climatically comfortable situations (windy sites on hot days or protected ones on wet days) for these periods of rest. These animal gathering points help organise the whole pasture unit (Aldezabal, 2001). The concentric distribution of animals around the resting area causes a significant gradient of fertility and there is clear visual evidence of variation in plant distribution, owing to their degree of tolerance to animal disturbance. Our objective is to explore and quantify the soil characteristics following these vegetation changes.

Materials and methods

The study area was a resting area zone situated in the Soaso summer pasture unit of the Broto Valley at 1700 m asl (Huesca province; 0º10’30’’ long. E, 42º39’30’’ lat. N). These pastures are located at the limits of the old *Pinus sylvestris* and *Pinus uncinata* forests, which were cut down in the Middle Ages (Montserrat, 1992). Five different types of vegetation were identified in the resting area. A transect was made crossing the zone from the central part to its periphery. In every vegetation type, vegetation plots (0.50 x 0.50 m) in pairs were made cutting through the plants and simultaneous soil samples (to 20 cm depth) were taken in every plot. All species cut were separated, dried and weighed to calculate their individual dry matter contribution (number of species and the percentage contribution from grasses). Vegetation (N, P, and K), soil (total N, nitrates, P, K, organic matter, actual pH and potential pH) mineral analyses were made. A Principal Components Analysis (PCA) was performed with these 12 variables studied at a total of 30 sampling points (6 cases in 5 vegetation types). Original data were typified as: $x_j = (x_i - \mu)\ \sigma^{-1}$, with x_i = original data, μ = mean, σ = standard deviation. According to the PCA analysis, the 12 variable interactions were reduced into a 2-factor graph absorbing a total of 80.4 % of the total variance, with different contributions of every variable included in each factor.

Results and discussion

The Principal Components Analysis (PCA), absorbing 80.4 % of the accumulated variance in the two first components, showed five clearly separated groups (Figure 1). Two groups (1 and 2, positioned nearest to the centre of the resting area) showed positive values on Axis I and the other three groups (group 3, a transitional group and groups 4 and 5 as a normal pasture situation) showed negative values: group 1 in the central part and 2, 3, 4 and 5 successively further from the centre. Considering Axis II, we found two groups (1 and 5) with positive values and the others (2, 3 and 4) with negative ones.

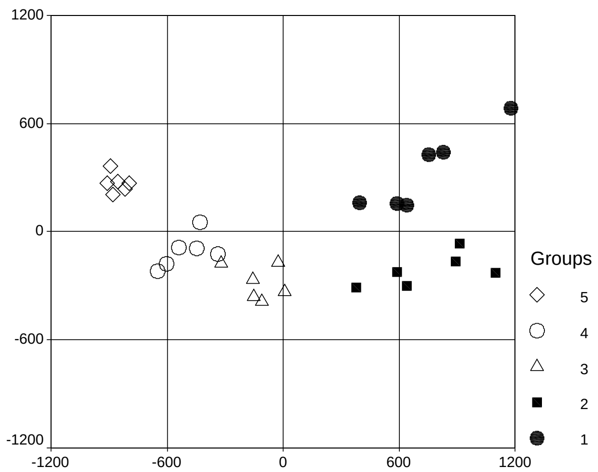

Figure 1. Samples distribution on the I and II axes of Principal Component Analysis. Five plant groups (1 to 5) and six samples (the same shape) in every group are shown. The groups follow a radial distribution from the central part of the resting area (1) to the periphery (5).

The factorial weights of every variable on every component are summarized in table 1. Axis I explains a positive correlation with vegetation P and K content, and soil N nitrate, P and pH; Axis II shows the main positive correlation between organic soil matter and total N.

The groups 1 and 2, which received large amounts of solid manure and urine amounts from animals, accumulate nitrate and K in the soil while the other groups (3, 4 and 5) ranged according to the plant and soil P.

The situation of the groups according to Axis II clearly showed a relationship between the amount of soil organic matter and total N. The soils of the groups 1 and 5 had the highest quantity of both parameters although for different reasons: in the case of group 1 through the influence of the animals, and in group 5 because of the low level of grazing, preference being shown for other pastures types such as *Bromion*, enabling *Nardion* to thrive on the accumulation of organic matter and total N.

Table 1. Every variable analysed with its weight (coordinates) in the two factors (F1 and F2 as axes of the Principal Component Analysis) and percentage of share variance (importance of every variable to the factor definition) between variable and factor.

Variables	F1 weight	F2 weight	Share variance 1	Share variance 2
Soil Olsen P (mg kg^{-1})	0.858	0.106	73.64	1.12
Soil organic matter (%)	0.369	0.903	13.61	81.45
Soil nitrates (mg kg^{-1})	0.895	0.224	80.05	5.04
Soil K (mg kg^{-1})	0.852	0.128	72.67	1.64
Soil total N (%)	0.522	0.819	27.24	67.04
Soil pH (H_2O)	0.817	-0.411	66.82	16.92
Soil pH (KCl)	0.861	-0.326	74.18	10.65
Vegetation number of species / 0.25 m^2	-0.459	-0.623	21.07	38.87
% Grasses	-0.647	0.631	41.89	39.82
Vegetation N (%)	0.818	0.039	66.88	0.15
Vegetation P (%)	0.942	-0.144	88.73	2.09
Vegetation K (%)	0.739	-0.429	54.69	18.38

The floristic characteristics of the five groups were as follows:
Group 1: Plant community dominated by *Lolium perenne* and *Trifolium repens* with a significant presence of *Poa annua,* with 7 species as the mean value.
Group 2: Plant community largely dominated by *Urtica dioica* and some presence of *Dactylis glomerata,* increasing the average number of species to 11.
Group 3: With a significant presence of *Cirsium eriophorum,* with increasing amounts of *Dactylis glomerata,* with 13 species as the mean value.
Group 4: With phytosociological characteristics of *Bromion,* with a clear dominance of *Festuca rubra* and presence of *Bromus erectus,* showing the maximum diversity with 14 species.
Group 5: Plant community with phytosociological characteristics of *Nardion*, dominated by *Nardus stricta* and decreasing the number of species to 11.

Conclusions

The principal variable found in the typical resting area vegetation types (groups 1 and 2) is controlled by the high content of nitrate and K in the soil. The other groups, group 3 being considered in a transitional situation and groups 4 and 5 as normal pasture, followed a gradient of soil and vegetation P content with less P in the more peripheral zones.
The second important factor is the organic matter and total N in the soil, showing a clear separation of groups 1 and 5 from groups 2, 3 and 4. The high content of soil organic matter in the groups 1 and 5 arose in different ways: in group 1, from direct manure and urine, and in group 5 from a lack of grazing exploitation, as the *Nardion* community is not favoured by the cattle.

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Topographic characteristics of two meadowlands in the Central Spanish Pyrenees

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Abstract

Topographic characteristics (altitude asl, size, slope and exposure) in two meadowlands of the Central Spanish Pyrenees were analysed. The management consists of only grazing (without irrigation) or mowing and grazing (with or without irrigation). Grazing animals are cows and sheep but cattle are the more important.

The preliminary results suggest that pastures and meadows show similar spatial distribution patterns in both localities. Pasture's size is always larger than meadow's size. Both meadows types (irrigated and not irrigated) have the lowest slop and, in the case of the more intensively managed ones (irrigated) they are situated in the bottom of the valley. The exposure is indifferent to management and is directly related to local hydrologic drainage system of rivers and streams.

Keywords: meadows, pastures, size of fields, altitude, slope, exposure

Introduction

An aspect of a mountain's landscape is its patchy structure as a consequence of the field characteristics: altitude, slope and orientation.

Depending on these characteristics, the use and management intensity of these fields differ. The most influential factor is the slope, which determines the type of machinery used (only in those less inclined) or the grazing management (in other cases). The altitude and the exposure control the growing season and the possibility of irrigation depends on other variables.

Another characteristic feature of mountain meadows and pastures is the small size of the ownership units. The possibility of irrigation depends on a pool of variables (economics, social, geographic, etc.). The aim of this study was to investigate if different land-uses exist in different mountain villages.

Materials and methods

Study area. The investigations were conducted during 1999-2002 in two valleys of the upper central Pyrenees (for a detailed description, see Fanlo *et al*., 2002; Fillat and Gómez, 1999). The study sites are Fragen (42º 37'N, 0º 10'W, 900 to 1300 m asl) and Espot (42º32'N, 1º05'E, 1100 to 1400 m asl) The management types are: only grazing (pastures) or mowing and grazing (meadows), the latter with or without irrigation. *Pinus sylvestris* woods dominate the shady slopes, whilst small woods of *Quercus gr. faginea* alternating with submediterranean shrubs *(Crataegus monigina, Prunus spinosa, Buxus sempervirens, Genista scorpius, Juniperus communis* and *Corylus avellana)* are found on the sunny slopes. Table 1 shows the number of patches of land and their use and surface.

Mapping of current use: The use of plots was determined from aerial photographs, direct observation-walking in the fields and questionnaires. The data obtained from manual digitalisation of cadastral (field survey) information were used to draw all plots. All the data were inserted into ArcView (ESRI) for recording, processing and viewing.

Data analysis: The data base files from ArcView were exported as Excel data sets and imported into STATISTICA programme. Means of altitude asl, exposure, slop and size were analysed by a one-way ANOVA. Significant differences were determined by the Fischer Protected LSD method.

Table 1. Number of patches and surface in both meadowlands.

Land-use	Espot meadowland	Fragen meadowland
Only grazing (pastures)	345	184
	174 ha	95 ha
Grazing and mowing (meadows)	25 irrigated	94 irrigated
	91 not irrigated	91 not irrigated
	70 ha	171 ha
Total patch number and surface	461	369
	244 ha	266 ha

Results and discussion

The analysis of variance of altitude revealed no significant effect of land-use (grazing or mowing) in Espot meadowland, but a significant effect in the case of Fragen meadowland and significant differences between both sites (Table 2).

Espot and Fragen meadows have similar slopes whereas Espot's pastures are more inclined than Fragen's (P < 0.001). Meadows of both valleys have less inclination than pastures, in agreement with results from other European mountains, for example in Passier Valley, South Tyrol (Tasser and Tappeiner, 2002) or in the Velence Mountains in Hungary (Bódis and Dormány, 2001).

Table 2. Topographic variables of experimental sites (pastures and measows).

Sites	Land use	Area (ha)	Exposure (0ºN, 180ºS)	Slope (º)	Altitude m asl
Espot	pasture	5.04 a	168.54 a	22.99 a	1385.50 a
		± 27.12	± 72.81	± 6.72	± 73.45
Espot	meadow	5.97 a	140.47 b	12.37 c	1364.70 a
		± 6.65	± 65.81	± 4.73	± 63.86
Fragen	meadow	3.30 a	144.51 b	12.39 c	1117.02 c
		± 3.06	± 71.09	± 7.36	± 131.05
Fragen	pasture	5.16 a	167.42 a	20.53 b	1151.75 b
		± 6.50	± 72.58	± 7.52	± 157.01

Mean ± SD (standard deviation). Means in the same column followed by the same letter, are not significantly different at the 0.05 probability level, according to LSD test.

Regarding exposure, pastures and meadows in the intra-valleys comparison are significantly different, with pastures prevalent in more sunny exposures. Area varies widely but no differences are significant between valleys or land use.

In Espot and Fragen non-irrigated meadows are at a higher altitude than irrigated meadows (Table 3). There are no slope differences between irrigated and non-irrigated meadows at both sites, but there are significant differences in their exposure, with irrigated meadows facing SE while those non-irrigated face more to the south.

The size of irrigated and non-irrigated meadows are similar in both localities.

Table 3. Topographic variables of experimental sites (irrigated and non-irrigated).

Sites	Land use	Area (ha)	Exposure (0ºN, 180ºS)	Slope (º)	Altitude m asl
Espot	non irrigated meadow	5.67 a ± 673	157.17 a ± 58.66ad	12.95 a ± 4.89	1380.47 a ± 61.22
Espot	irrigated meadow	7.01 a ± 635	82.01 c ± 55.96	10.35 a ± 3.52	1309.48 b ± 36.79
Fragen	irrigated meadow	3.40 a ± 3.41	131.37 b ± 63.58	11.43 a ± 5.86	994.77 d ± 71.54
Fragen	non irrigated meadow	3.28 a ± 2.98	147.43 a ± 72.40	12.60 a ± 7.65	1144.13 c ± 125.73

Mean ± SD (standard deviation). Means in the same column followed by the same letter, are not significant different at the 0.05 probability level, according to LSD test.

Conclusions

The altitude of meadowland depends on the geographic position, but in each valley pastures are placed higher than meadows.
Patches of land more intensively managed (irrigated meadows) are less steep.
The exposure depends on geographic characteristics of each valley.
Plot size is very variable independently of the land uses and site, and is a particular characteristic of land-ownership of mountain farms.

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Sustainable improvement of Mediterranean pastures

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Abstract

A sustainable pasture improvement system is described for the Mediterranean region. It involves the sowing of permanent pastures with biodiverse, legume-rich seed mixtures (formulated according to suit local soil and climatic conditions), the use of fertilisers (except N) according to soil analysis, and adequate grazing management. The results provided by farm-scale trials established in Portugal in 2001 on marginal lands, show that the system considerably increased pasture productivity when compared to natural pastures. A clear demonstration of the benefits of the system was found at 'Herdade dos Esquerdos', a 285 ha agroforestry farm (under *Quercus suber* / *Q. ilex* ssp. Ballota) situated in a zone of shallow acid soils and 550 mm annual rainfall, where the system has been progressively implemented since 1979. Previously, with a 9 year rotation of cereals and natural pastures gradually invaded by Cistus spp,. this farm carried 0.87 sheep ha^{-1} y^{-1}, and had low soil fertility (organic matter 0.7-1.2 %, phosphorus < 2 ppm). Today it has been converted into an 'organic farm' carrying 8 sheep ha^{-1} y^{-1}, with soil organic matter (SOM) increased to 1.45-4.4 % and phosphorus (P) to 5-40 ppm. Soil erosion has also been prevented and the noxious Cistus shrubs eradicated, thus achieving economic and environmental success.

Keywords: legumes, biodiversity, phosphate fertiliser, grazing management, soil fertility

Introduction

In the European Mediterranean region, there are large areas of marginal soils (shallow, stony, sandy, waterlogged, etc.) unsuitable for cereal cropping. These areas are now increasing as a result of the Common Agricultural Policy, since poor economic returns are forcing the abandonment of cereals in some areas, particularly those involved in the traditional rotations of bare fallow-cereal (1 or 2 years)-natural pasture (1 to 8 years). For example, since its entry into the European Union in 1985, Portugal has experienced a 42 % reduction in the area of cereals. The majority of this former cereal land has been converted into natural permanent pastures with low carrying capacity (0.1 to 0.5 cattle units of 400 kg LW ha^{-1} y^{-1}). Some land has become abandoned and invaded by noxious shrubs, thus degrading the landscape and increasing the risk of fire. Other traditional feed resources, such as stubbles and cereal straw, are also becoming scarce, and many farmers are sowing cereals to feed their grazing animals. Such a system is not sustainable, and to reverse the trend, a logical solution is to replace the natural pastures with productive and persistent sown pastures, which are able to produce high quality meat or milk at low cost. However, historically, sown pastures have played a minor role in the region, as the culture of the Mediterranean people consider pasture as a gift of nature which does not need to be sown or fertilised. Some past attempts to improve long-term sown pastures have also failed, due to the problems of availability of suitable cultivars, establishment and management (Crespo, 2000).

A system for sustainable permanent pasture improvement

Taking into account the advantages of the Mediterranean climate, which allows continuous grazing all year (green pastures from autumn to spring, dry pastures in summer), and favours the growth of legumes with their symbiotic N fixation, a system for sustainable permanent pasture improvement was developed in Portugal. The system consists of early autumn sowing of a complex seed mixture, formulated according to local soil and climatic conditions. Each seed mixture contains a diversity of species and cultivars of legumes and grasses, well adapted to local soil and climate and able to withstand rainfall variation from year to year (which leads to a shortening or lengthening of the growing season), and also ensuring pasture growth in divergent soil conditions, e.g., depth, structure, drainage or pH. The seed of each legume species is inoculated with its specific *Rhizobium* bacteria, and protected by a lime pellet to ensure effective nodulation and consequently high nitrogen fixation. Among the legumes, particular attention is given to the annual self-seeding species (*Trifolium subterraneum* ssps. *subterraneum*, *brachycalycinum* and *yanninicum*, *T. resupinatum* ssp. *resupinatum*, *T. michelianum*, *T. vesiculosum*, *T. hirtum*, *T. incarnatum*, *T. glanduliferum*, *Medicago polymorpha*, *M. truncatulla*, *M. rugosa*, *M. scutellata*, *M. sphaerocarpos*, *M. littoralis*, *Ornithopus compressus*, *O. sativus*, and *Biserrula pelecinus*). Amongst these we could choose cultivars diverging in their vegetative cycles and hard seed contents, most of which were selected in Australia from Mediterranean germplasm. In higher rainfall areas, or in deeper or wetter soils, appropriate cultivars of the perennial legume species (*Trifolium fragiferum, T. repens, T. pratense, Lotus corniculatus, L. pedunculatus, Medicago sativa, Hedysarum coronarium* and *Onobrychis viciifolia*) may be included. The role of legumes is to provide nitrogen at no cost, increase yield and quality (protein and intake) of the pasture, and increase soil fertility. Amongst the grasses, summer dormant cultivars of *Dactylis glomerata, Phalaris aquatica, Lolium perenne* and *Festuca arundinacea* are preferred, although some seeding annuals are used. The grasses circulate the surplus N fixed by legumes, thus preventing soil acidification, N pollution, and the invasion of the pastures by nitrophilous weeds e.g., *Carduus* spp., *Malva* spp., *Urtica* spp. Grasses also provide a balance to the feed value of mixed pastures in terms of energy and protein. There is an adequate use of fertilisers (except nitrogen) according to soil analysis. P is generally the key element, but at times K, Ca, Mg, and some trace elements (Mo, B, Cu, Zn) may be required. Indeed, most of the existing marginal soils are P deficient, and as legumes have a high demand for this nutrient, phosphorus plays the most important role in pasture plant nutrition, being applied at sowing time and top-dressed in each subsequent year. Once an adequate level is applied at sowing, maintenance requires only a low input, of 4 to 10 kg P ha^{-1} y^{-1}. Identical principles apply to K and Mg, when required. Ca and trace elements, if needed, are applied at longer intervals. Appropriate grazing management is adopted to maximize both productivity and persistence. High productivity is attained through the maintenance of a good balance between legumes and grasses, which ensures high rates of N fixation, and a high quality of the pasture. An adequate stocking rate must be maintained, as under-stocking tends to reduce legumes and favour grasses, whilst overstocking produces the opposite effect. Persistence of the annual legumes has two fundamental requirements: (i) building up an abundant soil seed bank in the year of sowing and maintaining it subsequently and (ii) grazing all dry pastures before the first autumn rains occur, in order to ensure a dense seedling emergence. Both these can be achieved through an adequate stocking rate and management, aimed at avoiding excessive grazing during the flowering and maturing period, and ensuring a complete removal of dry pasture.

Results

Two sets of results are presented to demonstrate the efficacy of the system. The first refers to 4 demonstration trials included in a Portuguese Agro project entitled 'Bio-diverse legume rich pastures: a sustainable alternative for the use of marginal lands', established in 2001 on farms with different marginal soils. To evaluate the impact of the system on a farm scale, two main treatments were allocated to 2 paddocks of about 15 ha each, without replicates: natural pasture; and sown pasture fertilised as recommended by soil analysis (SF). In order to determine the effect of the fertiliser on the natural pasture this paddock was split into two halves, one receiving no fertiliser (NN), and the other fertilised as SF (NF). The two paddocks were grazed regularly by cattle or sheep, according to management guidelines. Dry matter yields (DMY), botanical composition (BC), and *in vitro* digestibility (DMD) were evaluated on herbage samples cut periodically from randomly placed exclosure cages. Numbers of cattle or sheep grazing days were recorded and converted into cattle unit grazing days (CUGD). The mean results of the 4 demonstration trials, obtained in the 2nd year after establishment, are presented in table 1. These results show a marginal response of natural pastures to the application of fertilisers, and a strong superiority of the bio-diverse sown pastures, since their DMY and respective quality (BC and DMD) were considerably increased. It is worth noting that while DMY was more than doubled in SF when compared to NN, the number of CUGD increased 4-fold. This means that the grazing animals on SF benefited not only from the higher quantity of DM on offer, but also from its superior quality and intake, due to a high content of legumes well balanced with grasses, and less weeds.

Table 1. Comparison between natural non fertilised (NN), natural fertilised (NF) and sown fertilised (SF) pastures

	NN	NF	SF
DM yield (kg ha^{-1} y^{-1})	2936	3391	6369
Botanical composition (%)*	L-13; G-45; 0-42	L-12; G-55; O-33	L-44; G-45; O-11
In vitro DM digestibility (%)	62	64	70
CUGD ha^{-1} y^{-1} **	110	110	445

*L-legumes; G-grasses; O-other species, ** CUGD-cattle unit (400 kg LW) grazing days.

The second set of results gives records from an entire farm of 285 ha: ‘Herdade dos Esquerdos’, with 550 mm rainfall, eutric leptossol sand and undulating country, situated in Vaiamonte, Alentejo, Portugal in a *Quercus suber* + *Q. ilex* ssp. Ballota ‘montado’ area. In the past a rotation was practised consisting of bare fallow-wheat-oats followed by 6 years natural pastures, which were progressively invaded by fire prone shrubs (*Cistus* spp.). This had a profoundly negative impact on the grazing resources, including the acorns used for fattening grazing pigs, thus resulting in a poor stocking rate of 0.87 equivalent sheep ha^{-1} y^{-1}. In 1979 a programme of sustainable pasture improvement was initiated, and the old rotation was progressively abandoned by establishing a paddock per year with bio-diverse pastures, which were fertilised regularly with phosphate and grazed by a flock of growing sheep. Today the impact of the system can be identified at various levels. SOM increased from the original range of 0.7-1.2 % to 1.45-4.4 %, and P from < 2 ppm to 5-40 ppm. The lower levels were recorded in the paddocks of younger pastures and in those being regularly cut for hay. The life of the soil improved, as the abundance of earthworms, moles and dung beetles demonstrated. The stocking rate increased about nine fold, from the original 0.87 to 8 sheep ha^{-1} y^{-1}. The Cistus shrubs were completely eradicated as a result of raising the soil fertility and increasing the grazing pressure. The landscape has improved and the risks of erosion and fire, quite high in the past, are now much reduced. The farm is now certified as ‘organic,’ producing lamb meat, ewe milk cheese and Iberian pig meat. Today it provides a demonstration of how a sustainable pasture improvement programme can lead to a considerable increase of the farmer’s income and simultaneously create a better environment.

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Impact of soil-moisture change on plant communities succession in post-paludic grassland

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Abstract

The botanical composition of drained post-paludic natural grasslands in Central Poland was studied between 1991 and 1999. These meadows developed agriculturally valuable floristic communities, primarily representatives of class *Molinio-Arrhenatheretea*, order *Arrhenatheretalia*. Efficiently run drainage systems and appropriate grassland management ensured continued development of stable grassland communities. But deterioration in the maintenance of detailed drainage installations and declining grassland management led to an increase in soil-moisture level. In some post-paludic grassland sites representatives of class *Molinio-Arrhenatheretea* were subject to steady replacement by diverse hydrophilous species characteristic for swampy and boggy sites.

Keywords: plant communities, succession, post-paludic grassland, management, drainage

Introduction

Properly managed post-paludic grassland areas reclaimed and turned over to agriculture in the 1950-60s sustained plant communities from class *Molinio-Arrhenatheretea*, order *Arrhenatheretalia* or, less frequently, from order *Molinietalia*.

In the early 1990s, declining grassland management as well as neglected maintenance of detailed drainage systems were registered in some areas. Drainage and reclamation of grassland had triggered and accelerated processes of mineralisation of organic matter and the surface of post-paludic grassland subsided. It caused differentiation and increased humidity in some post-paludic grasslands as well as changes in meadow communities (Kozłowska and Szymczak, 2004). The aim of the present study was to analyse the transformation of plant communities in post-paludic grassland caused by rising soil moisture levels, particularly in sites situated in the headwater section of river valleys.

Materials and methods

The study was carried out between 1991 and 1999 and focused on post-paludic grassland sites in Central Poland situated in the middle course and headwater river valley section. In 19 selected plots soil type was determined (soil pit method), as well as groundwater level (in spring and during the 1st, 2nd and 3rd cut) and floristic composition (Klapp method). At the beginning and at the end of the study grassland communities were classified into phytosociological units on the basis of floristic composition. The number of species characteristic for each specific syntaxonomic unit (Matuszkiewicz, 2001) and the humidity index (HI) were assessed. The humidity index was used in 1991 to make a first classification of the studied sites into three humidity habitat groups (Klapp, 1965; Oświt, 1994): fresh, moist, heavily moist and wet.

Results and discussion

In the 1960-80 period post paludic grasslands were covered by grass communities, less frequently by herb-grass or sedge-grass communities from class *Molinio-Arrhenatheretea*.

Post-paludic grasslands belonging to the humidity habitat group I (fresh) registered little plant community transformation (Table 1). At the beginning and at the end of the study grasses were the predominant species (≥ 78 %).

Table 1. Botanical composition of grassland communities in three different humidity habitats in 1991, 1995 and 1999 (in %).

Groups and plant species	Humidity habitat								
	I - fresh			II - moist			III - heavily moist and wet		
	1991	1995	1999	1991	1995	1999	1991	1995	1999
Superior and fine quality grasses	74[1)] *60-95*[2)]	57 *37-80*	54 *20-81*	44 *16-63*	35 *18-58*	32 *11-62*	38 *28-50*	28 *18-38*	14 *3-35*
Alopecurus pratensis	21 *10-38*	16 *7-38*	12 *+-40*	10 *2-29*	8 *+-26*	8 *r-28*	4 *+-10*	2 *r-7*	1 *0-3*
Poa pratensis	30 *11-72*	22 *16-28*	21 *5-30*	19 *6-32*	14 *4-27*	11 *1-21*	19 *10-25*	14 *6-18*	4 *+-14*
Medium and inferior grasses	12 *2-22*	21 *3-57*	26 *8-74*	24 *16-34*	34 *21-59*	41 *20-79*	15 *9-26*	22 *15-23*	26 *20-41*
Deschampsia caespitosa	2 *r-13*	6 *+-30*	13 *+-35*	5 *1-15*	15 *1-40*	25 *2-75*	3 *+-5*	9 *1-21*	14 *1-40*
Total grasses	86 *77-100*	78 *67-94*	80 *71-94*	68 *42-80*	69 *43-79*	73 *43-90*	53 *43-65*	50 *38-65*	40 *30-55*
Legumes	1 *0-4*	2 *0-7*	1 *0-5*	2 *0-5*	2 *0-3*	2 *0-5*	2 *0-3*	1 *0-1*	0 *0*
Sedges	r *0-4*	r *0-3*	1 *0-6*	8 *r-18*	9 *2-18*	9 *2-22*	28 *24-32*	31 *25-40*	39 *28-50*
Herbs and weeds	13 *0-20*	20 *6-30*	18 *4-28*	22 *3-43*	20 *11-37*	16 *3-33*	17 *11-23*	18 *13-30*	21 *10-32*

[1)] average percentage, [2)] minimum and maximum percentages.

In all humidity habitat groups the proportion of superior and fine quality grasses decreased with time and the proportion of medium and inferior grasses increased. Other floristic groups showed little change and only in some sites there was a slight increase in herb and weed species.

Even at the outset of the study post-paludic grasslands in the habitat group II (moist) differed substantially in the proportion of grass species (42-80 %), registering a higher proportion of medium quality and inferior grasses than in group I (fresh). Towards the end of the study the overall proportion of grasses was either the same in both groups or occasionally higher in group I. In some sites, the proportion of medium quality and inferior grasses increased to sometimes 79 % (mainly *Deschampsia caespitosa* and *Holcus lanatus*), with a slight decrease noted also in the group of herb and weed species.

In heavily moist and wed post-paludic grassland (humidity habitat group III) botanical changes were more substantial. At the beginning of the study valuable grass species accounted for 28 to 50 %, followed by a sizeable proportion of sedges (24-32 %). Towards the end of the study superior and fine quality grass species declined giving way to sedges and medium and inferior grass species, occasionally also to herbs and weeds.

At the beginning and at the end of the study grassland communities included species from class *Molinio-Arrhenatheretea* (Table 2). In the fresh habitat (group I) the decline of superior and fine grasses, accompanied by increased proportion of medium and inferior quality grasses, did not cause any substantial change in the number of species characteristic for this syntaxonomic unit. In the moist habitat (group II) there was a decline in the number of species characteristic for class *Molinio-Arrhenatheretea*.

Table 2. Number of species characteristic for the syntaxonomic units in 1991 and 1999.

Syntaxonomic unit		Humidity habitat					
		I - fresh		II - moist		III - heavily moist and wet	
		1991	1999	1991	1999	1991	1999
Cl.	*Molinio-Arrhenatheretea*	7-8 (6-11)[1]	6-9 (10)	8-12	5-10	6-11	4-6
O.	*Arrhenatheretalia elatioris*	*3-4 (2-8)*	*3-4 (1-2)*	*0-2*	*0-2*	*0*	*0*
O.	*Molinietalia*	1 (0-2)	1-2	2-4	2-4	2-4	3-4
O.	*Phragmitetalia*	0	0	0	0	0-1	0-1
All.	*Magnocaricion*	0-1 (2-3)	0-2 (3)	0-3	1-3	1-4	2-6
All.	*Caricion nigrae*	*0*	*0-2*	*0-2*	*0-2*	*2*	*2-4*
Cl.	*Scheuchzerio-caricetea nigrae*	0	0	0	0	0-1	0-1
Total number of characteristic species		11-18	11-20	16-21	12-17	12-20	16-22

[1] in brackets = single occurrence.

Finally, in the heavily moist and wet environment (group III), the decrease in the number of species typical for *Molinio-Arrhenatheretea* was paralleled by an increased number of species characteristic for low moor communities from alliance *Magnocaricion* and *Carcion nigrae*.

Conclusions

The increase in groundwater level caused the gradual replacement of superior and fine quality grasses by less valuable plant species in heavily moist and wet post-paludic grasslands. Declining maintenance of drainage systems in headwater river valley sections favours the development of agriculturally less valuable plant communities typical for wet sites.

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Impact of soil-moisture change on transformation of post-paludic habitats

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Abstract

From 1991 to 1999 post-paludic grassland areas in Central Poland were studied. Soil, habitat, plant community type and groundwater level were determined on 19 selected plots. Organic soils were distinguished depending on the thickness of their organic layer, content of organic matter and mineralisation of organic nitrogen compound. The early 1990s were a period of declining maintenance of detailed drainage facilities in most of the studied grassland sites leading to increased groundwater levels and soil-moisture content. Floristic composition of grassland community was used to calculate site's humidity indexes, helping to distinguish initially three, and later five, humidity habitat groups. At the outset of the study period the majority of studied grassland sites fitted the humidity habitat group I (fresh). By 1999 the growing and more varied soil-moisture levels resulted in transformation of most sites, some of which then belonged to group IV of wet and paludic habitats.

Keywords: post-paludic grassland, habitat diversity, N mineralisation, humidity index

Introduction

In the 1950-60s the majority of paludic sites had been reclaimed and sown with grass and legume seed mixtures. The resulting post-paludic grassland in Poland, some 0.9 million hectares, was brought under similar management and fertiliser practices. The sites have different soils and groundwater levels, the latter subject to considerable fluctuations throughout the growing season and from one year to the next. Typically the lowest groundwater levels occur during the first and especially the second hay cut (summer drought). Agricultural potential of grassland depends on groundwater table depth during this period. Post-paludic grasslands are typical anthropogenic grasslands. They are characterized by the low stability of habitat and plant communities, but their transformation is easily triggered by declining maintenance of drainage system and grassland management. The aim of the present study was to analyse the developing differences in groundwater levels and soil-moisture content in post-paludic grassland following the interruption of drainage systems maintenance. We were also interested in their impact on the intensity of organic nitrogen mineralisation in soils and on the development of wet and paludic sites.

Materials and methods

The study was carried out between 1991 and 1999 and focused on river valley grasslands of Central Poland situated in the middle course and headwater section. Soil type and plant community composition was determined in 19 plots, using the soil pit method and the Klapp method, respectively. Groundwater levels were measured in spring and during the first to third cuts. The organic nitrogen mineralisation was determined using the method elaborated at the Geobotanical Institute in Zürich (Frąckowiak, 1991). Floristic composition was used to define a humidity index – HI (Klapp, 1965; Oświt, 1994). Depending on this index sites were distinguished into three humidity habitat groups (Oświt, 1994) defined at the outset of the study: fresh, moist, heavily moist and wet.

Results and discussion

Post-paludic soils were found to have organic layers of varying thickness, differing in the percentage organic matter and extent of the marshing and mineralisation process (Table 1). In heavily moist and wet habitats the extent of mineralisation was lower and the content in organic matter higher.

Table 1. Content of organic matter (%) and mineralisation of organic nitrogen in post-paludic soils during the growing season 1995 in soil layer 0-20 cm.

Humidity habitat	Soil	Number of sites	Organic matter (%)			Organic N mineralisation (kg N ha^{-1})		
			mean	min	max	mean	min	max
I – fresh	Mr[1]	3	34.9	22.0	49.6	148	130	164
	Mt[2]	7	46.6	20.2	79.5	137	90	267
mean		10	43.1	20.2	79.5	141	90	267
II – moist	Mr	3	34.6	20.1	60.4	155	111	231
	Mt	1	63.1	-	-	134	-	-
mean		4	41.7	20.1	63.1	150	111	231
III – heavily	Mr	1	55.1	-	-	71	-	-
moist and wet	Mt	4	74.4	53.6	86.7	68	40	92
mean		5	70.5	53.6	86.7	69	40	92

[1] Mr: mineral-moorsh soil, organic layer < 30 cm.
[2] Mt: peat-moorsh soil, organic layer > 30 cm.

Mineral-marsh soils had a thin organic layer (< 30 cm). In conditions of higher soil moisture (groups II and III) the organic layer was relatively little transformed. Even mineral-marsh soils had a high degree of organic matter and low degree of the organic nitrogen mineralisation. Peat-marsh soils had developed from peats with an organic layer of varying thickness and degree of decomposition.
Marked differences were observed in groundwater levels in the periods of the 1st and 2nd cuts (Table 2).

Table 2. Groundwater level fluctuation and mean level (in cm) in three grassland humidity habitat groups in 1991, 1995 and 1999.

Humidity habitat	1991		1995		1999	
	1st cut	2nd cut	1st cut	2nd cut	1st cut	2nd cut
I – fresh	58[1]	87	64	68	58	63
	40-70[2]	65-110	37-86	41-109	35-81	30-83
II – moist	37	70	52	60	41	46
	30-48	65-75	40-61	42-70	32-60	35-60
III – heavily moist and	25	53	28	44	20	33
wet	10-35	40-65	14-37	20-60	9-48	17-45

[1] mean ground water level, [2] minimum and maximum ground water level.

For grasslands of group I and II (fresh and moist respectively), the mean groundwater level during the first cut was similar at the beginning (1991) and at the end (1999) of the study period. At the time of the second cut it was slightly higher in 1999 than in 1991. Both groups showed increased groundwater level fluctuation at the end of the study. In grasslands of group III (heavily moist and wet) the mean groundwater level was higher at the end of the study, but only by 5 cm during the 1st cut and by 20 cm during the 2nd cut. At the end of the study period many grassland sites in group III were flooded (with water even up to 9 cm above the ground level) or waterlogged in the root layer. In the same group, the fluctuations of the groundwater level increased towards the end of the study period.

The organic nitrogen mineralisation was lowest in group III (< 92 kg N ha; Table 1), with a high groundwater level (Table 2). In groups I and II the process was similar, with substantial variation between individual sites.
Humidity indexes based on floristic composition increased in some grassland sites between 1991 and 1999 due to a gradual increase in groundwater level and due to the soil-moisture increase. It was therefore necessary, towards the end of the study period, to distinguish two additional humidity habitat groups: heavily wet and undergoing paludification (group IV) and seasonally drying paludic (group V, Table 3).

Table 3. Number of sites in the different groups of humidity habitats in 1991 and 1999.

Humidity habitat		HI[1]	1991	1999
I	fresh	5.3-5.9	10	7
II	moist	5.9-6.6	4	5
III	heavily moist and wet	6.6-7.3	5	2
IV	heavily wet and undergoing paludification	7.3-7.9	-	4
V	swampy, occasionally drying	7.9-8.3	-	1

[1] HI – humidity index of the meadow community.

Increase in soil-moisture content in post-paludic grassland was observed in sites lying in the headwater section of river valleys additionally fed by water from the surrounding dunes.

Conclusions

Interruption of drainage systems-maintenance led to the rise of soil-moisture in a part of post-paludic grassland sites lying in the headwater river valley section. This helped to check the mineralisation of organic matter and favoured the development of wet and paludic habitats.

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Effect of different management on the botanical composition of permanent grassland

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Abstract

The effect of different cutting and mulching regimes on the botanical composition of permanent grassland was studied in the Jizerské hory Mountains in the Czech Republic from 2000 to 2003. Treatments were: Unmanaged, mulched 1 to 3 times y^{-1} and harvested twice y^{-1}. The experimental area was casually harvested or grazed before start of the experiment. *Dactylis glomerata*, *Elytrigia repens* and *Festuca pratensis* were dominant species in the baseline data. Some prostrate herbs increased in frequently managed treatments during experiment. Cover of *Trifolium repens* increased from 1 to 21 % and *Taraxacum* spp. from 2 to 15 % in the mulched 3 times plots. On the other hand legumes disappeared and some undesirable species such as *Aegopodium podagraria, Cirsium arvense* and *Galium album* spread in unmanaged or mulched once plots. The number of plant species slightly increased in frequently managed plots and decreased in plots without management.

Keywords: meadow, disturbance frequency, biodiversity, legumes, management

Introduction

In the last decade of 20th century, reduction of cattle staff decreased the importance of semi-natural grasslands for forage production in the Czech Republic. Unmanaged meadows and pastures were changing into species poor grasslands with dominated by tall grasses and forbs with high competitive ability for light and nutrients. The absence of defoliation led in many cases to spread of weeds or alien species or succession to shrubs and trees. The effect of cutting or grazing on biodiversity has been studied frequently in Czech conditions, but little attention has been paid to mulching. The aim of our study was to compare the biodiversity on unmanaged, mulched and cut grassland.

Materials and methods

The experiment was carried in the Jizerské hory Mountains in the northern part of the Czech Republic. Altitude is 420 m above sea level, average annual temperature is 7.2 °C and annual precipitation is 803 mm. *Dactylis glomerata*, *Elytrigia repens* and *Festuca pratensis* were the dominant species. No fertiliser was applied to the meadow. Treatments were arranged in four completely randomized blocks in 5 x 10 m plots. Treatments were:

1. 2 x cutting with removal of the biomass (2C)
2. unmanaged grassland (U)
3. 1 x mulching in July (1M)
4. 2 x mulching in June and August (2M)
5. 3 x mulching in May, July and September (3M)

Mulching was done using the Uni Maher UM 19 machine which crushes and breaks down biomass to an even layer on the surface of the sward. Cover of plant species was recorded at the end of May each year. Nomenclature followed Kubat *et al.*, (2002). Redundancy analysis

(RDA) using the CANOCO program (ter Braak and Šmilauer, 1998) and ANOVA were used for data analysis.

Results and discussion

Prostrate dicotyledonous species (*Trifolium repens*, *Taraxacum* spp., *Veronica serpyllifolia*) spread in the frequently managed treatments during the experiment. We found a significant increase of legumes in these treatments (Table 1), predominantly *Trifolium repens*. Pavlu *et al.* (2003) also recorded increase of white clover under frequent defoliation on the pasture.

Table 1. Percentage cover of agrobotanical groups.

Treatment	2C				U				1M				2M				3M			
Year	2000	2001	2002	2003	2000	2001	2002	2003	2000	2001	2002	2003	2000	2001	2002	2003	2000	2001	2002	2003
Grasses	61	47	52	42	62	50	45	44	55	48	57	41	54	47	56	47	56	45	50	39
Legumes	7	22	18	27	7	6	0	1	9	11	4	9	7	20	10	12	9	23	23	30
Other forbs	22	20	21	24	22	28	33	36	25	28	32	43	30	23	27	35	27	21	22	25
Empty places	10	11	9	7	9	16	22	19	11	13	7	7	9	10	7	6	8	11	5	6

The cover of *Trifolium repens* increased most in the mulched 3 times treatment (3M) from 1 % to more than 20 % (Figure 1). Cover of this species increased from 1 % to 17 % in the twice cut treatment (2C), while in the unmanaged (U) or in the mulched once plots (1M) white clover disappeared and some undesirable dicotyledonous species and weeds increased (*Aegopodium podagraria*, *Cirsium arvense*, *Urtica dioica* and *Galium album*).

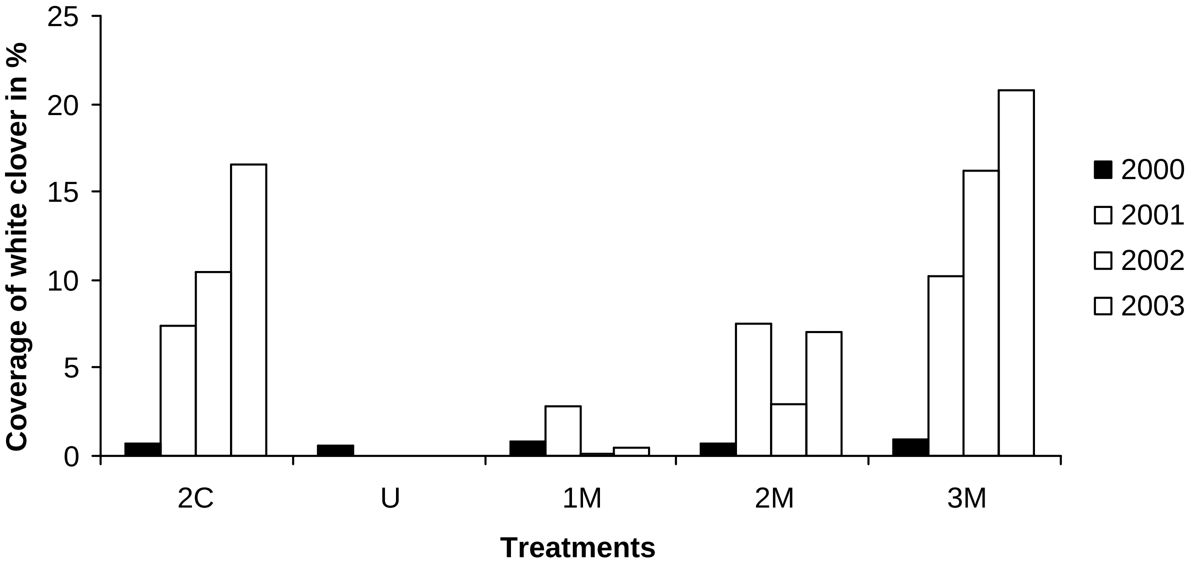

Figure 1. Average cover of *Trifolium repens* in the sward (2000-2003).

The coverage of *Aegopodium podagraria* increased from 4 % to 11 % in the unmanaged treatment (U) and to 18 % in the mulched once plots (1M). Cover of *Galium album* increased from 3 to 8 % in unmanaged grassland (U) and from 8 to 13 % in the mulched once treatment (1M). Cover of *Taraxacum* spp increased. from 2 % to 16 % in 2C, to 12 % in 2M and to 7 % in 3M respectively. Number of plant species slightly increased in managed treatments, but decreased in unmanaged grassland (Figure 2). This is in agreement with the finding of many other authors (e.g.. Bakker, 1989; Ryser *et al.*, 1995; Santrucek *et al.*, 2002) that the appropriate frequency of disturbance is one of the key factors for coexistence of a high number of plant species.

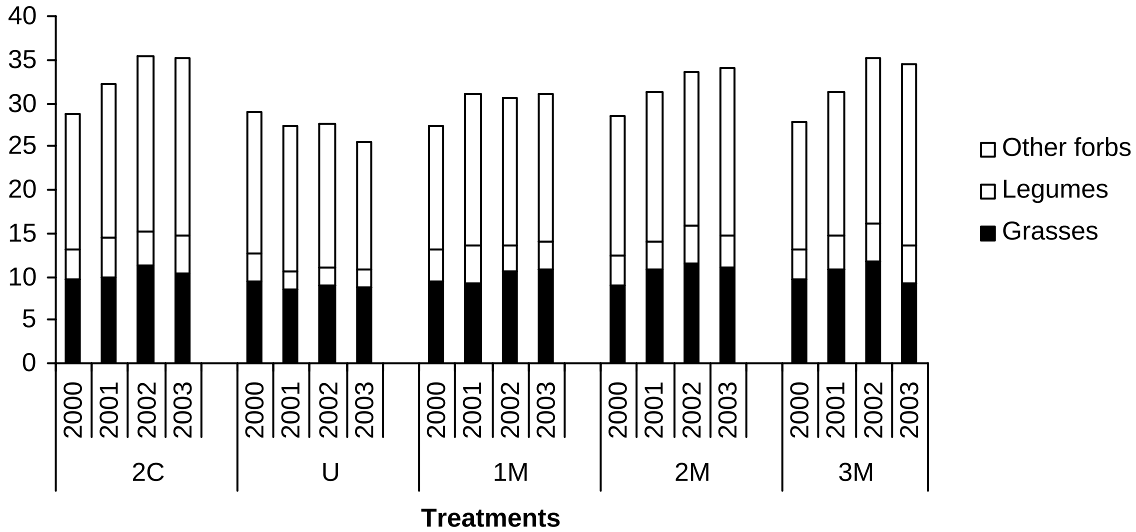

Figure 2. Average number of plant species.

Conclusions

Gradual increase of legume cover in the sward was promoted by frequent mulching and by cutting with biomass removal. Dicotyledonous weeds *Aegopodium podagraria, Cirsium arvense* and *Galium album* increased in unmanaged and mulched once plots. In contrast to unmanaged plots, mulching and cutting resulted in a slight increase in plant species number.
To restrict the spread of weeds and a decrease of species diversity, alternative managements must be practiced in areas where fodder production from grasslands cannot be justified in the Czech Republic.

Acknowledgements

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Festuca arundinacea Schr. and *Bromus marginatus* Ness et Stend. as possible energy crops in the Czech Republic

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Abstract

A comparison of yield and biomass quality of *Festuca arundinacea* Schr. and *Bromus marginatus* Ness et Stend. was performed to evaluate their suitability as a potential renewable energy source. The planting of energy crops is a possible use of surplus arable land in the Czech Republic.
The experiment was established in Prague in 2002. The yield of dry matter was higher in plots with *B. marginatus* (5,395 kg ha^{-1}) than with *F. arundinacea* (3,999 kg ha^{-1}) in the first year. The energy accumulation and N content in the biomass was studied at 14 days intervals. The variety used had a significant effect on calorific value ($P < 0.05$) which ranged from 16.97 to 18.51 kJ g^{-1}. Nitrogen content was significantly affected by time of sampling. *B. marginatus* was shown to be a more suitable energy crop than *F. arundinacea* due to higher yield and more favourable biomass quality.

Keywords: energy source, biomass, *Festuca arundinacea* Schr., *Bromus marginatus* Ness et Stend.

Introduction

Biomass for energy purposes may be one non-food alternative for production on arable land. Utilisation of marginal land for the growth of energy crops is in accordance with views that biomass species should require little fertiliser, thrive on poor soil and tolerate both wet and dry soils. The suitability of energy crops for either conversion into fuels or energy release through combustion can be measured by several indices. Primary fuel attributes that determine the suitability for combustion are; the total energy content, the total moisture content and the chemistry of ash (McLaughlin *et al*., 1996). Moisture content at harvest influences the cost of transportation and handling as well as the recoverable energy level, since moisture vaporization requires energy during the combustion process. Ash content and chemistry is important in the combustion process because it can contribute to the formation of deposits that reduce boiler efficiency and increase costs (Miles *et al*., 1993). The concentration of each particular mineral substance varies depending on the plant species and the plant part (Petersen, 1988). The plant age or stage of development when harvested, and the concentration of other minerals also have a significant influence (Landström *et al*., 1996).

Materials and methods

Tall fescue (*Festuca arundinacea* Schr.) and mountain brome (*Bromus marginatus* Ness et Stend.), were studied in a plot experiment. The experiment was carried out in a field (latitude, 50°08'N, longitude: 14°24' E) within the sugar beet production area at the Czech University of Agriculture in Prague (286 m asl). The soil in the experimental area was a deep loamy degraded chernozem with a permeable under layer. The soil was neutral or slightly alkaline. The content of available phosphorus and potassium in the 100-200 mm layer was known to be very high and the available magnesium content was also high. The area was classified as having a moderate to warm and mostly dry climatic. The average growing period was 172 days and the mean annual temperature was 7.9 °C (30 year mean). The long-term average precipitation was 526 mm y^{-1}. In 2002, the mean annual temperature was 9.3 °C and the annual sum of precipitation was 679.8 mm.

Individual plot size was 10 m^2 and the experimental treatments were established in a randomized block design with four replicates. Pure stands of *Festuca arundinacea* and *Bromus marginatus* were sown at a rate of 40 kg ha^{-1} and 85 kg ha^{-1}, respectively. Seeds were sown with a drill seeder with rows 125 mm apart. The sowing date was April 19.

Two harvests were carried out, one at the end of growing season (October) and a second, delayed harvest, in the following spring (March). Chemical analyses (sulphur, nitrogen, chlorine, and ash) and calorific value were performed on samples taken at 14 days intervals (from mid-August to mid-October). The calorific value was measured by using an automatic adiabatic calorimeter (LAGET MS 10 A). Analysis of variance was carried out on the variables for yield of DM ha^{-1}, yield of energy ha^{-1}, N content and ash content.

Results and discussion

The yields of above ground dry biomass were higher ($P < 0.001$) when harvested at the end of the growing season than at spring harvest. *B. marginatus* provided higher yields than *F. arundinacea* ($P < 0.001$). The reason for the higher loss of biomass during the winter on *B. marginatus* plots can be ascribed to differences in growth habit of the two species. On average, more than 60 % of *B. marginatus* biomass consisted of stems while in tall fescue, the major part of the harvested biomass consisted of leaf blades from tussocks (Pahkala and Pihala, 2000). Stems are more susceptible to loss of biomass during the winter due to unfavorable weather conditions, such as strong wind and snow cover. The difference in yield was greater during the autumn harvest (5,395.0 kg ha^{-1} *B. marginatus* and 3,999.0 kg ha^{-1} *F. arundinacea*) than in spring (2,663.0 kg ha^{-1} and 2,532.0 kg ha^{-1} respectively). The interaction of variety and harvest time on yield was significant ($P < 0.05$) (Figure 1).

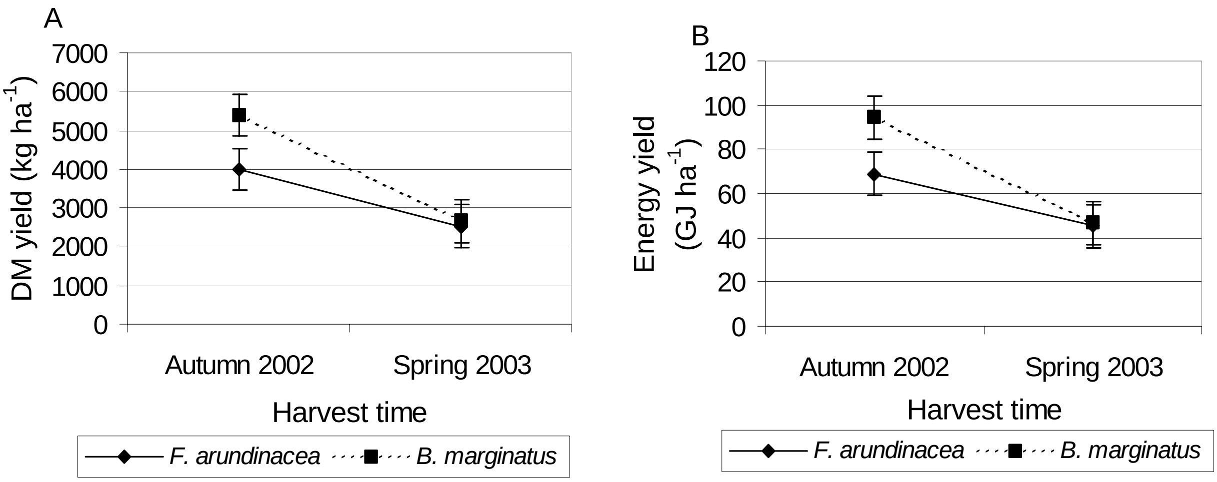

Figure 1. The interaction of grass species and harvest time on (A) dry matter yield (kg ha^{-1}) and (B) energy yield (GJ ha^{-1}), Scheffe $\alpha = 0.01$, n = 4.

Generally, there is little variation in the energy content of grass biomass, and the calorific value of grass species is known to average approximately 17 to 19 kJ g^{-1} (El Bassam, 1996). The calorific value of the biomass of *F. arundinacea* was lower ($P < 0.05$ range 17.0 to 17.8 kJ g^{-1}) than that of *B. marginatus* (range 17.4 to 18.5 kJ g^{-1}). The effect of sampling time was not significant. The total energy yield depended on dry biomass yield and consequently *B. marginatus* was superior to *F. arundinacea* in this respect.

High N content in biofuels can cause excessive NO / NO_2 formation during the combustion of biomass and thus the N content should not exceed a limit of 150 g kg^{-1}. When plants mature, many nutrients, especially easily movable nutrients such as N and K, are translocated to the underground parts of the plants and partly washed out. The N content of the biomass of *B. marginatus* was lower than that of *F. arundinacea* (13 g kg^{-1} and 17 g kg^{-1}, respectively). The ash component is known to vary greatly between families of plants and plant parts (Burvall, 1997). The ash content was lower ($P < 0.01$) in *B. marginatus* (104.6 g kg^{-1}) than in *F. arundinacea* (116.1 g kg^{-1}). Harvest date had little effect on this parameter. The lower ash content of *B. marginatus* can be explained by a lower leaf:stem ratio as ash content is higher in leaves compared to stems (Pahkala and Pihala, 2000). Cl and S contents in *F. arundinacea* were higher than those of *B. marginatus* (3.91 g kg^{-1}, 1.12 g kg^{-1} and 3.22 g kg^{-1} and 1.67 g kg^{-1} respectively). High Cl and S contents are inconvenient for direct combustion because these elements cause corrosion in fire tube boilers of biomass combustion plants (Obernberger, 1997).

Conclusions

The study showed that it is possible to use grass biomass for energy utilisation. The quality of the biofuel is dependent not only on grass species, but also on the time of cutting. For direct combustion a low leaf:stem ratio is required because leaf sheaths and especially leaf blades contain the highest content of undesirable chemical elements. On the basis of these results it appears that *B. marginatus* is more suitable for direct combustion than *F. arundinacea*.

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Development of forage areas and forage resources in Bulgaria during the period of transition

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Abstract

Agricultural land in Bulgaria covers an area of 6.25 million hectares, comprising 20 % commons and pastures, and 80 % arable land. During the transition period after the democratic changes in 1989, the agrarian reform and consequent reduction in animal number caused changes in the proportion of the pastures and areas of forage crops providing forage for herbivores. The share of pastures attributed to herbivores increased from 0.60 ha per conventional livestock unit (CLU) in 1990 to 1.03 ha per CLU in 2000. In the same period, the areas of forage crops decreased from 0.42 ha per CLU to 0.23 ha per CLU, mainly at the expense of maize grown for silage. Although the proportion of pastures increased, the use of alpine pastures decreased due to lack of animals. This caused low quality swards and expansion of bushes, ferns and non-edible plants, which makes these pastures unfit for use. There are two main feeding systems for ruminants, one based on grazing and cereal by-products, and the other based on forage crops, with a tendency towards an increase of the share of the second with a respective change in the structure of forage areas.

Keywords: forage areas, forage crops, grasslands

Introduction

In Bulgaria, 6.25 M ha, or more than half of the total area, is agricultural area, 20 % of it being common pastures and grasslands, and 80 % arable land. According to arable land, 0.6 ha per habitant, Bulgaria is rather ahead as compared to the average of 0.23 ha per habitant for the countries of the European Union (EU-15). This potential is a good prerequisite for development of sustainable forage production and stockbreeding. Unfortunately, during the transition period, negative changes occurred in both stockbreeding and production of forage for ruminants. The large co-operative farms were destroyed and the numbers of cattle and sheep were, more than halved. Today, more than 85 % of cows are bred on smallholdings, in numbers of one or two, as a means of family subsistence. The type of feeding and the structure of the ration were changed. The share of grazing in the ration, as well as that of by-products, was increased. The area of forage crops was reduced many times and the maize silage is now used only in the diets of animals bred on large farms. Two systems of feeding were formed: one based on grazing and cereal by-products for the cows bred on smallholdings, and the other based on preserved forages, silage or hay, for the animals in the large farms. A great part of high mountain grasslands remained unused leading to negative consequences for the swards.

Forage area and resources

Forage crops: The main forage crops in Bulgaria are lucerne and silage maize. The other forage crops, such as pea, vetch, etc. have a smaller share in the feeding of animals. Before the transition period, forage crops occupied about 20 % of arable land but nowadays their area decreased to below 6 % (Table 1). The reason is not only the decreased numbers of sheep and cattle, but also the changes in respective feeding systems. The main ration for the cows in smallholdings (up to five animals per farm, over 90 % of the total cow number) consists of grazing in summer and hay and crop by-products in winter. According to the study of Dinev *et al.* (2003) maize silage is used only in the feeding of cows in large farms with over fifty animals, averaging about 35 % of the ration dry matter. In the small farms with up to five cows, no silage is used, but the by-products comprise 34-35 % of dry matter of animal diet. This example gives an answer to the question why the area of silage maize has decreased over 7 times and the area of forage crops over 3.5 times as compared to 1990 (Table 1). No additional forage area is required for the cereal by-products, but much manual labour is necessary for their harvesting, particularly for harvesting of maize stover. Although this is a sign of extensive forage production and stockbreeding, the usage of agricultural wastes in the diets is compensating for the lack of silage and increasing the efficiency of land use.

Table 1. Development of forage areas (ha).

Land use (ha)	1980	1990	2000
Grasslands	1,741,950	1,823,180	1,602,400
Arable land	4,665,000	4,643,000	4,966,000
- forage crops (% of arable land)	873,500 (18.7)	103,403 (22.37)	283,000 (5.7)
- lucerne	380,292	399,576	150,741
- maize for silage	360,360	424,317	57,758

Source: NSI, 2001

Table 2. Forage areas per conventional livestock unit (CLU).

	1980	1990	2000
CSU, total	2,628,418	2,478,936	1,246,276
- cows	701,908	617,321	419,312
- ewe	6,271,910	5,006,961	1,757,899
Grasslands (ha CLU^{-1})	0.69	0.73	1.28
Forage crops (ha CLU^{-1})	0.33	0.42	0.23
- lucerne (ha CLU^{-1})	0.14	0.16	0.12
- maize for silage (ha CLU^{-1})	0.14	0.17	0.05

Source: NSI, 2001

Although the area of lucerne decreased over 2.5 times, as compared to the period before the beginning of transition, it remains the only forage crop for which the relative area per CLU did not decreased so drastically as, for example, that of maize for silage (Table 2). Lucerne hay is used in the feeding of almost all cows, in small and large farms, in a quantity of 3 to 20 % of the diet dry matter. The potential of lucerne as a forage source is high, but for lack of irrigation the annual yields are low 2500-5500 kg hay ha^{-1}.

Grasslands: The grassland area decreased by about 10 % during the period of transition. The reason was because after the restitution of the land some grassland area was transformed into arable land. In spite of that, because of the reduced animal numbers, the grassland area relative to the herbivore animal number increased. According to studies of Dinev *et al.* (2003) the share of grazing is from 14 to 35 % of the diet dry matter for the cows grown in farms with up to 50 cows.

The grasslands in Bulgaria are distributed as follows: lowland 15 %, hill (100 to 700 m) 58 %, mountain (700 to 1000 m) 12 %, high mountain (over 1000 m) 8 % and unclassified 7 %. There are about 300 species of herbaceous plants in them, about 60 grasses, 40 legumes and 200 other herbaceous species (Cheshmedjiev, 1980). The communities of *Chrysopogon gryllus* L., *Dichantium ischaemum* L. and *Poa bulbosa* L. have wide participation in the composition of foothill and mountain swards. The communities of *Agrostis capillaris*, *Festuca rubra*, and others have more limited participation. The bushes, such as *Paliurus spina-christi* Mill., *Juniperus oxycedrus* L. and *Continus coggygria* Mill.

occupy an important area of grasslands. The communities of *Chrysopogon gryllus* L., *Agrostis capillaris* and *Festuca* are used for grazing and hay. The yield of the natural common pastures and grasslands is low for lack of fertilising and for other melioration measures (Table 3).

Table 3. Yield and grasses:legumes:forbs ratio of natural swards.

Sward type	Yield (kg ha^{-1})			Grasses:legumes:forbs ratio		
	1989-1991	1994-1996	1999-2001	1989-1991	1994-1996	1999-2001
Chrysopogon gryllus	2522	2560	2342	88 : 3 : 9	68:5:27	78:5:17
Agrostis capillaris / Festuca fallax	3561	3138	2997	63 : 6: 31	68:11:21	74:8:18
Nardus stricta	1967	2249	2182	80 : 1 : 29	73:2:25	85:1:14

The *Chrysopogon gryllus* type has the widest distribution in the grassland swards situated up to 500-700 m. About 70 % of grasslands from the plain and foothill part of Bulgaria are located up to this altitude. The *Agrostis capillaris / Festuca fallax* type predominates in the mountain grasslands up to 1000-1200 m and the *Nardus stricta* type predominates in the high mountain pastures over 1200 m.

The share of grass components in the swards varies from 60 to about 90 % and that of the legume components is up to 10 %, which is in unison with data from earlier studies (Cheshmedjiev, 1980).

Conclusions

In the near future two feeding systems of the ruminants in Bulgaria, on which the forage resource use depends, will remain: one based on grazing and crop by-products for the animals on smallholdings and the other based on predominating share of forage crops (green or preserved) for the animals on large farms. The number of large farms will increase and simultaneously the areas occupied by silage maize, lucerne, grass-legume mixtures and other forage crops will increase appropriately.

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Influence of cutting intensity and nitrogen fertilisation on forbs in meadows of the Celje region

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Abstract

During two periods (1993-94, 1996-97) 74 inventories of botanical composition were done on differently managed natural meadows in the Celje region in Slovenia. On the basis of the inventories and the grassland management data, received from the farmers, the following conclusions can be drawn: Despite great botanical fluctuation of the swards during the years, it was established that nitrogen fertilisation and cutting frequency influenced this composition to some extent. The proportion of forbs was rather low at two cuts (8-16 %), moderate to rather high at three cuts (24-31 %) and moderate at four cuts per year (13-21 %). The number of plant species other than grasses and legumes was the highest in the two-cut system. *Achillea millefolium* and *Taraxacum officinale* prevailed at all cutting intensities.

Keywords: natural meadows, fertilisers, cutting, weeds, grass sward, botanical composition

Introduction

Because of cattle-breeding, fields in Slovenia are predominantly (40 %) sown with fodder plants (Korošec *et al*., 1992). At the same time the fodder grown on meadows is of a very poor quality (Korošec, 1984). The surface of meadows and pastures in Slovenia is not constant. According to one set of data it is 501,000 ha (Cunder *et al*., 1997), that is 64 % of agricultural land. Yet, according to another source of information it is only 265,490 ha, that is 34 % of agricultural land (Korošec, 1995; Leskošek and Šilc, 1983). The structure of the soil use in the Celje region is similar to the structure in Slovenia. There are 57,560 ha of meadows, which represent 62 % of agricultural land (Anonymous, 1993).
The aim of this study is to verify if the three-cut meadows, which are mown in May and fertilised with N, have more weeds than the two-cut and four-cut meadows. Forbs are useful components of fodder. They become weeds at the moment when they are overspread on certain areas and when they have to be controlled.

Materials and methods

During two periods (1993-94, 1996-97), 74 differently managed natural meadows were studied in the Celje region in Slovenia: 43 meadows were situated below 600 m asl, 31 above 600 m. At every inventory site the proportions of grasses, legumes and forbs were estimated (accuracy test with weighing). Within the forbs we specifically determined the leading species, e.g., milfoil (*Achillea millefolium* L.), yellow bedstraw (*Galium mollugo* L.) and dandelion (*Taraxacum officinale* Wigers in Weber). In relation to the cutting system and the amount of nitrogen, we made use of questionnaires. We estimated the amount of pure N on the basis of the quantity of bought and spread fertilisers (manure and mineral fertilisers). The meadows were then classified according to the number of cuts and the level of N fertilisation (40, 60, 80 and 100 kg N ha^{-1} cut^{-1}).

Results and discussion

Table 1 indicates the botanical composition of the meadows in relation to the number of cuts. The botanical composition of the two-cut meadows was still within the recommended limits in all the four years. Buchgraber (1995) recommends 50-70 % of grasses, 10-30 % of legumes and also 10-30 % of forbs on meadows, while Kessler (1994) recommends the same proportion of grasses, 10-20 % of legumes and 20-40 % of forbs on natural meadows.

Table 1. Effect of the number of cuts on the proportion of grasses, legumes and forbs (%).

		1993	1994	1996	1997	Mean
2-cut meadows	Grasses	69.4	68.1	53.0	50.5	60.3
	Legumes	18.1	23.8	31.0	34.8	26.9
	Forbs	12.5	8.1	16.0	14.7	12.8
3-cut meadows	Grasses	64.4	68.4	61.5	60.0	63.6
	Legumes	4.9	7.1	14.2	16.1	10.5
	Forbs	30.7	24.5	24.3	23.9	25.9
4-cut meadows	Grasses	77.0	79.8	79.3	83.5	79.9
	Legumes	2.4	5.2	2.2	4.0	3.4
	Forbs	20.6	15.0	18.5	12.5	16.7

Most of the two-cut meadows are fertilised with cattle manure, mostly with farmyard manure in autumn or in early spring and with liquid manure in spring and after every cut. Legumes increased and finally represented a third of the harvested herbage.

In the three-cut meadows, the proportion of legumes increased throughout the years and was highest in the last inventory year. In all areas the prevailing legume was red clover (*Trifolium pratense*); the second legume, also appearing frequently was white clover (*Trifolium repens*). Within the group of forbs, some species, for example milfoil and dandelion, increased consistently.

In the four-cut meadows, the legume component was very low; the prevailing legume was white clover. In comparison with the three-cut meadows the proportion of forbs was lower, the prevailing species being dandelion and milfoil.

The lowest proportion of forbs was measured at two cuts, where the average of all four inventory years was 12.8 %, which is even lower than in the Leskošek's (1998) experiments (18 % of forbs averaged over ten years). In the two-cut meadows the proportion of forbs in 1996 was 16.1 %, which was two times higher than the year before, but the proportion of individual forbs was nevertheless low because there was a greater number of different forbs.

The proportion of forbs in the three-cut meadows was the highest in the first inventory year, when it even exceeded the limit of 30 %. In the next two years the proportion was almost the same, and in the last year it slightly decreased, yet it was still higher than at two or four cuts.

With regard to the proportion of weeds the four-cut meadows can be placed between the two- and three-cut meadows. The proportion of forbs was 16.7 % on average.

At the lower level of N fertilisation the proportion of forbs on the two-cut meadows reached 12 % on average. At 60 kg N ha^{-1}, the proportion rose to 14 %, but it varied a lot throughout the years. Regardless of the fertilisation, the lowest proportion of forbs was measured in the year 1994 (8.7 % at 40 kg N ha^{-1} and 7.5 % at 60 kg N ha^{-1}). In fact there were no weeds – just herbs – on the two-cut meadows.

At three cuts the highest proportion of forbs was measured at 80 kg N ha^{-1}, but was a little lower at 100 kg N ha^{-1} after each utilisation. During the four years the proportion of forbs exceeded or was equal to 30 % in 42 % of all the inventories. The lowest proportion of forbs during the four years of inventories was found at 60 kg N ha^{-1}, but at the same time the fluctuation was the greatest. The lowest proportion of forbs was measured in 1996 (19 %) and the highest in 1993 (33 %). According to the estimated amount of N (40, 60, 80 and

100 kg N ha^{-1} cut^{-1}) the proportion of forbs was, on average over the four years, the highest at 80 kg N ha^{-1} cut^{-1}.

On average over of the four years the proportion of forbs on the four-cut meadows was between 15.5 and 16.2 % regardless of the N fertilisation. The difference among the levels of N fertilisation was on average very small; however, there was quite a fluctuation in the content of forbs each year. The proportion of forbs on the four-cut meadows was the highest at 80 kg N ha^{-1} cut^{-1}. When fertilising with 60 kg N ha^{-1} cut^{-1} the ratio of forbs was lower than when fertilising with 40 kg N ha^{-1} cut^{-1}.

Conclusions

After approximately 6-7 years of utilisation those meadows which were intensively exploited and mown in May became covered with a very high proportion of weeds. This mostly happened in the case of the three-cut meadows fertilised with various amounts of nitrogen. The proportion of forbs varied with different levels of nitrogen. In general the three-cut meadows had the highest proportion of forbs, especially those fertilised with 80 kg N ha^{-1}. The most frequent forbs were milfoil and dandelion, their content being quite high in some areas. There were only traces of yellow bedstraw, which is not a weed in the meadows of our region. The two-cut meadows contained weeds to a much smaller extent – in fact we could not claim that they contained weeds at all, since we found 54 different forbs. On the two-cut meadows none of the forbs exceeded 10 %. The proportion of forbs on the meadows fluctuated with years, which can sometimes give the feeling that the meadow does not contain weeds, yet such changes were not permanent.

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Available days and weather risk for hay and silage making in Switzerland

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Abstract

Frequent rainfall in the mountain regions of Switzerland keeps the grass growing and makes it easier to use manure after harvesting. However, field drying of roughage is rather difficult and needs more labour and machinery capacity, particularly with respect to high fodder quality. Long-term measurements of precipitation, air temperature, air humidity and sunshine by the National Meteorological Service enabled the Swiss Federal Research Station for Agricultural Economics and Engineering (FAT) to calculate the available days and weather risk in the fodder harvest, for about 100 different regions in Switzerland. A sufficient number of available days for hay making is particularly important for mountain farms, which have to conserve more than 50 percent of their grass yield for the long winter period. Here the technique of silage making in round bales shows some significant advantages because of its relatively short drying process and the possibility of transporting the bales in a separate process after harvest – if necessary even in a rainy period.

Keywords: field drying, hay making, silage making, available days, weather risk, rainfall

Introduction

In wide areas of the Swiss Alps and the Jura, grassland farming is the most appropriate type of agricultural production, both because of topography and climate. As altitude increases, however, the growing period shortens and the winter feeding period lengthens accordingly. At least above altitudes of around 1000 m asl, half the roughage required by cattle for a full year must be conserved in the form of hay or silage. Therefore, during the short mountain summer, top priority is given to the harvesting of good quality winter fodder. High weather requirements must be met if cut grass is to dry out properly in the field. Nevertheless, this method of conservation is still very widespread, particularly in locations with uneven topography. This is due firstly to the easier transport of dry fodder, and secondly to the widespread hard cheese production where the feeding of silage is prohibited for quality reasons. In the concerned areas, increasing interest in round bale silage system poses a dilemma between a site-specific modern conservation technique on the one hand, and the traditional kind of milk processing on the other.

Rainfall differences in the Alpine area and the Jura

The rainfall frequency statistics at the time of the important first cut already give the first indications of the locations where dry fodder has to be harvested under more difficult conditions. Table 1 shows the monthly rainfall distribution for three selected stations on a north-south section of the Alps. Lucerne represents a lowland location of around 450 m at the northern foot, Engelberg a mountain location at an altitude of 1000 m on the northern side and Piotta a mountain location at the same altitude on the southern side of the Alps. The higher rainfall frequency on the northern side of the Alps is due to the catchment effect of the alpine chain in relation to the westerly to northerly windstreams (windward side). In Piotta, i.e., on the leeward side of the Gotthard massif, the number of rainy days is considerably lower, especially during the fodder harvest period from June to August. The same applies by analogy to both sides of the Jura.

Table 1. Number of days with at least 1 mm rainfall at two locations (Lucerne, Engelberg) on the northern side of the Alps and one location (Piotta) on the southern side of the Alps (30-year means; source: MeteoSwiss).

Station	Altitude m asl	Rainy days												
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Lucerne	456	10.6	10.2	11.9	12.8	14.1	14.2	12.6	13.1	9.1	8.6	10.3	10.6	138.1
Engelberg	1035	12.3	11.7	14.0	14.2	15.6	16.1	15.2	14.7	10.9	9.4	11.8	12.0	157.9
Piotta	1007	7.9	7.7	9.1	10.0	12.5	11.0	9.8	10.6	7.9	8.4	9.1	8.2	112.2

Available harvesting days and weather risk, calculated on the basis of long-term weather data

Numerous field trials on the effect of precipitation, air temperature, air humidity and sunshine on the drying pattern of cut grass on the field were conducted at the FAT (Luder, 1996) and served as a basis to work out data to calculate drying possibilities. It was possible to estimate the number of potential available harvesting days using series of meteorological data taken over many years. Such planning values are associated with a certain weather risk, indicating the probability of missing the calculated number of available days. Figure 1 shows the available days for sun-dried hay in the lucerne region. This shows that available harvesting days increase with heightened weather risk. For reasons of clarity an average weather risk of 20 percent has hitherto been assumed in the labour planning of field work. Figure 1 shows that along the northern foot of the Alps the prevailing conditions until week 23 (period of the first cut with higher yields) tend to be unfavourable for the production of sun-dried hay. This is one of the reasons why shorter sun drying combined with subsequent ventilated hay drying has become very important in Switzerland.

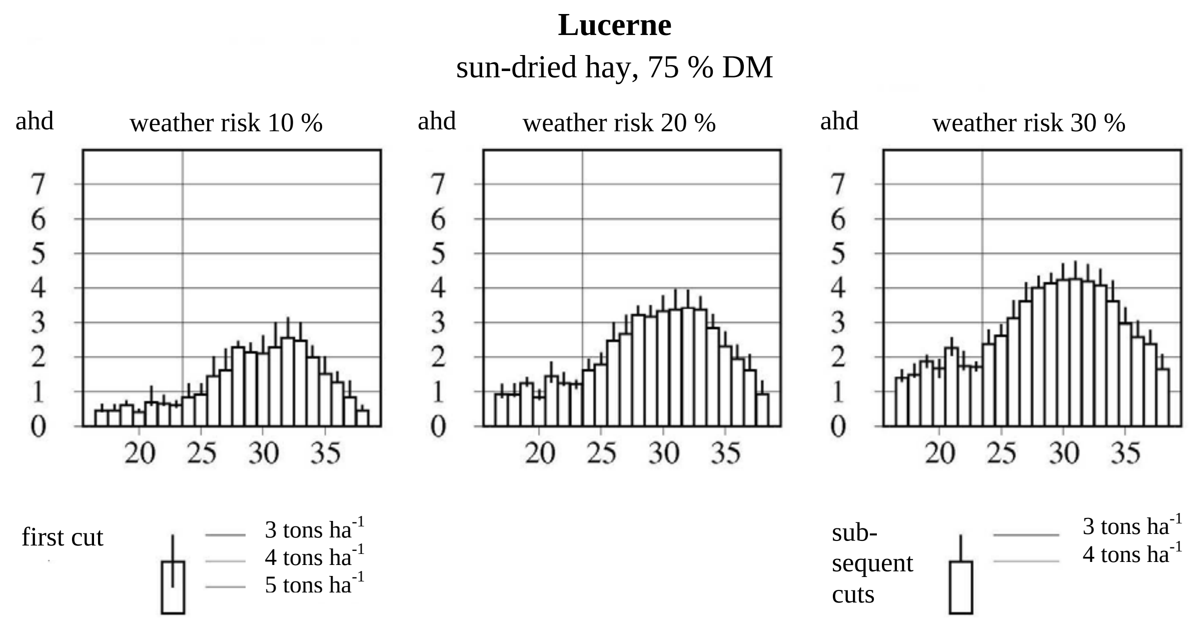

Figure 1. Available harvesting days (ahd) in weeks 17-38 for sun-dried hay in the lucerne region with varying weather risk, calculated from the measurement data of the lucerne meteorological station 1971-2000 (source: MeteoSwiss).

Comparison of various fodder conservation methods

Figure 2 shows that in Engelberg, on the windward side of the Swiss Alps, the climate is decidedly unfavourable for a rational hay harvest with few losses. This applies particularly to altitudes around 1000 m where the grass is ready for the first cut in June (weeks 23–26). This is where silage, with its shorter field drying phase and hence reduced weather sensitivity, gives the greatest advantages.

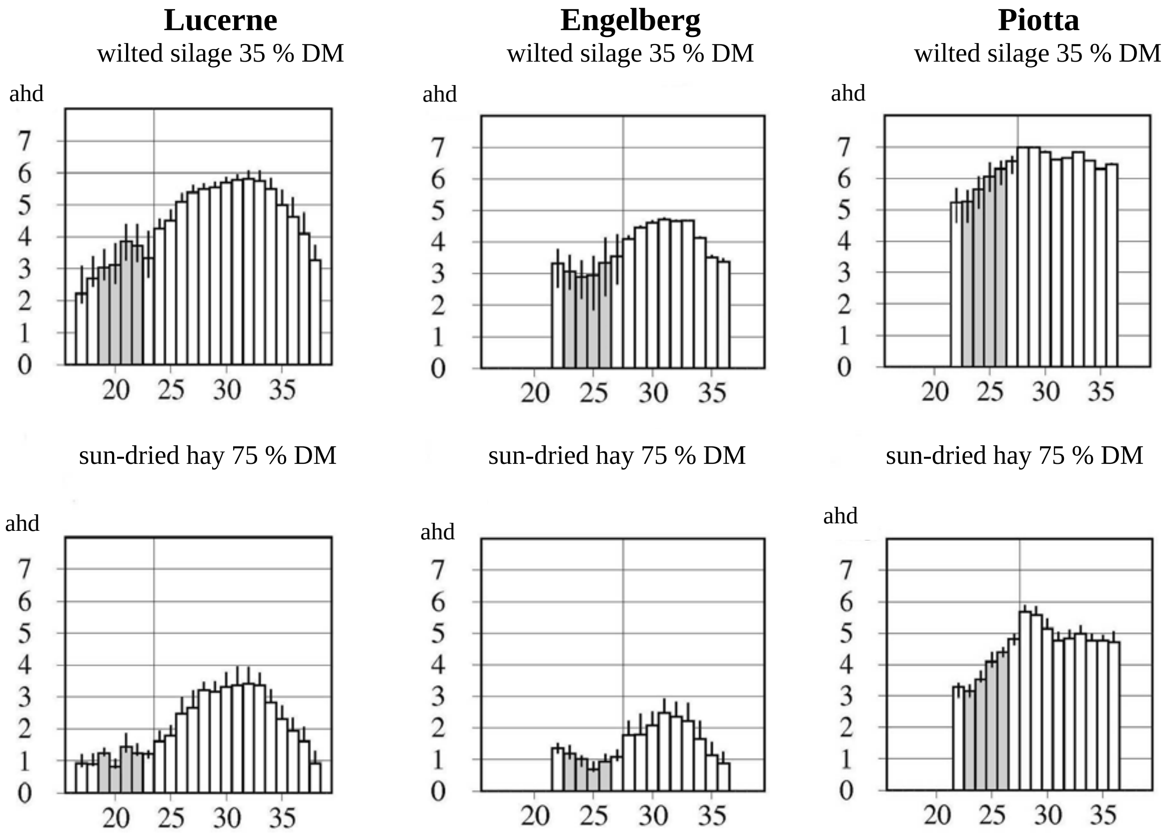

Figure 2. Comparison of available harvesting days (ahd) for wilted grass and sun-dried hay at three different locations on the Alps for a 20 percent weather risk. (First cut in Lucerne: weeks 19-22, in Engelberg and Piotta: weeks 23-26).

Conclusions

Unfavourable climatic conditions for the roughage harvest on sites exposed to westerly winds at an altitude of around 1000 m in the Swiss Alps and the Jura, can be mitigated by extending the period of the first cut (earlier beginning) and, if possible, making more wilted silage in round bales (Luder, 2002a). For many farmers the best method appears to be to contract out the round bale system. This not only allows them to make better use of, often brief, periods of fine weather, but also relieves them of forage transportation, frequently a time-consuming job during the best hours of the day (Luder, 2002b). The wrapped silage bales, however, even in bad weather can be brought to the farm by the contractor or the farmer himself.

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Limits to sustaining productivity, product quality and animal welfare in forage-based dairy systems

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Abstract

There seems little reason to think that limits to the capability of cows to secrete milk are close to being realised. Forages, alone, fail to support potential rates of milk yield per cow because the rate of forage intake limits nutritional support for milk production. In forage-based systems potential challenges to cow welfare arise through the inabilities of high merit cows to maintain a satisfactory energy balance. Future genetic selection for cows will not be for milk yield alone but will include selection for a range of traits aimed at sustaining both economic viability and cow welfare. Forage based systems of production bring mixed benefits for milk quality characteristics, and for environmental management. Adopting approaches that enable systems to develop that keep animal characteristics and system characteristics in beneficial balance is the key to sustainability. The likely polarisation of the industry in the future may well mean that the uniformity in approach to dairy production of the last few decades will change significantly.

Keywords: dairy cows, forage, intake, milk quality, welfare, genetics

1 Introduction

Almost up to the end of the twentieth century the underlying impetus for dairy production systems in most countries centred on increased yield per cow. Improvements in methods of grazing management and in the preservation and conservation of forages for winter feeding have been significant contributors to increased output per cow. The widespread adoption of forage maize, even in wet, western Europe, as a significant part of rations for housed feeding systems has further extended the contribution of forage to support enhanced output. Genetic improvement programmes for dairy cattle have emphasised increasing yield as the dominant selection goal.

In the developed world, and perhaps particularly in Europe and in North America, management systems have been adapted to the widespread availability of cattle with increased genetic capability for yield by increasing nutritional support. Frequently this has come in the form of higher inputs of concentrate supplements. In some systems increased milking frequency has been used to boost yields, and the growing adoption of robotic systems for milking is enabling this.

These moves to increased intensification of milk production reflect more competitive commercial challenges to producers. In many countries average herd size has also increased (Table 1) although there remain huge differences both amongst and within countries in herd sizes.

The adoption of ever more intensive systems present serious environmental, biological and sociological challenges. The control of nitrogen and phosphorus outputs from dairy herds (Castillo *et al*., 2000; Valk *et al*., 2000) will grow in importance as new legislation comes into play (for example, in Europe, the Water Framework Directive). There has been a steady, and substantial reduction in fertility in dairy cattle (Royal *et al*., 2000), with both genetic and environmental components (Pryce *et al*., 1997). The incidence of some diseases, especially lameness and mastitis has risen as yields per cow have risen (Ingvartsen *et al*., 2003). Social concerns about the impact of higher rates of productivity of cows on their welfare are enhancing the focus on animal welfare issues (e.g., FAWC, 1997; Hemsworth *et al*., 1995).

The extent to which these phenomena signal that limits to sustainable output, or productivity, are being met is, of course, debatable. It is certainly the case that for any system to be truly sustainable a balance has to be struck between the choice of appropriate genotypes and of the systems of management adopted to sustain them. Efficient use of forages to help sustain cost-effective output has always been a background theme in EU dairy systems. But the pressures and opportunities to exploit the apparent advantages of output per cow, even in quota-limited situations, has tended to reduce emphasis on more 'extensive' systems of management.

Data on rates of output per cow, and on herd size suggest a considerable drift towards more intensive systems of cow management. It is, however, surprisingly difficult to get robust information about the natures and distributions of systems in use across the dairy industry in Europe, and therefore difficult to gauge how they are evolving. The Farm Accounts Data Network (FADN) gives access to some information. Colson *et al.* (1996) have used FADN to identify the structural characteristics and economic performance of cattle systems in the EU. Not surprisingly their analyses show huge differences in the average intensity of dairy production systems amongst member states.

The growth in organic systems for milk production will, in general, have re-emphasised more extensive, forage-based systems of management. Nonetheless, the steady growth in both milk yield per cow and in herd size (Table 1) that has been seen across Europe is a fairly sure sign that, overall, the drift has been steadily towards more intensive systems of management.

One view of future EU dairying suggests a polarisation with some large, intensive units attempting to reduce costs and compete in world commodity markets. Others, responding to the high costs of land and labour, will adopt extensive systems with small units producing specialist milks that command a premium – perhaps as part-time farmers. This paper will consider the limitations (and opportunities) afforded by forages in these situations.

2 Limits to output and intake

Holmes (1951) (cited by Rae *et al*., 1987) reported on a herd of Ayrshire cows that produced 3400 kg of milk solely from grass and grass-based products. This should be compared against the current average milk yields of cows in some European countries (Table 1).

Table 1. Average annual milk yields (kg) per cow and, in parenthesis (), average herd size in a number of European countries. Comparative data for the years 1991 and 2001 are shown. Data from Dairy Facts and Figures (2002).

Country	1991		2001	
Germany	4883	(22.7)	6220	(31.2)
France	5165	(27.3)	5887	(32.7)
Italy	4020	(15.5)	4983	(22.2)
Netherlands	5890	(41.8)	7315	(47.0)
UK	5268	(69.4)	6505	(72.4)
Irish Republic	4168	(27.3)	4346	(34.3)
Denmark	6189	(38.9)	7231	(57.2)
Sweden	6038	(26.2)	7912	(32.0)
Spain	4211	(9.3)	5503	(17.5)

As regards milk yield per cow there seems to be little evidence, from performance records, that biological limits to output are being reached. Overall trends, both phenotypic and genetic, appear to continue to be linear, at least in Europe.

Because the genetic and phenotypic correlations between milk output and food intake are high and positive (Verkamp, 1998), the implication is that food intakes are increasing as milk yield does. However the rate of increase in energy intake has not matched the rate of increase in energy demand (for milk production) as a consequence of genetic selection for yield at least in systems based on grass and grass silage. Data from the Langhill Dairy Cattle Breeding Project (Verkamp *et al*., 1994), suggest that as a consequence of genetic improvement for milk yield, the rate of increase in intake of a mixed diet with a high proportionate content of grass silage, is less than the rate of increase in intake of a diet with lower grass silage content.

It remains something of an open question as to whether there are significant opportunities to increase the cow's capacity for forage consumption through genetic selection. Differences may exist between breeds in (scaled) forage intake capacity (Oldham, 1999; Nielsen *et al*., 2003). The existence of modest genotype × environment interactions where progeny of bulls evaluated in either intensive (Canadian) or extensive (New Zealand) systems of management have been studied in both environments could suggest some correlated advantage to forage intake capacity where sire selection is in high forage systems of management (Paterson, 1989). But overall there seems to have been little change in forage intake capacity of cows over the recent period of significant yield improvements. While average milk yields per cow have increased hugely (about 100 %) over the last 50 years, in contrast, the intake characteristics and energy content (digestibility) of forages have changed relatively little (around 1 % unit increase in digestibility per decade; Wilkins and Humphreys, 2003)

3 Nutritional constraints

The higher intake characteristics and higher digestibility of concentrates based on cereals and co-products from industries, such as sugar beet, oilseeds and brewing/distilling, have meant that farmers have had many alternatives to, and less need to rely on, forages to sustain increasing yields. It has become perceived as necessary to include increasing levels of fat in concentrates (particularly 'protected' fats) in order to sustain increased milk yields. Just as post-war farmers came to rely on N fertiliser, many, indeed most, producers have adopted 'concentrate-dependent' management systems. Various researchers have considered forage-only diets for cows: Castle (1982) achieved mid-lactation yields of 16 kg, whilst Rae *et al*. (1987) obtained lactation yields of 4700 kg with forage-only diets. Reflecting on a range of studies, Kolver (2003) suggests that dairy cows of average size may be capable of sustaining daily milk yields slightly in excess of 30 kg per day from pasture alone. The differences in yield levels (per cow) between these studies, and the earlier ones of Holmes probably reflect developments both in animal and grass genotypes over the intervening years.

High substitution rates when feeding high-quality forages mean that concentrates reduce the utilisation of forage. Castle and Watson (1976) and Sutton *et al*. (1994) showed that forage utilisation can be increased by feeding small amounts of high-protein concentrates alongside high-quality grass silages. Concentrate protein stimulates forage intakes, whereas concentrate energy tends to replace forage energy.

Comparison of grasses and legumes, whether grazed (Waghorn *et al*., 1989) or as silages (Dewhurst *et al*., 2003a), shows that the high digestibility of grasses is related to a higher rumen retention time, which in turn might limit feed intake. The legumes exhibit characteristics that might lead to reduced rumen retention times and higher voluntary intakes

– such as the very rapid fermentation rate of white clover or the rapid particle breakdown of lucerne.

Digestibility is the combined result of the inherent rates of fermentation or digestion of a feed and its residence time within the digestive tract. White clover scores in both of these areas. Partly as a result of its low fibre content, it has an inherently high rate of fermentation, so that despite a much lower retention time than ryegrass (and consequent higher intake), it remains more digestible than ryegrass. The problem with white clover is low yield and so its attributes need to be developed in a higher-yielding forage. In order to introduce white clover-like attributes into grasses through breeding, it is important to consider both the rates of fermentation of grass in addition to end-point digestibility. The high-sugar perennial ryegrasses developed at IGER have had some success in this regard.

Dewhurst *et al*. (2003a) obtained 6 kg d^{-1} more milk from white clover silage than from ryegrass silage in two experiments that utilised all forage cuts made during a growing season. There is more prospect of increasing the contribution of grass by considering intake than digestibility (or at least considering the two simultaneously). The other potential approach to increasing energy intake from forages is to increase their lipid content. We recently obtained preliminary QTL for fatty acids in a ryegrass family (Humphreys, Turner and Dewhurst, unpublished), though management factors are also important (Dewhurst *et al*., 2001).

Progress with breeding for increased digestibility of grasses might also have been limited because of the need to take multiple traits into consideration in order to ensure listing of a variety. Prospects for the future might emphasise the lipid content of grasses, to enhance energy concentrations, rather more than the focus on sugar content that has been a main point of interest in recent years.

4 Environment

There is increased concern about the environmental footprint of dairy farming, with significant nitrogen losses to soil and water and an important contribution to atmospheric methane – a greenhouse gas. Ruminants contribute around 90 Tg y^{-1} to the atmosphere (Johnson *et al*., 2000). The generally high contents of fibre and protein, and low content of more readily fermented carbohydrates in forages leads to increased losses of these potential pollutants per unit of intake.

Rumen microbial efficiency is often low when single forages are fed as sole feed (Agricultural Research Council, 1984). Whilst legumes may be attractive diet components for other reasons, their high protein content can lead to wastage of nitrogen (Dewhurst *et al*., 2003a). These problems can be overcome by inclusion of concentrates or use of forage mixtures. These effects have been attributed to improvements in the synchronisation of energy and protein supply in the rumen; however, the synchrony concept has been difficult to evaluate (Dewhurst *et al*., 2000) and it is better to think about balance between energy and protein supply on a longer time-scale. Grass breeders at IGER have produced ryegrasses with a higher content of water-soluble carbohydrates and slightly lower protein content (Humphreys, 1989), which have led to improved N utilisation by dairy cows, particularly reduced urinary N losses (Miller *et al*., 2001). Recent studies have used live-cultured silage inoculants with high-sugar ryegrasses to produce grass silage with very high levels of residual sugars – these also exhibited increased nitrogen efficiency in the rumen (Merry *et al*., 2004).

High-forage diets also tend to the lead to production of more methane per unit of energy intake (Blaxter and Clapperton, 1965). This is partly related to their promoting a high-acetate fermentation in the rumen. Recent development of ryegrasses with a high content of water-soluble carbohydrates, which produce relatively less acetate and more propionate in the rumen, might provide one route to reducing methane output from forages. Dietary lipids, particularly medium-chain saturated fatty acids and long-chain unsaturated fatty acids (Blaxter and Czerkawski, 1966), have also been used to reduce methane output, so efforts to increase the lipid content of forages through genetic selections based on QTL (Humphreys, Turner and Dewhurst, unpublished) or agronomy (Dewhurst *et al*., 2001) may be of benefit. There is preliminary evidence that secondary plant metabolites, such as the condensed tannins in *Lotus* and *Hedysarum* might reduce methanogenesis (Woodward *et al*., 2001; 2002).

Variability in forage composition is a major limitation in the use of forages, with implications for all of the aspects being considered here – production potential, animal health and welfare, environmental effects, and product quality. Legumes show much less variation in composition than grasses. Flowering is a major source of variation in the composition of grasses, so work to understand and manipulate the genetics of flowering (e.g., Donnison *et al*., 2002) is important. However, these developments must take account of the need for seed production if new varieties are to be introduced.

Although high-forage diets appear inefficient when considering pollution per unit of intake or per unit of product, they can contribute to reduced pollution in a particular area because they are associated with reduced stocking rates. In these ways, the judgement about environmental constraints on forages is coloured by issues to do with world food supply and trade in food and animal feeds.

5 Limits to product quality

Farmers that adopt a less intensive, forage-based production system need unique selling points, in aspects such as product composition, animal welfare or environmental effects, in order to command a higher price in the market.

Consumers are much more aware of ‘diet and health’ and so the market wants relatively more protein and less fat, whilst there is a growing interest in various unsaturated fatty acids (notably omega-3 polyunsaturated fatty acids and conjugated linoleic acids).

Unfortunately heavy reliance on forages tends to lead to higher concentrations of fat and lower concentrations of protein in milk, although higher milk protein concentrations can be achieved by replacing some grass silage with virtually any other forage (Phipps *et al*., 1995). It is now known that an isomer of conjugated linoleic acid (*trans*-10, *cis*-12) is involved in the milk fat depression associated with high levels of concentrate feeding. There is some variation in the production of this fatty acid between forages (notably, being higher when feeding red clover), so there is potential to develop lower-fat milks when feeding high-forage diets.

The polyunsaturated fatty acids of forages represent both an opportunity and a potential problem for milk quality. Grazing of young, leafy grass represents the best natural way to produce milk with enhanced levels of conjugated linoleic acids (CLA) (Dewhurst *et al*., 2003b). CLA have been identified as having beneficial effects on body fatness and health (in rats, at least). When present in high concentrations they would also be expected to increase the spreadability of butter (for example: Thomson and Van Der Poel, 2000). Similarly, red clover offers the best natural route to increasing levels of the omega-3 fatty acid alpha-linolenic acid in milk (Dewhurst *et al*., 2003a). However, these effects on polyunsaturated fatty acids might also lead to reduced shelf-life (Al-Mabruk *et al*., 2004). To deliver the quantities of CLA that may be beneficial to human health would require very significant increases in their concentrations in animal products, including milk. Nonetheless exploitation of forages as a platform for the production of milks with significantly elevated concentrations of CLAs deserves pursuit – although, realistically, dairy products may never do more than make a partial contribution to the health benefits that may accrue from increased consumption of CLAs by the human population.

Variability in both quantity and quality represents a major problem with forages and one which farmers have avoided by the use of concentrates. This leads to variability in product attributes (e.g., Thomson and Van Der Poel, 2000). Factors such as seasonal patterns, drought and flowering all have large effects on forage characteristics. Again, legumes tend to show less variability in composition over the growing season when grown as pure stands, but they tend to have shorter growing seasons than grass and introduce variability because of the large changes in grass/legume ratios within swards over the growing season. Introducing new feeds into the diet of dairy cows is likely to affect the taste of milk. For example, Bertilsson *et al*. (2001) observed an increased incidence of 'off flavour' in milk when grass silage was replaced with silage made from red or white clover. Consumers may become accustomed to a particular flavour in milk – preferences reflect what consumers are used to – but variability over the season might be more of a problem.

6 Challenges to cow welfare

Welfare is frequently judged against the 'Five Freedoms' that should be open to animals:

- Freedom from hunger and thirst
- Freedom from discomfort
- Freedom from pain, injury and disease
- Freedom to express normal behaviours
- Freedom from fear and distress

It is sometimes suggested that reduced fertility in cows is a welfare issue. It is not; cows do not suffer simply because they are not pregnant. However reduced fertility may be a consequence of other conditions that are challenges to welfare.

As we have already said genetic selection for, predominantly, milk, or milk solids, yield has resulted in rates of increase in milk (energy) secretion that outstrip the rates of increase in food (energy) intake by dairy cattle populations. In the UK situation the scale of this discrepancy in energy balance, as a consequence of genetic selection for productive output, has been estimated as approximately 0.5 MJ ME deficit per day per kg (genetic) increase in milk fat and protein yield (Oldham, 1999). Continuous pursuit of selection goals focussed only, or predominantly, on output will, therefore, predictably lead to increasing energy deficits in cows, leading to reduced condition and impaired welfare.

To counteract these predictable consequences attention is now turning to the development of genetic selection indexes that combine information on multiple traits, taking account of 'welfare relevant' as well as 'productive' traits, in economic indexes.

Coffey *et al*. (2003) have suggested that body energy, or an index of its change, is a suitable candidate for inclusion in future genetic selection indexes. The profile of condition score (CS) change throughout lactation is known to have a genetic component and work is underway to explore optimal ways to incorporate CS profiles into future selection goals (Coffey *et al*., 2003). Reducing rates of loss of condition (or body energy) whilst also maintaining, or even increasing milk (energy) yield is, of course, equivalent to selecting for increased food intake. The extent to which this is achievable with forage-based systems deserves attention through research.

An important consequence of reduced energy status, especially in early lactation, is likely to be increased susceptibility to metabolic disease (there may also be more general implications for immunological status (Sinclair *et al*., 1999)) and hence a challenge to welfare. The impact of reduced, or changing, energy status on endocrine balance also interferes with a number of reproductive processes (Royal *et al*., 2002), underlying the genetic and phenotypic relationships between milk yield and fertility.

The limits to intake imposed by high forage systems makes it likely that these deleterious relationships may become exaggerated. New genetic selection indexes that aim specifically to include selection to ameliorate negative effects on fertility are about to be introduced in the UK. It will be interesting to see if they operate as effectively in high forage systems of management as in more feed intensive systems.

Particularly common, and painful diseases of dairy cattle are those associated with lameness. Lameness is not necessarily associated with milk yield *per* se although some nutritional factors that affect milk yield (eg high intakes of starch and/or protein) can also be associated with increased lameness. There are metabolic and environmental origins of the diseases. In high forage systems it is more likely to be environmental factors that matter, especially during winter housing and where fluid, N-rich excreta accumulate in walkways.

7 Overcoming limitations

Options to overcome limitations that apply in any systems are simple to express in broad terms. They centre on:

- Appropriate choice of animal and plant genotypes
- Appropriate choice of feed resources and the management of feeding
- Appropriate management of the physical environment, including housing
- Appropriate disease management strategies

The key issue, of course, in each case is what is ‘appropriate’?

We can expect future genetic selection of cows to continue to have a strong emphasis on selection for yield, but with greater emphasis on multi-trait selection to moderate, and ideally reverse, negative correlated effects on health, welfare and fertility traits. The presence of some G × E effects might suggest a need for specific attention to be given to the selection of sires whose progeny will be managed in high forage, more extensive systems. Both for enhancing health and welfare, and suitability to more extensive systems attention may return to the use of cross-breeding.

The future development of appropriate forage genotypes should emphasise characteristics that facilitate consistency of supply (including seasonal variation) and effects on product quality (fatty acids, taints and factors affecting shelf-life of milk and dairy products). While we can expect there to be continuing progress in improving intake characteristics and digestibility of forages, it seems likely that the rate of progress will continue to be slow. The opportunities arising out of molecular genetic studies in grasses and legumes give hope that progress towards improving forages to enhance milk qualities may, however, be considerably faster.

Main routes to overcoming disease issues can be expected to centre on improved biosecurity, more automated methods for disease detection and inclusion of disease resistance in genetic selection goals. Automation, especially in the form of wider use of robotics, will steadily influence management and housing structures and routines. The extent to which robotics can be adopted in very extensive systems is a challenge to the imagination.

8 Concluding comments

There seems little reason to think that limits to the capability of cows to secrete milk are close to being realised. There appear to be distinct limits to the ability of forages, alone, to allow potential rates of milk yield per cow to be realised because the characteristics of forages are such that the rate of forage intake limits nutritional support for milk production. In forage-based systems there are therefore potential challenges to cow welfare through the abilities of cows' abilities to maintain a satisfactory energy balance. Adopting approaches that enable systems to develop that keep animal characteristics and system characteristics in beneficial balance is the key to sustainability. The likely polarisation of the industry in the future may well mean that the uniformity in approach to dairy production of the last few decades will change significantly.

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Effects of grass-based diets on the content of micronutrients and fatty acids in bovine and caprine dairy products

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Abstract

This paper presents recent results from studies to verify whether it is possible to modify, in bovine and caprine dairy products, the content of components which are of nutritional interest to consumers, by changing the composition of the animal diet. The main components described were the minor and major fatty acids (including C18:1 and C18:2 isomers), lipophilic micronutrients (carotenoids, vitamins A and E) and the global antioxidant status. For bovine milk and cheese, diets rich in concentrate or maize silage, when compared to grass-based diets, especially pasture, led to a lower content in carotenoids and vitamin E and an impaired antioxidant status. Milk from pasture was also richer in oleic and conjugated linoleic acids (CLA) than milk from concentrate or maize silage diets. However, the influence of the pasture seems to be variable depending on the developmental stage or the botanical composition of the grass. These experimental results were confirmed by analyses of bulk milk or cheeses originating from different geographic areas where diets vary. For caprine milk or cheese, the response of milk fatty acids composition to diet is similar to that of cows at least for major fatty acids including CLA, and several interactions between effects of forage (corn silage, alfalfa or ryegrass hay, fresh grass) and of lipid supplements (linseed oil or high-oleic sunflower oil) on major and minor fatty acids, including *trans* 18:1 and 18:2 isomers were observed. Furthermore, grazing goats, when compared to goats kept indoors and fed hay, showed a higher content of unsaturated fatty acids, CLA, vitamin A and a better antioxidant status. In conclusion, varying diet composition allows the content of micronutrients and fatty acids in dairy products to change rapidly and efficiently.

Keywords: dairy products, fatty acids, vitamins A and E, forages, cow, goat

1 Introduction

The role of plant products in the health of consumers has been well established by epidemiological approaches (Steinmetz and Potter, 1996; Ness and Powless, 1997) but the role of animal products, in particular dairy products, has yet to be fully studied. Dairy products are rich in saturated fatty acids, some hydrocarbons and salt (in most cheeses) which are considered as risk factors for cardiovascular diseases in humans (Grant, 1998) if ingested in excess. Nevertheless, dairy products are also well known for providing high value proteins, vitamins (A, B group, K) and minerals such as calcium, phosphorus, magnesium, zinc and copper (Debry, 2001). Dairy product fatty acids are mainly saturated but they also consist of about 1/3 unsaturated fatty acids which may not only reduce the cholesterol content in blood, but in some cases even have anticarcinogenic effects and assist in developing protection against cardiovascular diseases (Jensen, 2002). In particular, isomers of conjugated linoleic acid (CLA) have an anticarcinogenic effect in rats and mice and perhaps in humans. The latter still has to be demonstrated (Parodi, 2001). Linoleic (C18:2 n-6) and linolenic acids (C18:3 n-3) are even known as 'essential fatty acids' which cannot be synthesised by man and animals and it would be of interest to increase the n-3 fatty acids in human nutrition.

Data concerning the content of micronutrients in dairy products are still incomplete. Literature is available on the variability of the composition of milk fatty acids as influenced by the animal's diet, in particular with respect to fatty acids that may have a potential positive or negative effect on human health (Chilliard *et al*., 2000, 2001). In contrast, only few data are available for micronutrients. Early results (Thomson *et al*., 1964) show that the fat-soluble micronutrient fraction of dairy products, in particular carotenoids and vitamin A and E, may vary to a large extent according to the diet. So, as a means of modifying content of some micronutrients and fatty acids in dairy products, dietary factors seem to be very effective, easy to use and allow the desired effect to be achieved rapidly. In addition, the animal's diet is increasingly considered by the consumer as an important criterion to judge animal product quality. In particular, grass-based diets benefit from a positive image that it is important to be objectively confirmed and quantified.

This paper presents recent results from studies to verify whether it is possible to modify, by the diet given to animals, the content of components of bovine and caprine dairy products which are of potential nutritional interest to consumers. The focus will be put on unsaturated C18 fatty acids (including C18:1 and C18:2 isomers), on fat soluble micronutrients (carotenoids, vitamins A and E) and on the global antioxidant status.

2 Fatty Acids

2.1 Origin in milk

In this review, particular emphasis is placed on conjugated linoleic acids (CLA) in milk of cows and goats. CLA refers to various positional and geometric isomers of linoleic acid, each with a conjugated double-bond arrangement. The *cis*-9, *trans*-11 CLA (rumenic acid, RA) is the major isomer found in ruminant milk (80-90 %) (Bauman *et al*., 2001). The precursors of CLA are polyunsaturated FA (PUFA) present in ruminant diets, mainly linoleic (LA) and α-linolenic (LNA) acids. LNA is found primarily in green forages (and in linseed), whereas LA predominates in corn silage, cereals and several oilseeds. The extent of ruminal biohydrogenation of LNA and LA is on average 90 and 80 %, respectively (Chilliard *et al*., 2001). LA content of milk fat ranges between 2 and 3 % with most diets without lipid supplements and LNA to less than 1 % when cows graze pasture (Chilliard *et al*., 2001). RA is an intermediate in the rumen hydrogenation of linoleic acid, whereas *trans*-11 C18:1 (*trans*-vaccenic acid, TVA) is a common intermediate in the biohydrogenation of both LA and LNA. The final step of the hydrogenation of polyunsaturated FA produces stearic acid. Milk RA originates either from the intestinal absorption and transfer to the mammary gland of RA produced in the rumen, or primarily from the enzymatic delta-9 desaturation of TVA by mammary cells (more than 2/3 of total milk RA, according to Griinari *et al*., 2000).

2.2 Effect of dietary factors in cows

Dietary factors that increase milk RA are: i) the supply of lipid substrates rich in LA or LNA; ii) factors that change the rumen environment and inhibit hydrogenation of TVA into 18:0; and iii) the interactions between these factors (Bauman *et al*., 2001).

2.3 Forages

Pasture has been associated with high conjugated diene content in milk for decades (Kuzdzal-Savoie and Kuzdzal, 1961). Elevated values of CLA have been reported in response to grazing (0.5-1.7 % of total fatty acids vs 0.3-0.5 % for winter diets) however, large variation in the response can be observed due to seasonal changes in grass availability or maturity, to its fibre, lipid and LNA percentages and to other unknown factors (Chilliard *et al*., 2002). The CLA concentration in milk fat increased linearly up to 2.2 % as the amount of pasture was increased in the diet (33 to 100 % of DMI) (Dhiman *et al*., 1999), whereas a low grass DM allowance (Stanton *et al*., 1997) decreased milk CLA levels to 0.5 %. We recently conducted a study comparing a concentrate-rich diet (65 % concentrates / 35 % hay) with 6 diets rich either in corn silage (87 %), ryegrass silage (86 %), ryegrass hay (90 %), natural grassland hay (87 %) or pasture (100 %) of either young or aged mountain natural grassland (Ferlay *et al*., 2002a). The highest value of RA was observed when cows grazed young grass and the lowest with the concentrate-rich diet (Figure 1). The diets based on corn silage, hay, ryegrass silage and aged grass were intermediate. This suggests that pasture does not always increase milk RA compared to hay, but only when the grass is young enough, i.e., when rich in FA and LNA content (Bauchart *et al*., 1984).

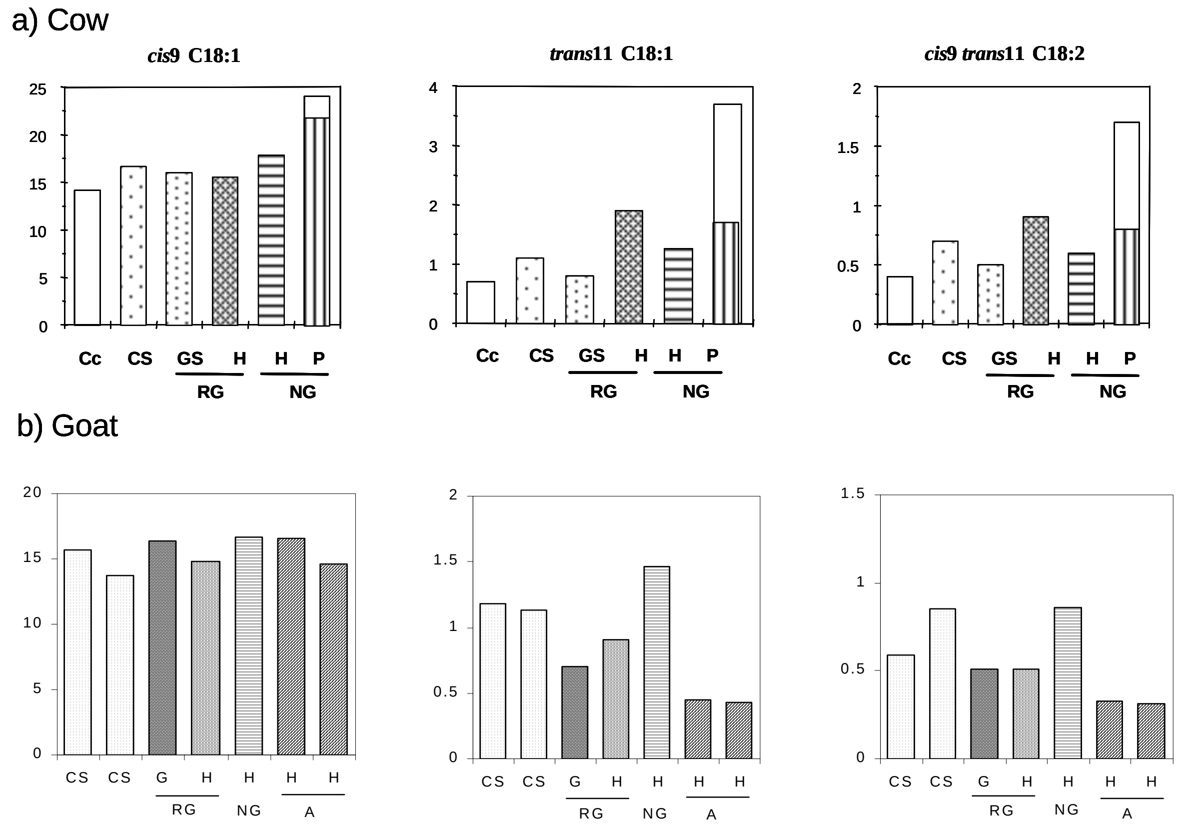

Figure 1. Effects of the type of forage on the percentage of oleic, *trans* vaccenic and rumenic acids in cow (a, Ferlay *et al*., 2002) or goat (b, Chilliard *et al*., 2002a; Rouel *et al*., 2003; Bernard *et al*., unpublished data) milk fat. Abbreviations used: A, alfalfa; Cc, concentrate-based diet; CS, corn silage; G, green grass indoor; GS, grass silage; H, hay; NG, natural grassland; P, pasture at 3 or 6 weeks; RG, ryegrass.

Botanical composition is another important factor, as suggested by the high value of CLA in milk from highlands (2.4 %) compared with lowlands (0.9 %) (Collomb *et al*., 2001). In cheeses, the same trend was reported by Lucas *et al*. (2003) (1.1 and 1.6 respectively in cheeses from lowland and highland pasture). Similarly, milk CLA content was higher with diets containing silage of semi-natural grasslands than with those containing silage of monoculture grasslands (ryegrass) (Fievez *et al*., 2002) (0.5 and 0.3 %, respectively). CLA and TVA were slightly higher when cows consumed diploid perennial ryegrass compared to a tetraploid perennial ryegrass or tall fescue; grass species or cultivars had a minor effect on milk CLA concentration (Delagarde and Peyraud, 2002).

The effect of pasture and its botanical composition observed under experimental conditions has been recently confirmed in bulk milk collected over one year in dairy factories located in the mountain area of Massif Central (France). In that trial, RA content of bulk milk varied from 0.3 % to 2.0 %. It was 0.4 and 1.0 % on average in winter (cows fed conserved forages) and in summer (cows grazing part-time), respectively. During summer, a positive correlation between RA and the proportions estimated by surveys of pastured grass (r = 0.61, $P < 0.001$) or permanent grassland (r = 0.75, $P < 0.001$) in the forages was found (Martin *et al.*, unpublished data).

The cheese-making process seems to modify the milk fatty acid composition only to a very small extent: Ferlay *et al.* (2002b) showed that neither the pasteurization nor the type of cheese (Cantal or Saint-Nectaire) modified the proportion of RA, LA or LNA in cheese fat. For the pressed cheeses produced in this trial, RA depended only on the cows' diet, which modified the RA content of milk in agreement with Zeppa *et al.* (2003).

2.4 Supplementation of diet with lipids and interactions with forages

The most efficient way to increase CLA is to supplement the diet with lipids. The addition of plant oils rich in PUFA (LA or LNA) to dairy cows' diets increases the total CLA and RA content of milk. As reviewed by Chilliard *et al.* (2000), the response to soybean oil is linear up to at least a level of 4 % of oil in the diet (up to 2.0 % of CLA in total milk FA). Free oils are more effective than crude whole oilseeds, whereas extruded, micronized or heat-treated oilseeds have an intermediate effect (Chouinard *et al.*, 2001). It is likely that the gradual release of PUFA from oilseeds, compared with free oils, results in a greater hydrogenation of TVA, thus yielding more 18:0 and less TVA available for absorption in the intestine (Chilliard *et al.*, 2003a). We studied recently the kinetics of appearance of *trans*10-, *trans*11-18:1, and RA in milk after addition of linseed or sunflower oil (5 % of DMI) into diets based on either grass hay or corn silage for 3 weeks. The kinetics of *trans*11-18:1 and RA percentages was curvilinear for the 2 oils from the first week, whereas *trans*10-18:1 increased firstly very slightly and then strongly from the third week. The kinetics of response of each FA depended on interactions between nature of forage and oil supplementation. Nevertheless, after 3 weeks of supplementation, *trans*10-, *trans*11-18:1 and *cis*9,*trans*11-18:2 percentages did not differ between the two oils within a given forage (Chilliard *et al*, 2003c, Ferlay *et al.*, 2003a). In other respects, lipid supplementation (5 % of linseed or 5 % of sunflower oil) had a noticeable influence on raw milk flavour for 55 and 62 % of the panelists, respectively (Dubroeucq *et al.*, 2002).

2.5 Effect of dietary factors in goats

Although the regulation of lactose and lipid metabolism differs between dairy cows and goats (Chilliard *et al.*, 2003a,b), the proportions of the different *trans*18:1 isomers and CLA in milk fat are similar in caprine (LeDoux *et al.*, 2002) and bovine species (Precht and Molkentin, 1997). However, the effects of dietary factors are not always the same. For example, fat CLA in goat milk was similar between winter diets and summer at pasture (Jahreis *et al.*, 1999). In other respects, CLA varied between 0.4 and 0.9 % of total FA in animals receiving conventional winter diets (Alonso *et al.*, 1999) and up to 4 % in goats receiving lipid-supplemented diets (Chilliard *et al.*, 2003a). A comparison of 5 different forages (Figure 1) showed minor effects on milk fatty acids: oleic acid percentage was stable, whereas the highest levels of TVA and RA were observed with either corn silage or natural grassland hay, and the lowest with alfalfa hay. Corn silage increased the level of *trans*-10-18:1. Green ryegrass fed to animals indoors gave results within the range of the conserved forages (Figure 1). We investigated recently the interaction between the type of forage (alfalfa hay vs. corn silage vs. fresh ryegrass or hay) and dietary fat supplements (linseed oil vs. high oleic sunflower oil, at 5-6 % of diet DM) (Chilliard *et al*., 2003a,b; Ferlay *et al*., 2003b; Rouel *et al*., 2003). Addition of linseed oil increased sharply C18:0, RA and LNA percentages and addition of high oleic sunflower oil increased sharply C18:0 and oleic acid, and slightly RA percentages. Both supplementations decreased C12:0-C16:0, and thus also reduced the theoretical atherogenicity index (C12:0 + 4 x C14:0 + C16:0 / sum of unsaturated FA) of milk fat. The main findings concerning RA synthesis are: i) there were significant interaction effects between oil and forage type, with lower responses to both oils when the forage was corn silage, probably because the *trans*10-18:1 pathway increased at the expense of the *trans*11 pathway in the rumen; ii) dietary LNA is efficient to increase TVA and RA secretion; iii) the association of linseed oil to either alfalfa or ryegrass hay, or green ryegrass, increased RA percentage up to 3.2-3.8 % of milk total FA, i.e., within the range of the highest values found in dairy cows (Chilliard *et al*., 2000, 2001). In other respects, the supplementation with linseed oil increased sharply several other *trans* isomers of 18:1 or 18:2, and the putative positive or negative effects of these FA on human health remain to be evaluated. Furthermore, concerning cheese making, lipid supplementation induced more intense flavour and higher melting textures (linked to the higher fat in dry matter) of 5 types of cheese. Only minor defects such as fish flavour were noticed sometimes for the alfalfa hay diet supplemented with linseed oil (Gaborit *et al*., 2004).

3 Cholesterol

The cholesterol content of dairy fat varies from 0.3 to 0.6 g 100 g^{-1} fat (Jensen, 2002). The increase in cholesterol level in human blood due to consumption of dairy products is only marginal (Debry *et al*., 2001). In ruminants, the cholesterol appears to originate from two main sources: 1) up-take by the mammary gland from plasma lipoproteins containing exogenous (dietary) or endogenously synthesized cholesterol (from the liver and small intestine); 2) *de novo* synthesis within the mammary gland. Its content in dairy products varies according to the stage of lactation (Di Trana *et al*., 2001) and feeding treatments (Storry, 1988).

The cholesterol content of dairy products is inversely correlated to the energy balance of the diet. The type of forage does not directly influence the cholesterol content of dairy products, though variations are sometimes attributed to diets (Table 1, Marisco *et al.,* 1993, Di Trana *et al.,* 2001) when diets are not isoenergetic.

4 Vitamin A (Retinol) and Carotenoids

4.1 Origin in dairy products

Vitamin A is an essential fat-soluble vitamin involved in multiple critical biological functions such as embryonic development, growth, vision and regulation of gene expression. Because most mammals cannot carry out its synthesis de novo, vitamin A has to be provided in the diet. In human nutrition, vitamin A is provided directly in animal products (such as cod liver oil, animal liver, meat, milk and eggs), whereas plant products (such as carrots, spinach, fruits, vegetable oils and other vegetable) provide pro-vitamin A (i.e., carotenoids, like α-, β-carotene and β-cryptoxanthin) which may be, after specific cleavage in the intestine and liver, transformed to retinal (Sauvant *et al*., 2002). Dairy products represent an interesting source of vitamin A for the adult consumer and the main source for the new-born (Debry, 2001). In cows and goats, vitamin A comes principally from the conversion of forage carotenoids into vitamin A. Carotenoids are essential pigments of plants. Their primary function is to protect the plant against photo-oxidation and to contribute together with chlorophylls to the capture of light energy. They have been shown to contribute to antioxidant activities through quenching of activated species of oxygen ($^1O_2$) and scavenging of free radicals. Cattle differ from most farm animals in that they have a significant concentration of circulating β-carotene in their blood. The β-carotene in milk comes from blood after the uptake by the mammary gland and results in yellow coloration of both body fat and milk. This may affect consumer acceptance of the product and could facilitate the traceability of animal products coming from grass-based diets (Prache *et al*., 2002).

Table 1. Effects of the type of forage on the content of cholesterol, of vitamin A (retinol) and E (tocopherol) and on the degree of antioxidant protection in goat milk and cheese (From Pizzoferrato *et al*., 2000; Fedele *et al*., 2001). Abbreviations used: a.u., arbitrary unit; D.A.P., degree of antioxidant protection; G, grazing goats; G-high, G-low, grazing goats supplemented with 900 g d^{-1} (high) or 600 g d^{-1} concentrate (low); GRD-GRND, grazing goats supplemented with 600g d^{-1} of rapidly or less rapidly degradable concentrate; H, housed goats (hay + 600g d^{-1} concentrate).

‘Cheese Trial’				
Diets	H	G	G-low	G-High
Cholesterol (mg 100 g^{-1} DM)	145^{ab}	128^{c}	137^{ac}	152^{b}
Retinol (*cis*+*trans*) (μg 100 g^{-1} DM)	40^{c}	394^{a}	334^{a}	211^{b}
Tocopherol (μg 100 g^{-1} DM)	970^{b}	1174^{a}	1148^{a}	851^{b}
D.A.P., 10^{-3} a.u.	5.3	7.6	8.3	5.7
‘Milk Trial’				
Diets	H	G	GRD	GNRD
Cholesterol (mg 100 g^{-1} DM)	110^{a}	106^{a}	92^{b}	101^{ab}
Retinol (*cis*+*trans*) (μg 100 g^{-1} DM)	469^{b}	513^{ab}	476^{ab}	562^{a}
Tocopherol (μg 100 g^{-1} DM)	645^{b}	941^{a}	811^{a}	932^{a}
D.A.P., 10-3 a.u.	0.84	0.79	0.82	0.58

4.2 Control by feeding in cow dairy products

A high β-carotene content of milk has been associated with pasture for decades (Thomson *et al*., 1964). β-carotene in milk depends directly on β-carotene content of forages. It is only found in grass and is degraded during grass drying and preservation proportionally to the degree of light exposure, as β-carotene in highly UV-sensitive (Park *et al*., 1983). This explains why grass silage contains more β-carotene than hay (Coulon and Priolo, 2002). In a recent trial where seven diets were compared (a concentrate-rich diet, corn silage, ryegrass silage, ryegrass hay, natural grassland hay and pasture grass of either young or aged mountain natural grassland), we analysed a xanthophyll, lutein and β-carotene in milk. On average, their concentrations were 0.011, 0.027 and 0.127 mg L^{-1}, respectively (Martin *et al*., 2002). Significant differences were observed between the diets in particular for β-carotene, being higher in milk from pasture (especially with young sward) and ryegrass silage (Table 2).

For the hay-based diets, the concentration in milk was lower for natural grassland than for ryegrass hay. We confirmed that β-carotene in milk was directly related to β-carotene in blood and to the amount of β-carotene ingested by cows. Nevertheless, for the corn silage diet in which β-carotene concentration was zero, we found a small amount in blood and milk, suggesting that the release of reserves from adipose from previous diets offered to these cows was involved. Vitamin A content in milk varied according to diet (higher concentration when cows grazed a young sward or when they were fed ryegrass silage), although the blood level was unaffected because of the animal's metabolic regulation.

Table 2. Effects of the type of forages on the content in cow milk of carotenoids, vitamin A and E and antioxidant status (From Martin *et al*., 2002). Abbreviations used: Cc, concentrate-based diet (65 % concentrate / 35 % hay); CS, corn silage (87 %); NGH, natural grassland hay (87 %); P3 – P6, pasture at 3 or 6 weeks (100 %); RGH, ryegrass hay (90 %); GS, ryegrass silage (86 %).

Diets	Cc	MS	RGS	RGH	NGH	P3	P6
Lutein (mg L^{-1})	0.026^{a}	0.024^{a}	0.027^{a}	0.03^{ab}	0.024^{a}	0.032^{b}	0.027^{a}
xanthophylls (mg L^{-1})	0.022	0.016	0.008	0.009	0.007	/	0.009
β-carotene, (mg L^{-1})	0.12^{c}	0.10^{cd}	0.17^{ab}	0.13^{c}	0.09^{d}	0.19^{a}	0.16^{b}
Vitamin A (mg L^{-1})	0.16^{ab}	0.11^{b}	0.18^{ab}	0.17^{ab}	0.12^{b}	0.20^{a}	0.14^{ab}
Vitamin E (mg L^{-1})	0.46^{a}	0.48^{a}	0.62^{b}	0.47^{a}	0.47^{a}	0.63^{b}	0.62^{b}
Antioxidant status (mmol L^{-1})	1.19^{a}	1.28^{a}	1.56^{ab}	1.48^{ab}	1.23^{a}	/	1.75^{b}

In a bulk milk trial where samples were collected over one year from different dairies in the Massif Central area (Martin *et al*., unpublished data), we confirmed the higher β-carotene content of milk from cows fed pasture grass or, during winter, with grass-silage based diets. In contrast we didn't observe any influence of the season or the type of forage on milk vitamin A content. This probably can be explained by the practice of feeding vitamin A supplementation, which masks the influence of different vitamin A contents in forage, observed under experimental conditions. In cheeses, even when milk is pasteurized, β-carotene is transferred with minimal losses through the whey as cheese β-carotene content is about 11 times higher in cheese than in milk and there is a very close linear relationship between β-carotene in milk and in cheese (r = 0.97). In contrast, surprisingly we observed that an important part of the milk vitamin A seems to be lost in whey during cheese-making as the concentration in cheese is only 5-6 times higher than in milk.

4.3 Control by feeding in goat dairy products

In goat's milk, in contrast to cow's milk, only vitamin A and no β-carotene is found. This explains why bovine dairy products are more yellow than caprine (and ovine) dairy products. The concentration of vitamin A in goat milk and cheese is about 2 times higher than in cow milk and cheese. According to the feeding systems, the cheese retinol content (*cis* + *trans* retinol), decreased when herbage intake decreased, until a very low value was reached in the housed system, where no herbage was used at all (Table 1). The effect of the feeding systems is similar in milk and cheese.

5 Vitamin E (Tocopherols) and Antioxidant Status

5.1 Origin and role in dairy products

Vitamin E is the principal fat-soluble antioxidant in the body and is found in lipoproteins, especially low density lipoproteins (LDL and VLDL). It enhances the cell's protection against free radicals' attack. Vitamin E content of feed is diverse and fresh herbage, especially if young, is generally richer (about 90 % more) than conserved herbage. Dairy products provide only a marginal part of the vitamin E required in human nutrition (Debry, 2001) but vitamin E is important in protecting dairy compounds from oxidation. In milk, vitamin E is inversely correlated with oxidized flavours (Schingoethe *et al*., 1978). The global antioxidant status corresponds to a global functional analysis of the fatty acid's susceptibility to oxidation. It depends on the fatty acid's composition (PUFA are more easily oxidized) and on the antioxidant content in milk.

5.2 *Control by feeding in cow dairy products*

As with vitamin A and β-carotene, we found recently that the vitamin E content was higher in milk from cows fed pasture or ryegrass silage than in milk from cows fed either a concentrate-rich diet, corn silage, ryegrass hay, or natural grassland hay (Martin *et al*., 2002) (Table 2). In that trial, the vitamin E concentration in milk was related to its concentration in blood ($r = 0.60$). These results are consistent with early studies which showed that the content of vitamin E in milk was higher in summer when cows graze pastures and lower in winter when cows are fed dry forages (Krukovski *et al*., 1950; Thompson *et al*., 1964; Kanno *et al*., 1968). At a larger scale, bulk milk of pasture origin is also richer in vitamin E than milk produced from winter diets (0.82 vs. 0.63 mg L^{-1}). The same trend was observed in Abondance cheese by Lucas *et al*. (2003) who also found a higher vitamin E content in highland cheeses than in lowland cheeses (7.9 and 6.0 g kg^{-1}, respectively) during the grazing season. The latter difference could be due to the botanical composition of the grass or to its vegetative stage. In cheeses, neither pasteurization nor cheese variety seems to have an effect on vitamin E content which is closely related to content in milk ($r = 0.82$) and is on average about 10 times higher, which indicates that the loss of vitamin E through the whey is small (Martin *et al*., unpublished data).

The global antioxidant status of milk from different diets revealed higher antioxidant protection in milk from pasture although its PUFA content was higher (Table 2). This result is only partly explained by the higher content of vitamin E.

5.3 *Control by feeding in goat dairy products*

In goat dairy products, the herbage appears also to be a strategic feed for the enrichment of milk and cheeses in vitamin E. Milk and cheeses from grazing goats not supplemented or supplemented with low amounts of concentrate showed higher tocopherol contents than milk and cheeses from goats either fed hay and concentrates or grazing but supplemented with high amounts of concentrate (Table 1). In the latter treatment, the highest concentrate supplementation decreased herbage intake by about 30 %. In fact, a positive correlation between milk tocopherol content and herbage intake of goats was confirmed.

The antioxidant protection exerted by tocopherol on cholesterol, calculated for cheese and milk according to Pizzoferrato *et al*. (2000) shows that cholesterol in cheese and milk from grazing goats has a higher antioxidant protection than in milk and cheese from housed goats (Table 1).

6 Conclusions

Feeding studies in cows and goats indicate that milk FA which have a potential positive role on human health, as well as carotenoids and vitamins A and E, can be enhanced generally, cheaply and rapidly by several feeding factors. In comparison to concentrate or corn-silage diets, large increases in desired milk FA and in milk vitamin A and E were observed with diets rich in grass, in particular when young. In addition, several observations indicate that a higher botanical diversity in pasture is associated with higher concentrations of desired FA and micronutrients in milk and cheeses. The latter results are also very interesting but further studies are needed to separate fully the respective influences of botanical composition and stage of development of the grass. The most efficient way to change the FA composition of dairy products is to add oilseeds rich in PUFA in the ruminant diets. Hence, the progress in the knowledge of the effects of these different diets on milk FA composition could be used to develop new feeding strategies for dairy cows in order to increase the nutritional value of milk fat. Nevertheless, in other respects, milk or dairy products resulting from the addition of PUFA to the diet (from other sources than fresh grass) could be more sensitive to oxidation. Further studies are needed to determine if antioxidants (e.g., vitamin E) and / or other micronutrients could interact with PUFA metabolism, in order to better control the potential effects of these feeding strategies on the organoleptic quality of dairy products.

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New realisations for the estimation of the ensiling potential of forages

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Abstract

The estimation of the ensiling potential of forages is based on the dry matter (DM) content and the ratio of water-soluble carbohydrates and buffering capacity (WSC / BC). New results have led to the realisation that the ensiling potential cannot be sufficiently characterised by DM and WSC / BC only. When green forage with a low/without nitrate content was ensiled, many silages contained butyric acid (BA), although DM and WSC / BC of green forage indicated to expect a BA-free silage. The aim of this work is to determine the threshold values of ensiling potential depending on nitrate content. In two experiments with *Dactylis glomerata*, a variation of nitrate content, DM and WSC / BC was tested with both a low and increased clostridia spore contamination (295 experiment cells, each kept in replicates). A new concept was developed, which allowed a reliable prediction of the risk of butyric acid in silages. In addition to the DM content and ratio of WSC /BC, the nitrate content in connection with clostridia spore content of ensiled material has to be considered as well. If the nitrate content is low, wilting is only sufficient in combination with strategic application of silage additives.

Keywords: Ensiling potential, ensilage, silage, nitrate, clostridia spores

Introduction

The present model of Weißbach *et al*. (1974) is the basis for the estimation of the ensiling potential of forages. The equation DM $_{min.}$ [g kg^{-1}] = 450-80 WSC / BC, indicated in the ‘threshold values of ensiling potential’, describes the value combination of DM content and ratio WSC / BC, which is required in green forage to produce a butyric acid (BA)-free silage.
However, new results proved that the ensiling potential of forages cannot be sufficiently characterised by DM content and the WSC / BC ratio only. When herbage with a low nitrate content or without nitrate was ensiled, many silages contained BA, although the DM content and the WSC / BC ratio indicated to expect BA-free silages (Weiß, 2000).
The aim of this work is to determine the necessary threshold conditions in green forage for DM, WSC / BC ratio and nitrate content that is required to produce a BA-free silage by applying the current level of knowledge about the fermentation process. The content of clostridia spores in green forage is considered as well. The fermentability coefficient (FC) (Schmidt *et al*., 1971) is used to estimate the ensiling potential: FC = DM (%) + 8 WSC / BC.

Materials and methods

The fermentation process in *Dactylis glomerata*, first growth (E 1) and third growth (E 2), was investigated under laboratory conditions (Polip Iv, 2001) in order to determine the threshold values of ensiling potential. In each case a variation of nitrate content (0.4-13.3 g NO_3 kg^{-1} DM) with a variation of DM content (135-394 g kg^{-1} in E 1; 208-406 g kg^{-1} in E 2) and WSC / BC ratio (1.9-3.1 in E 1; 1.6-2.3 in E 2) was combined in order to produce both BA-free silages and silages with BA. Each value combination of ensiling material was tested with a low clostridial spore content (cleanly harvested) and with increased clostridial spore contamination (by addition of clostridia spores). The lowest number in each class value represents the parameters of the natural green fodder. The variations of WSC / BC ratio were obtained by additions of glucose and those of nitrate content by adding potassium nitrate

(KNO_3). The contamination degree with clostridia spores in the block with low content was approx. 0.2 x 10^2 spores g^{-1} fresh matter (FM) and in the block with increased (high) content approx. 10^3 (E 1) and 10^4 (E 2) spores g^{-1} FM. The silages were examined after 180 days of storage (const. 25 °C). Experiment E 1 consisted of 156 experiment cells and experiment E 2 contained 139 experiment cells, each kept in replicates. The silages were analysed for pH-value, the lactic acid contents (HPLC), volatile fatty acids (GC), alcohol (sum ethanol + propanol) (GC), ammonia (Conway), water-soluble carbohydrates (method with Anthron) and clostridia spores (most probable number, MPN).

Results and discussion

As a first step, the minimum nitrate content (MNC) in green forage was determined by the mean of a graphic analysis procedure for each examined combination of DM content as well as a WSC / BC-ratio producing a BA-free silage (procedure see by Polip Iv, 2001). The values of MNC were applied in a function of FC-value for low clostridia spore content and for high clostridia spore content of green forage (Table 1).

Table 1. Minimum nitrate content (MNC) in green forage for producing a BA-free silage, depending on FC value and on contamination of the green forage with spores of clostridia.

FC	MNC (g NO_3 kg $^{-1}$ DM) for green forage	
	content of clostridia spores:	
	Low	*High*
32	5.8	5.8
35	5.3	5.8
40	4.4	5.3
45	3.5	4.9
50	3.1	4.4
55	2.2	3.5
60	1.3	3.1

Within the examined FC-range of 32-60, it was possible to calculate the required MNC for each DM content, WSC / BC-ratio and clostridia spore content. On the basis of these data, the minimum DM content (DM_{min}) of green forage was determined, which is necessary to produce an anaerobic stable silage as a function of the nitrate content and WSC / BC-ratio in forages (Figure 1). The threshold value line constructed for 4 g NO_3 kg^{-1} DM (Figure 1)

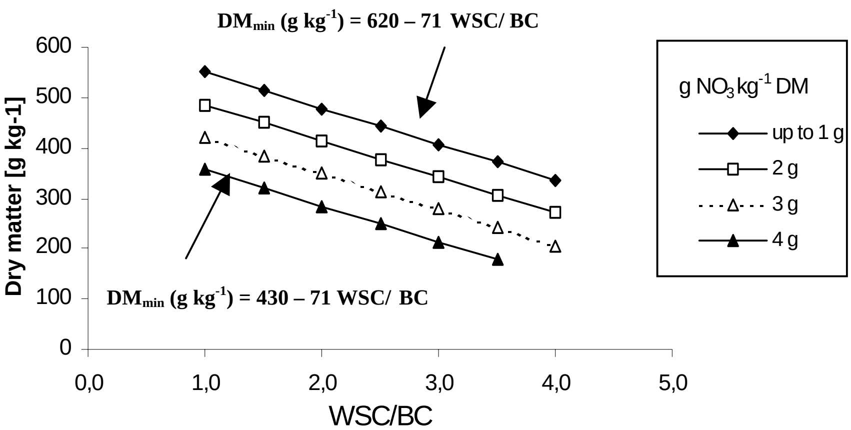

Figure 1. Minimum dry matter content (DM_{min}) depending on WSC / BC ratio and nitrate content in green forage, low in clostridia spore.

almost agrees with the threshold value line of Weißbach *et al*. (1974), which is derived from different fodder plants. Ensiling material with lower nitrate content requires a higher DM_{min}. Ensiling material with higher clostridia spore contamination and low nitrate content requires an even higher DM_{min} (without figure). Each of the 4 equations for DM_{min}, both for low and high clostridial spores, were integrated into one term (Table 2). The threshold values for ensiling potential were applied to data from other experiments with *Dactylis glomerata* and *Festuca species* low in nitrate (Figure 2). These experiments were carried out with green forage produced under practical farming conditions.

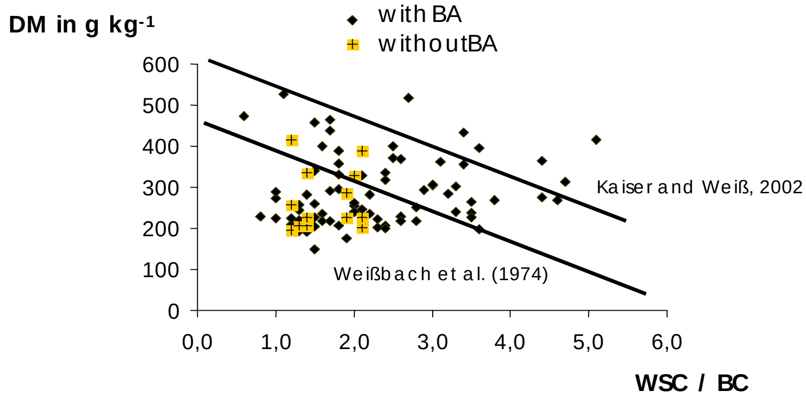

Figure 2. Silages with and without butyric acid (BA) made from green forage with nitrate content < 0,5 g NO_3 kg^{-1} DM, depending on DM content, WSC / BC ratio and nitrate content; N = 90.

Conclusions

In the new model for the estimation of the ensiling potential of forages (Table 2), the nitrate content in connection with clostridia spore content of material at ensiling has to be considered, in addition to the DM content and WSC / BC-ratio. In favour of the decision about ensiling technological measures of securing fermentation quality it is advisable to evaluate the parameters DM, WSC / BC, nitrate and clostridia spore content separately. For the most ensilable material in practice (WSC / BC ≤ 1.0 to 3.0; nitrate content < 2 g NO_3 kg^{-1} DM) the minimum dry matter content for producing a BA-free silage is equal to or higher than the technological maximum DM content of 450 g kg^{-1}. Good fermentation quality in such silages cannot be secured by wilting only. Therefore, the strategic use of silage additives should be considered under practical conditions. In ensiling material with a DM range under 300 to 350 g kg^{-1}, chemical silage additives (with nitrite) should be used. In green forage with a higher DM content, the biological silage additives are recommended.

Table 2. Model for the estimation of the ensiling potential of forages.

Content of nitrate ($g\ NO_3\ kg^{-1}$ DM)	Threshold values of ensiling potential for producing butyric acid- free silages	
< 4.4	DM_{min} depends on:	DM_{min} = 680-64 NO_3*-71 WSC./ BC
	• WSC / BC	(*low in clostridia spores*)
low in nitrate /	• Nitrate content	DM_{min} = 1000-113 NO_3*-130 WSC/ BC
without nitrate	• Clostridia spore content	(*high in clostridia spores*)
4.4-13	DM_{min} depends on:	
with nitrate	• WSC/ BC	DM_{min} = 450-80 WSC/ BC

* NO_3 in g kg^{-1} DM

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Vitamin content of forages as influenced by harvest and ensiling techniques

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Abstract

The use of synthetic vitamins to organically raise ruminants has been forbidden since the year 2000, due to EU regulations. The objective of this trial was, therefore, to study the effects of ensiling, storage type, and silage additive on concentrations of vitamin E and beta-carotene in forages. The trial was conducted on seven organic dairy farms, of which two farms used bunker silos, two farms ensiled in round bales and three farms had tower silos. Within each storage type, one farm used acidic additive and one used inoculants. The farmers also ensiled some herbage without adding additives. Concentrations of vitamin E and beta-carotene in fresh herbage can be preserved during harvest and ensiling if conditions are good. There may be a greater risk of vitamin E loss in round-baled silage than in silage stored in silos. Average silage vitamin E content of 36 (s.d. 24) mg alpha-tocopherol per kg of dry matter (DM) in this study is considerably lower than the Swedish tabulated value of 115 mg alfa-tocopherol kg^{-1} DM. Also, the beta-carotene concentration only was 22 (s.d. 20) mg kg^{-1} DM in this study. Consequently, it is imperative to investigate whether dairy cows can maintain their production and health when no synthetic vitamins are added to their diets.

Keywords: vitamin, forage, ensiling, silage additive

Introduction

The use of synthetic vitamins to organically raise ruminants has been forbidden since the year 2000, due to EU regulations. Consequently, it is important to investigate the vitamin contents of forages that constitute a major portion of diets fed to ruminants in organic farming. Vitamins A and E are of great importance for ruminants (Weiss, 1998). Vitamin A occurs as carotenes in plants, of which beta-carotene dominates. Shortage of vitamin A can depress the immune system and the sight and cause reproductive disturbances. There are eight naturally occurring vitamin E active tocopherols of which alpha-tocopherol has the highest biological activity. Shortage of vitamin E can cause a depressed immune system, muscle degeneration and reproductive disturbances. Vitamin E is an antioxidant and it prevents oxidation of unsaturated fatty acids that cause odour and bad flavour of milk (Jensen, 2000). The objectives of this study were to study the effects of harvest and ensiling in different storage systems (bunker, tower, round bale) on the contents of beta-carotene and vitamin E in forages. In addition, effects of storage time and silage additive on silage vitamin contents were determined.

Materials and methods

Seven organic dairy farms in south-western Sweden were used in the trial that included both first and second harvest of forages in the summer of 2001. Two farms had bunker silos, two farms used round bales and three farms had tower silos. One of the two farms that had bunker silos or round bales used an acidic additive whereas the other farm used inoculants as a silage additive. Also, part of the herbage on each farm was ensiled without any additive. One of the three farms that had tower silos, used an acidic silage additive whereas the other two farms used inoculants. One of the two farms that used inoculants ensiled forage from the first harvest with an additive whereas forage from the second harvest was ensiled without any additive. Standing forage before being cut and cut forage wilted in windrows before ensiling were sampled for vitamin analysis. Forage botanical composition and stage of maturity were determined. Silages were sampled for vitamin contents three times during the feed-out period (in the beginning, in the middle and at the end) of each harvest. In total, forty samples of fresh herbage and sixty silage samples were analysed for vitamin contents after freeze drying. Chemical composition of the silages was determined.

Results and discussion

Percentage clover was 43 and 64 % of dry matter (DM) at the first and second harvest, respectively. Average silage DM concentration was 32.0 (s.d. 7.4) %. Nutrient contents of the silages were 10.1 and 11.7 MJ metabolisable energy, 140 and 180 g crude protein and 440 and 420 g NDF per kg of DM during first and second harvest, respectively. Lactic, acetic and butyric acid concentrations of the silages were 7.0, 1.6 and < 0.06 % of DM, respectively. Despite a low pH of 3.6-4.5, concentrations of ammonium-nitrogen in the silages were as high as 93-154 g kg^{-1} of total nitrogen.
Over-all average concentration of alpha-tocopherol in silage from this study was 36 (s.d. 24) mg kg^{-1} DM, which is considerably lower than the Swedish tabulated value of 115 mg kg^{-1} DM (Spörndly, 1999; Figures 1 and 2). Average concentration of beta-carotene in the silage was also low (22 (s.d. 20) mg kg^{-1} DM). Feeding requirements for the vitamins A and E have increased for dairy cows (NRC, 2001), which is of great concern regarding the EU law that forbids the use of synthetic vitamins in organic ruminant production.
Wilting of cut forage in windrows did not decrease the vitamin contents of fresh forage (Figures 1 and 2). Vitamin contents of silages stored in silos were similar to the vitamin contents of fresh forage from both harvests. However, the vitamin E concentration decreased during ensiling in round bales at the first harvest but there were no differences in vitamin E contents between round-baled silage and fresh forage during the second harvest. There may be a greater risk of oxygen penetration and oxidation of vitamin E in round-baled silage than in silo-stored silage.

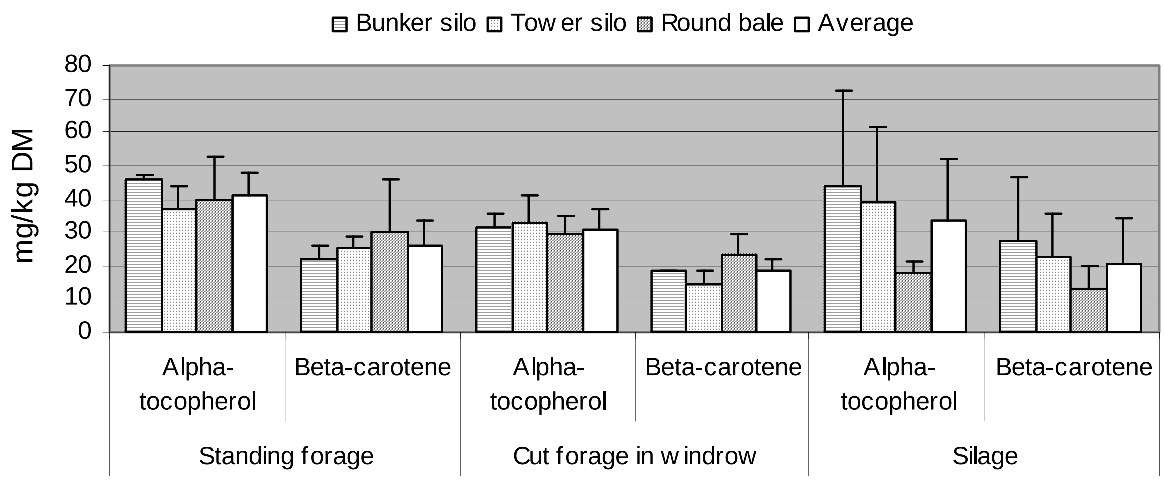

Figure 1. Concentrations of alpha-tocopherol (vitamin E) and beta-carotene (pro-vitamin A) in fresh herbage (n = 2-4) and silage (n = 11-12) from farms with different storage types during first harvest.

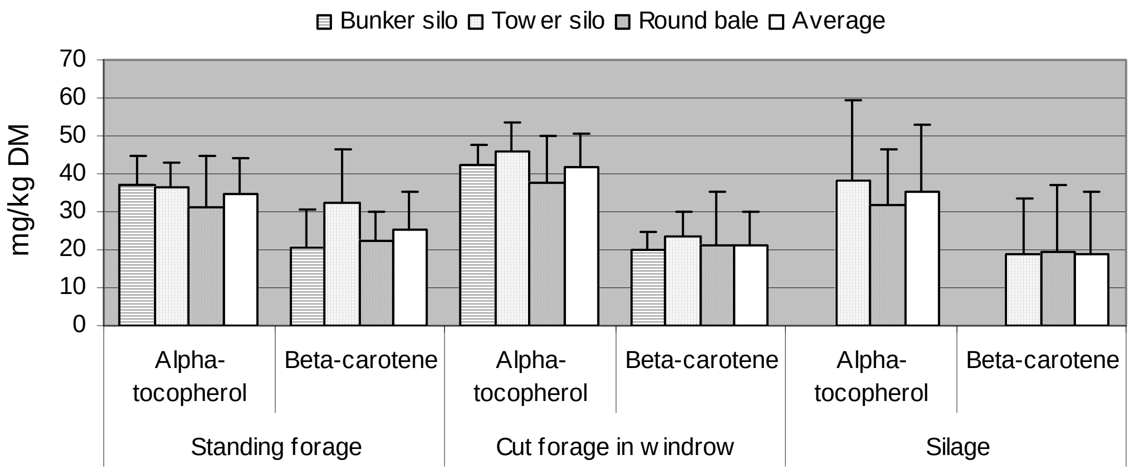

Figure 2. Concentrations of alpha-tocopherol (vitamin E) and beta-carotene (pro-vitamin A) in fresh herbage (n = 2-4) and silage (n = 8-14) from farms with different storage types during second harvest. Three silage samples from bunker silos contained 87 mg alpha-tocopherol kg^{-1} DM and 62 mg beta-carotene kg^{-1} DM.

Concentrations of vitamin-E and beta-carotene in round-baled silage decreased, on average, by 49 % (from 35 to 18 mg alpha-tocopherol kg^{-1} DM) and 37 % (from 19 to 12 mg beta-carotene kg^{-1} DM), respectively, during a three-month period. Effects of silage additive on silage vitamin contents varied between harvests. Acid-treated silage tended to have a lower vitamin E content than untreated or inoculated silage at the first harvest (21 vs. 37 mg alpha-tocopherol kg^{-1} DM), whereas inoculated silage tended to have the lowest vitamin E concentration during the second harvest (20 vs. 45 mg alpha-tocopherol kg^{-1} DM).

Conclusions

Concentrations of vitamin E and beta-carotene of forages can be preserved during harvest and ensiling if the conditions are good (high nutritional and hygienic qualities of the silages and good weather conditions). The lower average vitamin contents of the forages in this study, compared with existing tabulated values, indicate the significance of investigating the production and the health of organic dairy cattle that is fed no synthetic vitamins in their diets.

Acknowledgement

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Silage effluent production from round baled grass silage

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Abstract

When storing wrapped round bales of grass silage, nutrient losses can occur due to leakage of silage effluent. This is undesirable for both economic and environmental reasons. Six trials with a total of 62 bales of silage from a temporary ley showed the dry matter (DM) content of the initial silage to be the principal determinant of the quantity of silage effluent. If DM content of the initial silage exceeded 25 %, no further drainage of silage effluent was observed. The maximum average DM loss measured due to silage effluent was 4.5 % of the total DM in the initial silage (trial 1).
In all of the trials, at least 75 % of the total quantity of silage effluent ran off in the first 45 days. Storing the round bales on-end or lengthwise did not evidently affect the quantity of effluent.

Keywords: grass silage, round bale, silage effluent, plastic film

Introduction

Storing wrapped round bales of grass silage involves the risk of silage effluent leakage. The effluent can drain into surface water or groundwater where its environmentally relevant properties, such as a low pH value and high nutrient content, acquire significance. The low pH value can disturb the natural balance of the water, while oxidative decomposition of the nutrients may have an oxygen-depleting effect, with corresponding consequences for the aquatic biocoenosis (Stewart and McCullough, 1974).
Trials were conducted to determine the influence of wilting on the quantity of effluent produced and to define the DM threshold above which no silage effluent has to be expected. Furthermore, the influence of different stacking methods (e.g., on-end or lengthwise) on the quantity of silage effluent and the time-dependent effluent accumulation was examined.

Materials and methods

62 round bales produced in six different trials with a temporary ley were examined with regard to the following parameters:

- DM and nutrient content (silage and effluent)
- crude fibre content
- periodically measured weight and DM losses caused by leaking effluent
- BOD_5 of the effluent: biological oxygen demand for the decomposition processes of the organic matter during five days at 20 °C (mg O_2 l^{-1})

The bales were wrapped with six layers of stretch film (500 mm) and stocked indoors to protect them from external influences. Forty-three bales were stocked lengthwise and 19 on-end without stacking. The measurement period lasted 102 days in each trial. Using a mixed effects model, it was evaluated as to whether DM loss depended on DM content of the initial silage and the storing method (lengthwise, on-end). DM loss and DM content were arcsin transformed to ensure normal distribution assumptions. 'Trial' was included as a random effect.

Results and discussion

The total ensiled fresh weight amounted to 57,960 kg (Table 1). The DM content varied between 12.9 and 37.7 % (Table 1) covered the critical range of DM in which leaking effluent can occur. The crude fibre content of the initial fodder was between 19.6 and 25.4 % (Table 1). These values do not considerably differ from the values usually measured for well-balanced grass-clover mix. In all of the trials, average effluent production varied between 0 and 109.9 kg t^{-1} of initial silage; the corresponding average DM losses caused by leaking effluent ranged from 0 to 4.5 % of ensiled DM (Table 1).

Table 1. Parameters and results of the six trials.

Parameter	Unit	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6
Ensiled fresh weight	kg	6,080	8,880	7,300	13,690	6,880	14,860
Number of bales	bales on-end	6	6	4	13	6	8
	bales lengthwise	0	6	4	1	0	8
DM content of the initial	% min	12.9	25.0	15.6	15.8	21.7	14.6
silage (range from min to max)	% max	13.9	37.7	19.6	29.1	31.9	27.0
Crude fibre of initial silage	% of the DM	23.6	22.7	19.6	23.5	23.2	25.4
Average effluent production	kg $t^{-1}_{\text{initial silage}}$	109.9	0	45.6	43.2	0	57.3
DM losses caused by leaking effluent	% of total ensiled DM	4.5	0	1.9	1.5	0	2.2

The main goal was to identify the DM threshold above which no effluent leaking occurred. According to the regression model without transformation ($Y = 0.01x^2 - 0.83x + 14.22$ and $r^2 = 0.72$), the threshold lies at approx. 25 % of DM (Figure 1). Above this value, in general, no dry matter losses caused by leaking effluent would be expected. In trial number two and five, no effluent could be measured (Table 1).

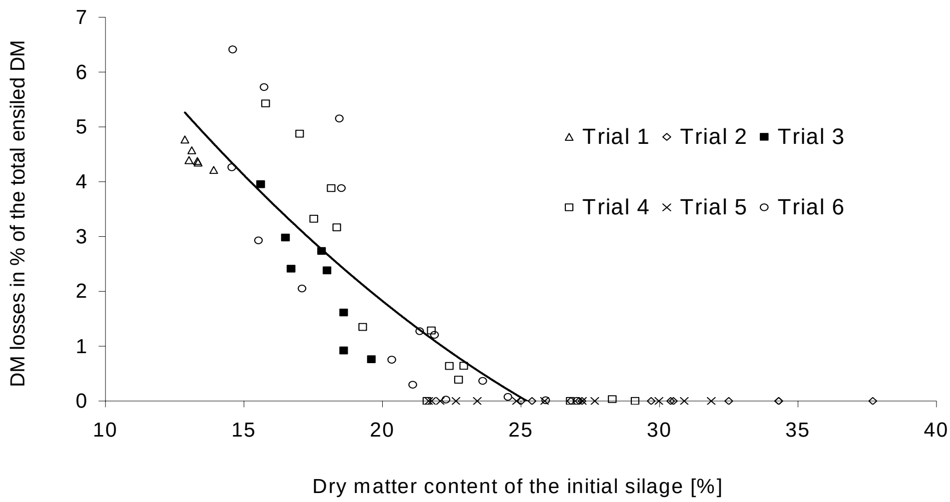

Figure 1. DM losses in six trials caused by leaking effluent depending on different DM contents of the initial silage over a period of 102 days.

The significant correlation between the DM content of the initial silage and the DM losses caused by leaking effluent was supported by the mixed effect model:

(arcsin(sqr(Y)) = 0.64 - 1.15*arcsin(sqr(x)); F-test, $P < 0.0001$).

The storing method had no influence on the DM losses: (F-test, $P = 0.19$). Figure 2 shows the temporal course of leaking effluent. At the beginning of the measuring period, flow rates of up to 544 g h^{-1} were measured per ton of initial fodder. After 45 days in each trial, at least

75 % of the total effluent amount leaked. This indicates that the primary time section is of major importance during the stocking period.

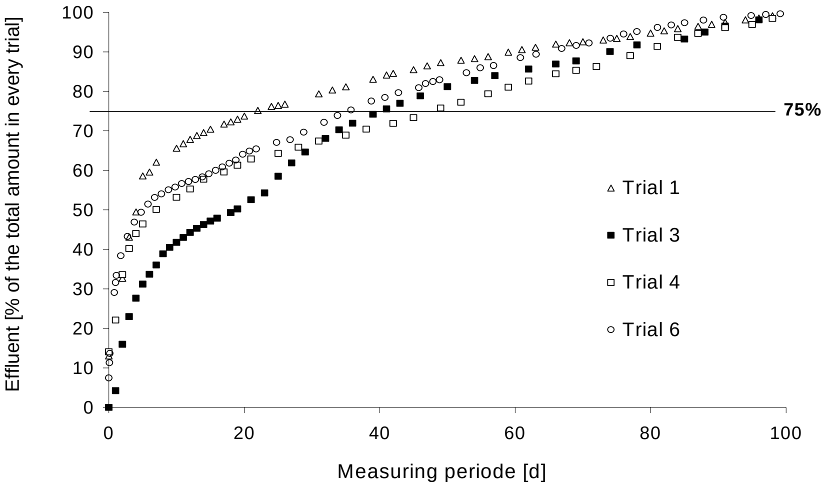

Figure 2. Temporal accumulation of silage effluent. 100 % corresponds to the total leaking amount in each trial after 102 days.

The damage to the aquatic biocoenosis caused by silage effluent is usually not provoked by toxic ingredients but by the oxygen depletion of fermentable sugars (organic matter) (Stewart and McCullough, 1974). Therefore, the BOD_5 value is mainly responsible for the ecological impact. The mean BOD_5 value for silage effluent with a DM content of 8.1 % from baled silage was 67,667 mg O_2 l^{-1} (standard deviation (SD): 2,309 mg O_2 l^{-1}). This value is slightly higher than the values measured for effluent from other silage systems like bunker silage (53,717 mg O_2 l^{-1}) (Kahlstatt *et al.*, 1996) and tower silage (42,624 mg O_2 l^{-1}) (Wyss and Rohner, 1996). DM content of the effluent must be taken into account in order to interpret the BOD_5 values. In the six trials, the DM content increased from 4.2 to 9.2 % during the measuring period, i.e., DM contents were very high when the BOD_5 values were examined. This could be the reason for the relatively high BOD_5 values compared with the values from other silage systems.
The BOD_5 values measured for silage effluent are up to 150 times higher than BOD_5 values recorded for settled domestic sewage (Kahlstatt *et al.*, 1996). Additionally, the high total nitrogen (N) content of 3.90 kg m^{-3} (SD 0.07 kg m^{-3}) and the ammonia-N content of 0.56 kg m^{-3} (SD = 0.01 kg m^{-3}) – comparable with cattle slurry – shows the pollution capability of this agricultural seepage.

Conclusions

Silage effluent is sewage with a high potential ecological impact caused by high BOD_5 values. No leaking effluent was observed for round baled grass silage with a DM content of more than 25 %. DM losses caused by leaking effluent did not depend on storage method.

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Effect of weather conditions, stage of plant growth and N application on yield and quality of grassland in Bosnia and Herzegovina

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Abstract

Grassland is the most important source of forage for cattle and sheep in Bosnia and Herzegovina. However, extensive grassland management (one late cut and no N application) results in low yield and poor forage quality. With the aim of improving day to day management of grassland, the objective of this study was to determine the effect of weather conditions, stage of plant growth and low rates of nitrogen fertiliser on forage yield and quality.

The results of a two-year experiment showed that the three examined factors had a significant influence on both yield and forage quality. DM yield ranged from 2.55 to 11.3 t ha^{-1}. Stage of plant growth and weather conditions had a greater effect on the crude protein content and protein yield, as well as crude fibre content, than did the application of fertiliser N. Significantly more forage of better quality could be obtained by cutting at the heading stage of plant growth and application of 30 to 60 kg ha^{-1} N.

Keywords: grassland, forage yield, forage quality

Introduction

More than half of Bosnia's agricultural area is grassland, making grassland the most important source of forage for cattle and sheep. Although environmentally friendly, extensive grassland management systems (cutting and haymaking in the stage of seed maturing, permanent grazing and no fertiliser) result in low yields and low quality of forage. Such forage makes animal production very expensive. Some improvement in grassland management would help to achieve higher yields of better quality forage while remaining environmentally friendly.

The objective of this study was to determine the effect of weather conditions, stage of plant growth and low rates of nitrogen fertiliser on forage yield and quality at a specific grassland site. Several authors (Makedos and Papanastasis, 1996; Stjepanovic *et al.*, 1998; Hein and Older, 1999) have suggested positive effects arising from low rates of nitrogen fertiliser on forage yield and quality. Mijatović and Pavešić-Popović (1975), Batinica and Basovic (1979), Odoradi *et al*. (1996) and Sima and Pacurar (2002) all reported that the stage of plant growth influences both herbage yield and quality.

Materials and methods

The experiment was carried out during the period of 2002-2003 on a two-year old grass sward consisting of 65 % grasses, 30 % herbs and 5 % legumes. The area had previously grown barley for seed. The experiment was undertaken in Gracanica's hilly region, at Vina (300 m above sea level), where average annual precipitation is 870 mm and average annual temperature is 10.6 °C. The soil characteristics were as follows: the pH was at 6.1 (in KCl) and 100 g of soil contained 6.4 mg P, 13.2 mg K and 260 mg. The objective of the experiment was to examine the effect of weather conditions, three levels of nitrogen fertiliser and harvesting at two stages of plant growth on forage yield and quality.

The experiment was set out as a randomised complete block design with four replicates per treatment. Plot size was 6 m^2. There were three N rates, 30 (N30), 60 (N60) and

80 (N80) kg N ha^{-1} applied in early spring, plus a zero N (N0) treatment (control). The swards were harvested at two stages of plant growth: (I) heading stage and (II) flowering stage. Protein yield was calculated on the basis of dry matter yield (DM) and DM protein content (N × 6.25). Total N was determined using the Kjeldahl method and fibre was determined by the Weende method. Results were subjected to ANOVA and compared by LSD test.

Results and discussion

Weather conditions influenced both forage yield and quality. Spring 2002 was very wet with periods of both cold and warm weather. In 2003 the weather was quite the opposite: low temperature until the second part of April and no rain. Due to more favourable weather conditions, the forage yield in 2002 was higher at both stages of plant growth, than in 2003 (Table 1). The differences in DM yield and protein yield were significant for the flowering stage due to shorter sward plants, as a result of faster inflorescence development than plant growth (high temperature and no rain). The forage quality, measured as protein content and protein yield, was significantly higher in 2002 than in 2003. Crude protein content ranged from 62 to 177 g kg^{-1} DM in 2002 and from 66 to 104 g kg^{-1} DM in 2003. Unlike crude protein, the crude fibre content was higher on all treatments in 2002 (289 to 344 g kg^{-1}) than in 2003 (215 to 300 g kg^{-1}).

Table 1. Effect of weather conditions on dry matter yield and protein yield.

Year	Heading stage				Flowering stage			
	N0	N30	N60	N80	N0	N30	N60	N80
				DM yield (t ha^{-1})				
2002	3.05	4.09	5.04	5.73	6.05***	7.35**	9.80***	11.3**
2003	2.22	3.48	4.81	4.91	3.36	4.73	6.02	6.27
LSD $_{0.05}$					1.39	1.71	1.39	2.67
LSD $_{0.01}$					2.10	2.59	2.10	4.05
LSD $_{0.001}$					2.36	4.16	3.38	6.51
				Protein yield(kg ha^{-1})				
2002	457.5*	724.4**	787.4**	952.0***	369.37	456.0*	627.4*	757.3**
2003	210.6	349.8	487.3	509.7	260.4	313.2	485.0	474.2
LSD $_{0.05}$	165.5	162.1	179.5	129.9		110.2	100.1	181.0
LSD $_{0.01}$	250.6	245.6	271.7	196.8		166.8	151.6	274.2
LSD $_{0.001}$	402.8	394.8	436.8	316.4		268.1	247.7	440.8

Nitrogen fertiliser, at each of the three applied levels (Table 2) significantly increased DM production. The N0 treatment had the lowest yield, regardless of plant growth stage or year (2.55 to 6.05 t ha^{-1}). The N80 treatment produced the highest DM yield and was significantly higher than the N30 at both stages of growth and in both years. In most cases, significant differences in DM yield were found between the N30 and N60 treatments. Higher rates of applied nitrogen affected not only DM yield, but also botanical composition, increasing grass portion (up to 80-84 %), and reducing herbs and legumes in the sward. Forage yield was also influenced by stage of plant growth at defoliation, resulting in significantly lower yields being obtained at the heading stage. Increasing the N rate increased DM yields. Nitrogen application resulted in increased total protein yield (Table 2). This result was more a consequence of increased forage yield than of higher protein content in the DM. The lowest protein yield was achieved on the N0 treatment and the highest on the N80 treatment, regardless of weather conditions or stage of plant growth at defoliation. Nevertheless, the stage of plant growth had a greater effect on protein yield than did N application due to a much higher protein content in the heading stage (82.5-177.0 g kg^{-1} DM) than in the flowering stage (61.0-81.0 g kg^{-1} DM).

Table 2. Effect of N application and stage of plant growth on DM and protein yield.

Treatment	Growth stage at harvest			
	Heading		Flowering	
	2002	2003	2002	2003
	DM yield (t ha^{-1})			
N0	3.05	2.22	6.05	3.36
N30	4.09*	3.48**	7.35	4.73***
N60	5.04**	4.81***	9.80**	6.02***
N80	5.73***	4.91***	11.30**	6.27***
LSD $_{0.05}$	1.04	0.56	1.92	0.61
LSD $_{0.01}$	1.41	0.75	2.61	0.83
LSD $_{0.001}$	1.89	1.02	3.49	1.11
	Protein yield (kg ha^{-1})			
N0	458	210	371	260
N30	722**	350***	453	313***
N60	787***	488***	626***	485***
N80	950***	510***	757***	473***
LSD $_{0.05}$	166.5	24.6	135.4	25.6
LSD $_{0.01}$	225.7	33.9	183.5	35.3
LSD $_{0.001}$	302.2	46.6	249.7	48.5

Conclusions

The results highlight the influence of low rates of nitrogen fertiliser and stage of plant growth on forage and protein yield. To improve forage yield and quality in an excessive extensive grassland management system such as in Bosnia, it would be sufficient to apply 60 to 80 kg N ha^{-1} to swards and to defoliate during the heading stage.

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Effects of fertilisation (potassium and phosphorus) on the quality of grassland

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Abstract

Primary and secondary metabolic contents of semi-natural grassland (association *Lolio-Cynosuretum typicum*) of Strážov Upland locality have been observed. A non-fertilised control and a treatment fertilised with potassium and phosphorus were compared in our experiment. The grass was cut three times during the vegetation period. Compared with the non-fertilised control, the fertilised treatment had a higher crude protein content, but a lower digestibility of organic matter and a higher lignin content. A relatively high proportion of dicotyledon plants (53-65 %) contributed to high values for the index of potential negative activity, with a maximum of 165 in the second cut in the non-fertilised treatment and 175 in the third cut in the fertilised treatment. The use of this index as a laboratory parameter allows better evaluation of the nutritive value of grassland.

Keywords: semi-natural grassland, fertilisation, primary and secondary metabolites, digestion of organic matter

Introduction

The fertilisation of grassland causes a decrease in the number of plant species. The problem of the lack of legumes in grassland can be solved by fertilisation (potassium and phosphorus) and by introduction of productive varieties of clover (Krajčovič *et al*., 1995). The primary and secondary metabolic contents are influenced by the above mentioned agronomic input (Scehovic, 1994; Holúbek and Kuzma, 2003).

Materials and methods

In 1993, field trials (perennial grassland and grassland with additional sowing) were established in the area of Stražov Upland, site Chvojnica. We used the sowing machine S-2-024 to sow the clover-grass mixture into the original grassland. In spring, two plots were fertilised ($P_{30} + K_{60}$ kg ha^{-1}) and a perennial grassland-association *Lolio-Cynosuretum typicum* was used as a non-fertilised treatment. The grassland was cut three times during the vegetation period: the first cut in the growing phase was at the ear-emergence stage of the prevailing grass types, the second four or five weeks later and the third six or eight weeks after the second cut. Chemical analyses were carried out by the Swiss Federal Agricultural Research Station in Nyon (Dr. Ján Scehovic) and the Department of Fodder Growing, Slovak University of Agriculture in Nitra. Methods of index quantification, climatic and soil characteristics were evaluated in the work of Holúbek and Kuzma (2003).

Results and discussion

During the 3 years of our experiment, the composition of the grassland was dominated by dicotyledon plants (53-65 %). The composition was influenced by the growth period, climatic conditions of individual years and periodicity of the plants' development. The results for yield and dry matter quality are shown in tables 1-3. Non-fertilised grassland produced about 3.78 t DM ha^{-1}, fertilised grassland 4.66 t DM ha^{-1}, and fertilised grassland with additional sowing 6.08 t DM ha^{-1}.

The quality of forage from perennial grassland and grassland with additional sowing is dependent on the age and developmental phase of the plants, and the floristic composition (Scehovich, 1994; Holúbek and Kuzma, 2003). The dominance of dicotyledon plants influences the chemical composition of grassland as well as its nutritive value. Therefore, special attention was paid to the content of phenols. According to Scehovic (1994), phenols are significant because of their important functions in the ruminant. The most important are lignin, soluble and insoluble phenols. The quality of grassland in relation to the content of phenols is expressed by the index of potential negative activity (Scehovic, 1994). In our experiment, we used this index to quantify the negative potential effect of inhibitors that are present in the plant organism or plant community. It integrates the negative effect of all components that inhibit the degradation of fibre. The results of our experiment (Tables 1-3) showed that only grassland of the first cut had index values smaller than 120. According to Scehovic (1994), the following plants have a high index: *Hypericum perforatum* 285, *Alchemilla vulgaris* 242, *Salvia pratensis* 193, *Leontodon hispidus* 184 *and Centaurea jacea* 136.

Table 1. Quality parameters of grass after additional sowing and PK fertilisation (mean of 3 years).

Quality parameter	Cuts		
	1	2	3
Dry matter (t ha^{-1})	3.35	1.53	1.20
Crude protein (g kg^{-1})	169.7	143.0	167.0
Digestible protein in the intestine (g kg^{-1})	103.5	94.3	98.1
NEL (MJ kg^{-1})	5.38	5.02	4.93
Digestibility of organic matter (%)	70.6	68.4	67.8
Fibre (g kg^{-1})	211.3	216.3	214.7
Lignin (g kg^{-1})	63.8	62.1	73.3
Soluble phenols (g kg^{-1})	33.2	35.1	32.5
Insoluble phenols (g kg^{-1})	12.5	12.8	13.6
Index of potential negative activity	103.4	135.1	150.6

Table 2. Quality parameters of grass after PK fertilisation (mean of 3 years).

Quality parameter	Cuts		
	1	2	3
Dry matter (t ha^{-1})	2.59	1.29	0.78
Crude protein (g kg^{-1})	181.7	147.0	171.3
Digestible protein in the intestine (g kg^{-1})	103.5	92.6	96.6
NEL (MJ kg^{-1})	5.50	5.27	4.76
Digestibility of organic matter (%)	66.3	65.1	60.7
Fibre (g kg^{-1})	213.7	207.3	221.0
Lignin (g kg^{-1})	55.5	60.9	71.0
Soluble phenols (g kg^{-1})	28.0	31.7	28.4
Insoluble phenols (g kg^{-1})	12.9	12.2	13.6
Index of potential negative activity	110.0	134.8	142.5

Table 3. Quality parameters of grass of the non-fertilised control (mean of 3 years).

Quality parameter	Cuts		
	1	2	3
Dry matter (t ha^{-1})	2.12	1.11	0.55
Crude protein (g kg^{-1})	168.3	136.7	158.0
Digestible protein in the intestine (g kg^{-1})	103.0	84.2	96.1
NEL (MJ kg^{-1})	5.92	5.44	5.14
Digestibility of organic matter (%)	72.8	70.0	67.7
Fibre (g kg^{-1})	210.0	202.3	214.7
Lignin (g kg^{-1})	54.5	63.1	68.2
Soluble phenols (g kg^{-1})	32.9	37.5	34.4
Insoluble phenols (g kg^{-1})	11.8	12.5	13.8
Index of potential negative activity	116.5	165.0	159.7

Conclusions

After three years of fertilisation, dicotyledon plants dominated the observed grassland. Clovers, (*Trifolium pratense* variety Sigord and *Trifolium repens* variety Huia) that were sown additionally into the perennial grassland, did not grow in the expected quantity. Grassland with fertilisation (PK fertiliser) and additional sowing was more productive than perennial grassland fertilised by PK fertiliser (+1.42 t ha^{-1} DM). The content of crude protein was in accordance with a healthy nutrition of ruminants. The energy value of dry matter, except at the third cut, did not decrease below 5.0 MJ NEL kg^{-1} dry matter. The high proportion of dicotyledon plants was indicated by a high content of phenols and a high index of potential negative activity. Only grass in the first cut had a satisfactory index below 120.

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The quantity and quality of pasture yields in three different habitats

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Abstract

Results of a three year (1999-2001) study on the yields and quality of of two pastures for cows (with conventional and natural farming) located in periodically dry (A), medium-wet (B) and wet (C) habitats are presented.
It was found that under similar habitat conditions conventional farming resulted in DM yield of 8.5 t ha^{-1} whereas natural pasture gave from 2 to 5 t ha^{-1}. The yields from the pasture with conventional farming contained more crude protein (up to 6.3 %), had less crude fibre (approx. 3.5 %), were more digestible (approx. 3 %) and had higher energy concentration (approx. 0.7 MJ).
Despite the higher and more valuable yields obtained from conventionally farmed pastures, there is no need to radical improve natural pastures, because of their great natural and landscape values. Rich biodiversity is also a valuable feature.

Keywords: pasture, farming, yields, digestibility, crude protein

Introduction

Pastures are a source of cheap and valuable fodder in summer period and a valuable element in the landscape. In recent years the area of pastures has considerably decreased to 1.03 million hectares (GUS, 2003). This results from low cattle numbers. Moreover, pasture areas are used sporadically or have been completely abandoned. Consequently, they are gradually naturalised. In order to stop this process it is necessary to adopt extensive forms of utilisation and grazing of animals. The aim of this study was to estimate yield and quality of natural or conventionally farmed pastures on mineral soils in three habitats.

Materials and methods

During the years 1999-2001 the study was carried out at Falenty, on two pastures conventionally utilised (I) and natural (II) in three habitats: periodically dry (A), moderately wet (B) and wet (C). Ground water levels between April and September were, in A -135 cm, in B -129 cm and in C -82 cm. Pasture I was fertilised as follows: 150 kg N ha^{-1}, 80 kg P_2O_5 ha^{-1} and 120 kg K_2O ha^{-1}. Pasture II was not fertilised but only grazed by dairy cows. The nutritive value of the sward was calculated from the content of crude protein and crude fibre evaluated by the NIRS method by means of an InfraAlyzer 450. The digestibility was calculated according to Pawlak's equation: $Y = 103 – 1.2 \times W$, where W is the crude fibre concentration in DM (Pawlak, 1988; 1990). Energetic value of the herbage was calculated according to the equation: $K = 1.19 – 0.016 \times W + 0.009 \times Z$ (Ostrowski, 1982), where W is the concentration of crude fibre, and Z is the concentration of crude protein in DM yield. Useful value of sward (Lwu) was calculated according to Filipek (1973). The stocking rate for cattle was calculated on the basis of yields and pasture utilisation. Utilisation at the following levels was assumed:
Pasture I in habitat A – 90 %, B – 80 % and C – 55 %, pasture II in habitat A – 65 %, B – 65 % and C – 45 %.

Results

Significantly higher yields were obtained from pasture I than II in all habitats and years. Greatest differences in yields between pasture I and II were found in habitat A and B, and the lowest in habitat C. The average DM yield over 3 years for pasture II was only 27.7 % of that for pasture I in habitat A, 32.2 % in habitat B and 56.3 % in habitat C (Table 1). The content of DM in fresh forage did not differ from that usually acknowledged as optimum and only on pasture II in habitat A and B it was too high. The DM yields were obtained over the grazing season, usually lasting about 160 days, for variable stocking rates (Table 2). The main group of plants contributing to yields were grasses, especially on pasture A. Their average proportion, depending on pasture and habitat varied from 68 to 78 %, and only on pasture II in habitat C it did not exceed 42 %. Legumes were represented by white clover (*Trifolium repens* L.). Herbs and weeds contributed most to the yields on pasture II in habitat C (58 %, Table 3).

Calculated utilisation value of the sward (Lwu) was very good on pasture I in habitats A and B and average in habitat C (Table 3). The value on pasture II in habitats A and B was fairly good and in habitat C average.

Table 1. DM yields and content.

Year	Pasture I			Pasture II		
	Habitats			Habitats		
	A	B	C	A	B	C
	Yield, (t ha^{-1})					
1999	4.85	7.62	6.28	3.49	3.16	5.61
2000	7.68	8.27	9.51	1.29	2.58	5.24
2001	10.97	9.99	10.30	1.74	2.59	3.84
Mean	7.83	8.63	8.70	2.17	2.78	4.90
	Content of DM (%)					
Mean 1999-2001	20.76	20.07	23.03	28.26	27.78	20.53

Table 2. Calculated net yield (t ha^{-1}) and possible stock of cattle on pasture (DJP ha^{-1}).

	Pasture I			Pasture II		
	Habitats			Habitats		
	A	B	C	A	B	C
Net yield	7.05	6.90	4.79	1.41	1.81	2.21
Cattle stock	3.1	3.0	2.1	0.6	0.8	1.0

Table 3. Percentage share of plant groups in the yield (%) and their usable (Lwu) and nutritive values.

	Pasture I			Pasture II		
	Habitats			Habitats		
	A	B	C	A	B	C
Grasses (%)	74	70	78	74	68	42
Legumes (%)	10	6	+	2	+	+
Herbs and weeds (%)	16	24	22	24	32	58
Usable value of sward (Lwu)	9.0	8.2	5.6	6.5	6.7	4.7
Crude protein (g kg^{-1})	177.3	206.3	180.0	151.9	143.3	147.
Crude fibre (g kg^{-1})	278.1	264.7	274.3	301.0	300.9	283.3
Digestibility of organic matter (%)	69.6	71.2	70.1	66.9	66.9	69.0
Net energy (MJ kg kg^{-1}DM)	5.4	5.7	5.4	5.0	5.0	5.1

Crude protein concentration in DM was significantly higher from pasture I than from pasture II. It was influenced by nitrogen fertilisation, more favourable botanical composition of the sward and greater frequency of utilisation – 5 rotations in comparison with only 3 on pasture

II (Table 3). The highest crude protein concentration was found in herbage from pasture I in habitat B, and from pasture II in habitat A. In herbage from other habitats the concentration of this component was similar, but on pasture II it was lower by 3-4 % compared with the sward of pasture I. The largest differences were noted in habitat B (6.30 %), and the lowest in habitat A (2.54 %). Crude fibre content showed an opposite trend. The highest concentration of this component was in herbage from pasture II, particularly in habitats A and B.

Nutritive value of pasture herbage, evaluated from its digestibility and net energy concentration was not high. Digestibility on pasture I was 70-71 %, and on pasture II 67-69 % (Table 3). The greatest differences in herbage digestibility between pasture I and II were noted in habitat B (average about 4 %), then in habitat A (average about 2.5 %) and the lowest in habitat C (average about 1 %).

Energetic value of herbage did not differ significantly between habitats or between pastures (5.0-5.7 MJ kg^{-1} DM). Higher energy forage (by 0.3-0.7 MJ kg^{-1} DM) was obtained from pasture I than pasture II.

Conclusions

The appropriate utilisation of pasture under similar habitat conditions permitted yields of 8.5 t ha^{-1} DM. The utilisation also influenced herbage quality and botanical composition of the sward. But there is no need of radical improvements to natural pastures because they have, as do all grasslands, great natural and landscape values. The areas of average or poor productive value should be maintained and protected against naturalisation and afforestation by systematic utilisation. A very useful feature of natural pastures is their rich biodiversity.

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Yield, quality and ecologically balanced utilisation of semi-natural grasslands on coastal areas of Estonia

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Abstract

The larger areas of species-rich coastal meadows are situated in the western part of Estonia and on the islands of the western coast. Salt marshes of the Baltic Sea are mostly not natural biotopes. They have developed during a long period of agricultural use, mainly by grazing of beef cattle and sheep. The coastal meadows, in comparison with organic sown grasslands in the same area, were studied in 2001 (four research areas) and in 2002 (ten areas). The plant material was analysed for crude protein, acid detergent fibre, neutral detergent fibre, P, K, Ca, Mg. The hay DM-yield ranged from 6.3 g m^{-2} in the plant association dominated by *Juncus gerardii* to 330 g m^{-2} in a grass sward rich in *Festuca rubra*. The content of mineral elements (P, Mg, K) in hay was quite low, and the digestibility values ranged between 57 % in case of *Phragmites australis,* and 68 % in the plant association dominated by *Juncus gerardii*. Low digestibility is due to a high content of acid detergent fibre in the fodder.

Keywords: coastal grasslands, soils, productivity, hay quality

Introduction

Traditionally large areas of seashore meadows and islands were grazed and mown, so that valuable plant associations, rich in species, developed. During the last ten years, due to the development of ecological agriculture in Estonia, the number of agricultural producers (especially smaller family farms), interested in improving the use of semi-natural grasslands for animal production, has increased significantly. According to the publication of the Statistical Office of Estonia (Agriculture, 2002) the total average area of semi-natural grasslands (grazed or cut) in the last four years (1998-2001) extended to 149,740 ha, with an average DM yield approximately 1400 kg ha^{-1}. About 54 % of this area was mainly grazed (the average DM yield being about 1350 kg ha^{-1}), 41 % was used for haymaking (1400 kg DM ha^{-1}), and 5 % was cut for making silage and fresh fodder (1800 kg DM ha^{-1}). It is essential to continue the traditional utilisation of coastal meadows to preserve the biodiversity of the area. However it should be economically profitable for the farmers to run and manage these areas. The quality of fodder is an important factor for farms which use the coastal areas for grazing. The aim of this investigation was to analyse the quality of the grass on coastal grasslands and compare it with that of sown grasslands.

Materials and methods

The farm studied was Ristitee, in South-Eastern Hiiumaa, which has total area of 544 ha, of which approximately 350 ha comprises coastal meadows. This area has been divided into 3-7 parts. It is grazed by horses (55) and beef cattle (total 66, incl. 3 pedigree Scottish Highland cattle) making a total of about 100 animal units. Thus, the grazing intensity is quite low and varies over the area, depending on the productivity of the meadows. In some places the grazing has not been intensive enough to control the spread of reeds (*Phragmites australis*). The growing seasons during the experiment differed: the year 2001 was quite humid and therefore favourable for intensive grass growth, but in 2002 it was very hot and dry. Due to extensive grazing there was no serious grass shortage in the coastal meadows, even in 2002.

The researched coastal meadows were grouped by their management and the dominant species (Table 1).

Table 1. The types of grasslands studied.

No. of research area	Type of grassland	Use of grassland	Dominating species
1	Sown grassland (relatively new)	Cutting, grazing	*Trifolium pratense, Elytrigia repens, Phleum pratense, Dactylis glomerata*
2	Sown grassland (old)	Grazing, partly not used	*Alopecurus pratensis, Dactylus glomerata, Festuca pratensis*
3	Coastal pasture	Grazing	*Juncus gerardii, Phleum pratense*
4	Coastal meadow	Grazing	*Juncus gerardii, Festuca rubra*
5	*Phragmitetum australis* association	Grazed or not used	*Phragmites australis*

The herbage in each research area was cut in four replicates (plots 6 m^2) twice per season, weighed and a subsample (1 kg) was taken to estimate the DM yield. A subsample taken for botanical analysis was sorted/grouped by species and weighed separately. The plant material was analysed for crude protein (CP), acid detergent fibre (ADF), neutral detergent fibre (NDF), P, K, Ca and Mg. The digestible DM (DDM = 88.90 - (0.779*ADF), %), the DM daily intake (DMI = 120/NDF, % of cattle weight), the relative feed value (RFV = (DMI*DDM) / 1.29, points) and the metabolizable energy (ME) content were calculated on the bases of ADF and NDF (National Research Council, 2001). Data were statistically analysed by ANOVA**,** and the Least Significant Differences ($LSD_{0.05}$) are presented.

Results and discussion

The special ecological value of salt marshes was found in the rich and very specialised vegetation, in these areas which have been traditionally grazed. The most common plant associations in the studied coastal meadows were *Clauco-Juncetum gerardii* and *Festucetum rubrae* with its subassociations of *Agrostidetosum stolonifera* and *Festuco-Caricetum nigrae*. The most widespread species were *Festuca rubra* and *Juncus gerardii*, comprising up to 71 % and 73 % in the examined plant associations, respectively. The proportion of other species varied widely in different research areas. One of the studied coastal meadows had a remarkably high content (16 %) of legumes in its botanical composition, including *Lotus corniculatus*, *Trifolium pratense*, *Trifolium maritimum* and *Trifolium repens* in their plant associations. The most prevalent species in sown grasslands were *Trifolium pratense*, *Phleum pratense and Elytrigia repens* (Table 1). The hay DM-yield ranged from 630 kg ha^{-1} in the plant association dominated by *Juncus gerardii* to 3300 kg ha^{-1} in the grass sward rich in *Festuca rubra*.

Traditionally plant associations in coastal meadows have been used for grazing for a long time due to the stable quality of feed and good animal performance. Herbage quality for fodder was found to be low in the plant association dominated by *Phragmites australis* but was relatively high in the sward rich in *Juncus gerardii* (Table 2). The content of mineral elements (P, Mg, K) in hay was also quite low and digestibility was low to satisfactory, ranging from 57 % in the case of *Phragmites australis*, to 68 % in the plant association which included mainly *Juncus gerardii* (51 %). This plant association had also a high energy content, containing 10.8 MJ kg^{-1} of metabolizable energy. Low DM digestibility was due to a high content of acid detergent fibre in the fodder, samples of reed and an ungrazed meadow dominated by *Alopecurus pratensis* and *Elytrigia repens* having the highest values.

Table 2. Nutritive value of grass from cultural and semi-natural grasslands.

No. of research area	Content, % of DM CP	ADF	NDF	DDM (%)	DMI (%)	RFV (points)	ME (MJ kg^{-1} DM)
1	10.6	31.9	54.8	64.0	2.2	109	10.1
2	9.8	39.2	63.0	58.4	1.9	86	9.0
3	10.0	26.9	55.5	67.9	2.2	114	10.8
4	10.2	32.9	61.7	63.3	1.9	96	9.9
5	9.2	41.0	74.6	57.0	1.6	71	8.7
$LSD_{0.05}$	2.3	4.6	5.4	3.5	0.16	8.7	0.6

When comparing the hay quality of different types of grassland, it is obvious that the *Phragmites australis* plant association had the lowest values. However, in addition to reed, cattle also had access to herbage of much higher quality – the associations rich in *Juncus gerardii*, or sown grasslands rich in valuable forage legumes and grasses. Such a mixed diet seemed to be very suitable for beef cattle and horses. The initial experience of using Scottish highland cattle on Ristitee farm for environmental conservation management of coastal meadows is also quite promising. The most restrictive factors to achieving high productivity from dairy cows are low productivity of such meadows, and low protein and energy contents of herbage.

Conclusions

Salt marshes of the Baltic Sea are not natural biotopes but they have been developed by traditional agricultural use, mainly by grazing beef cattle and sheep. The disintegration of collective farms since 1991 and insufficient development of private farms have led to decreasing numbers of cattle. The consequences of this can be changes in flora, the overgrowth of meadows, and the disappearance of many species that finally lead to the degradation of species-diverse coastal grasslands.

The quality of grass on coastal meadows varies very much, ranging from a low quality in the case of *Phragmites australis,* to a relatively high quality in the plant association dominated by *Juncus gerardii*. The nutrient content and fodder quality of semi-natural grasslands were similar to, or even better than, sown grasslands.

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Changes in the quality of some Lithuanian grasses as affected by cutting time in spring

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Abstract

In this study we used the samples of different grass species and varieties bred at the Lithuanian Institute of Agriculture (LIA) and herbage samples from farmland swards. The herbage was cut at different times (May – 1st ten-day period of June), dried and scanned by NIRS-6500. Chemical composition and quality parameters such as crude protein (CP), water soluble carbohydrates (WSC), crude fibre (CF), modified acid detergent fibre (MADF), neutral detergent fibre (NDF) and DM digestibility (DMD) were predicted by the equations developed at the Analytical Laboratory of LIA. Onset of maturity during the primary growth phase in spring was accompanied by great changes in nutritive value: increase of CF from 170-253 to 278-375 g kg^{-1} DM, MADF from 155-290 to 281-367 g kg^{-1} OM, NDF from 325-520 to 522-685 g kg^{-1} OM, decline of CP from 162-216 to 75-140 g kg^{-1} DM and DMD from 667-888 g kg^{-1} DM to 443-581 g kg^{-1} DM. WSC content in most cases increased during the first ten-day period of May and then started to decline. Individual grass species and varieties or herbage of swards with a different botanical composition were found to differ in quality, however, senescence dynamics was similar.

Keywords: grasses, chemical composition, NIRS prediction, cutting time

Introduction

Soil and climate conditions usually determine the type of forage that is most commonly grown in a region. Traditional swards in Lithuania include the grasses *Phleum pratense* L., *Dactylis glomerata* L. and *Poa pratensis* L. *D. glomerata* is well adapted to the severe conditions of Lithuania and is high-yielding, however, it overgrows early and loses its nutritive value. *Lolium perenne* L. produces high-quality forage but demonstrates a poor over-winter survival under Lithuanian conditions. The quality of perennial forage grasses is affected by many factors: genotype, agrometeorological conditions, harvesting time, etc. (Lamb *et al*., 2003; Paplauskiene and Tarakanovas, 2000). Successful results in using NIRS for estimating forage composition and its nutritive value have been reported in recent years (Butkute *et al*., 2003; Undersander *et al*., 1993). The prediction of CP and ADF contents by NIRS is one of the official methods of the Association of Official Analytical Chemists (Undersander *et al*., 1993). The aim of the present study was to evaluate the quality dynamics of the LIA-bred grasses and swards differing in botanical composition in relation to the cutting time in spring.

Materials and methods

In the present study two herbage sample sets were analysed. The first sample set comprised 5 individual species (7 varieties) bred at the Lithuanian Institute of Agriculture. The plants were grown in the same environment in 2000. The samples were collected at weekly intervals from the beginning of May to the 1st ten-day period of June. The second sample set included herbage samples from farmers' swards differing in botanical composition grown in 1998. Assay samples were taken from 10 places of each replication and a composite average sample weighing not less than 500 g was made. Fresh samples were chopped into 3-5 cm pieces, fixed at 105 °C for

15 min, dried at (65 ± 5)° C, ground by Cyclotec mill with 1 mm sieve and scanned by the NIRS-6500 using Spinning Module. For CP, CF, MADF, NDF, WSC and DMD the spectra were predicted by the equations, developed at the Analytical Laboratory of LIA (Butkute *et al*., 2003). The statistics of equations: coefficient of correlation in calibration RSQ and standard error in calibration SEC (g kg^{-1}) were 0.95 and 8.6 for CP, 0.96 and 11.3 for CF, 0.98 and 7.8 for MADF, 0.98 and 13.8 for NDF, 0.97 and 12.2 for WSC, 0.93 and 27.1 DMD respectively.

Results and discussion

Lithuania's climate is more severe than that of many European countries and the rates of growth and development of grasses are also different. Generally, the first cut of all herbage species accounts for the largest share in the forage prepared for winter. During the maturation stage individual perennial grasses lose their nutritive value at a different rate (Figure 1).

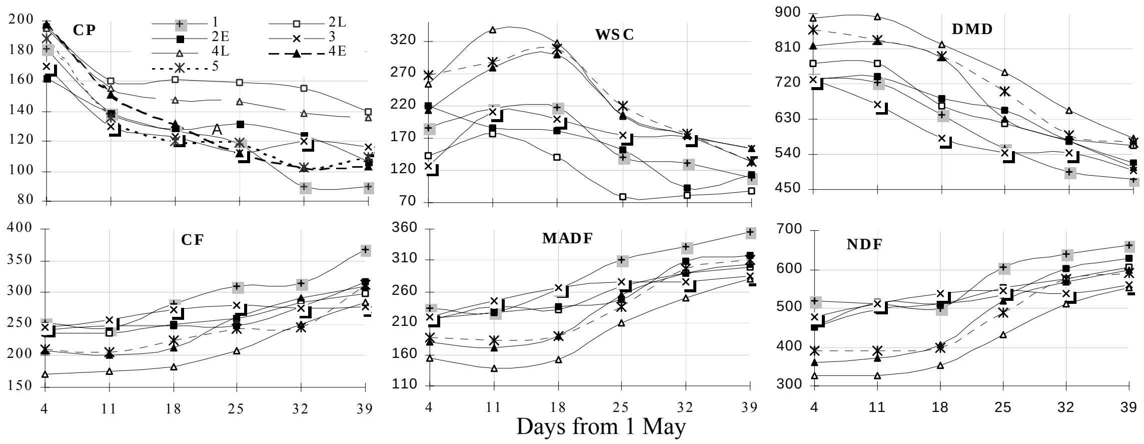

Figure 1. The content of quality components (g kg^{-1}) in individual grass species and varieties on sampling dates in spring. 1: *Dactylis glomerata*, 2: *Phleum pratensis*, 3: *Poa pratense*, 4: *Lolium perenne*, 5: *Festulolium*; L: late-maturing, E: early-maturing cultivars.

Crude protein was very sensitive to the stage of grass maturity. In all grasses, the protein content had dramatically dropped (22.5-52.5 g kg^{-1} depending on the species or variety) by the first week of the investigation. The CP content in the DM of phytomass declined further, but at a different rate depending on the earliness of varieties and species. With advancing maturity, the content in CP and DMD most rapidly decreases in the plant of early-maturing varieties and species: ryegrass (4E), timothy (2E), meadow-grass (3) and especially in cocksfoot (1). This is related to the fact that with advancing maturity the stem:leaf ratio increases, and that grass leaf is superior to stem in crude protein content (Lamb *et al*., 2003; Paplauskienė and Tarakanovas, 2000). At the beginning of the experiments, the highest content of fibre fractions (CF, MADF, NDF) was identified in cocksfoot, meadow-grass and both varieties of timothy. The concentration of fibres increased with time in the mass of all tested plants. During the whole experimental period, the highest content of all fibre fractions was identified in cocksfoot, while in meadow-grass the variation of their content was the lowest. WSC contents in most cases increased during the first ten-day period of May. The high contents persisted for another week and then to started decline. Plant species, variety and growth stage affected WSC content in grasses. WSC levels are usually the highest in plants grown in low temperatures and high light intensity. The first ten-day period of May was characterised by cool but sunny weather, which at the end of the second ten-day period was replaced by warmer and often cloudy weather. The decrease in WSC values with later plant maturity could be associated with intensive increase in fibre content.

Thus, when herbs are grown for forage, they should be harvested at an early stage of maturity. Various strategies can be used to maintain the availability of forage with a good nutritive value. One of them is to plant a mixture of grasses and legumes that is characterised by different rates of growth and maturity throughout the season. Senescence dynamics of the herbage of swards with different botanical composition was similar to that of individual grasses, however, some peculiarities were distinguished (Figure 2).

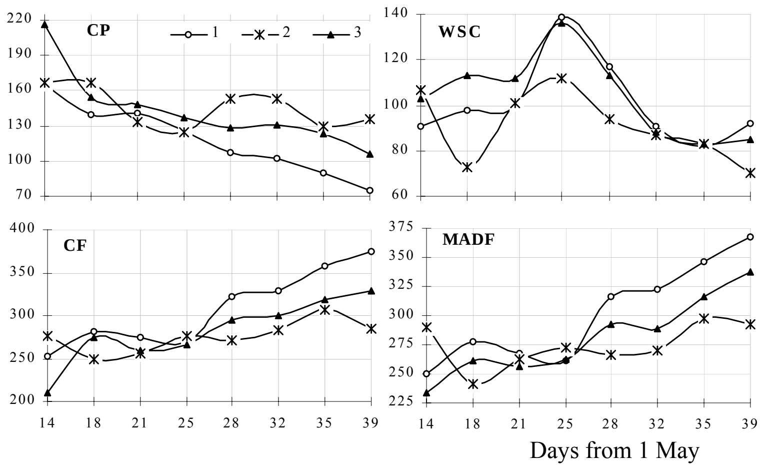

Figure 2. The content of quality components (g kg^{-1}) in sward herbage on sampling dates in spring. 1- mixture of grass species with 40-60 % of *D. glomerata*, 2- grass-legume mixture with 40-60 % of *Phleum pratensis*, 3- mixture of grass of early-maturing species with 10-40 % of red clover.

During the experimental period, quality parameters of the grass mixture (1) with cocksfoot accounting for 40-60 % of DM deteriorated more rapidly than those of the other mixtures containing red clover. In the samples of this sward, the content of CP declined from 165 to 75, DMD from 672 to 443 g kg^{-1} and CF, NDF and ADF tended to accumulate more intensively. In the grass mixture (3) including early-maturing grasses and 10-40 % red clover (depending on harvesting time), quality parameters changed analogically to those of pure grass mixture but only at a slower rate. Grasses mature faster than legumes. The nutritional quality of grasses drops faster. If early heading species such as cocksfoot and meadow-grass are used, harvesting must be early, otherwise quality and palatability may suffer. Grasses in the herbage were overgrown and of low feeding value, which was slightly compensated by the legumes present in the mixture. Chemical composition of the grass mixture composed of 40-60 % timothy and red clover (2) changed insignificantly. Like in individual grasses, WSC content varied inconsistently, with an increase during the third ten-day period of May.

Conclusions

The stage of forage plants at cutting is a very important factor affecting the nutritional value of grass, especially of early maturing species and varieties. Biomass quality variation of grass species differing in maturation rate was different. Quality parameters of the timothy and red clover mixture characterised by a later maturity were the slowest to change.

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Comparison of white clover / grass quality of permanent and temporary grasslands in Western Lithuania

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Abstract

The nutritive value and quality of *Trifolium repens* L. grown in different grass mixtures were investigated in permanent (PG) and temporary (TG) grasslands in two field experiments in Lithuania. Sward type had a marked effect on the growth and development, and on the persistence of *Trifolium repens* L. in grazed grasslands. *Trifolium repens* L. performed best in mixtures with *Poa pratensis* L. in permanent, and with *Phleum pratense* L. in temporary, swards. However, the tested swards contained the lowest metabolisable energy, compared with the other *Trifolium repens* L/grass swards. Both PG and TG grasslands produced high quality forage. The highest content of crude protein was found in *Trifolium repens* L./*Phleum pratense* L. mixtures in PG and TG and *Trifolium repens* L./complex mixture-2 TG. The lowest content of crude fibre was identified in the *Trifolium repens* L./*Poa pratensis* L. mixture in PG. A medium correlation (r = 0.55) was established between the content of white clover in the sward and crude fibre in the dry matter yield.

Keywords: permanent and temporary grasslands, quality of forage, *Trifolium repens* L.

Introduction

Simulated grazing depressed the grass yield in white clover/timothy/meadow fescue mixtures, but not in white clover/smooth meadow grass mixtures (Jorgensen and Rapp, 2000). The suitability of timothy as a companion with clover for the northern marginal areas was compared to that of smooth meadow grass (Helgadottir *et al*., 2002). On grazed grassland in lowland Poland meadow grass swards provide the best conditions for improved white clover development (Rogalski and Kryszak, 2001). The mixtures of white clover/timothy or white clover/perennial ryegrass are recommended in temporary grasslands for grazing in the conditions of Lithuania. In permanent grasslands the most common species are white clover/timothy, ryegrass, meadow fescue and meadow grass mixtures. Such swards contain 192 g of crude protein, 231 g of crude fibre and 10 MJ per kg of DM (Daugeliene, 1995; Skuodiene, 2003).

In the present study we compared the yield and quality of different white clover/grass swards, in permanent grasslands for 6 years, and temporary grasslands for 3 years.

Materials and methods

The experiments were conducted in Western Lithuania. The trial design consisted of 2 blocks: permanent (PG) and temporary (TG) grasslands.

The soil of the experimental site PG was a sod podzolic *Endocalcaric Gleysol* (GLk2) light loam on medium loam with top soil's pH_{KCl} 6.05, available P_2O_5 132 mg kg^{-1} and K_2O 104 mg kg^{-1}. The swards were fertilised annually in spring with 60 kg ha^{-1} of both P_2O_5 and K_2 O. The soil of the experimental site TG was a sod podzolic *Orthieutric Albeluvisols* (JIb2) light loam on medium loam with top soil's pH_{KCl} 5.8, available P_2O_5 222 mg kg^{-1} and K_2O 275 mg kg^{-1}. The swards were fertilised annually in spring with 60 kg ha^{-1} of P_2O_5 and 90 kg ha^{-1} of K_2 O. No nitrogen fertiliser was applied in the first year. 90 kg N ha^{-1} was applied in the second year and 60 kg ha^{-1} in the third year. The following seed mixture rates were used for PG and TG:

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PG *Trifolium repens* L. cv. Atoliai	3.5 kg ha^{-1}
PG *Phleum pratense* L. cv. Gintaras II	2.4 kg ha^{-1}
PG *Poa pratensis* L. cv. Lanka	2.8 kg ha^{-1}
TG *Trifolium repens* L. cv. Atoliai	2.7 kg ha^{-1}
TG *Phleum pratense* L. cv. Gintaras II	4.0 kg ha^{-1}
TG *Lolium perenne* L. Veja	7.2 kg ha^{-1}

The complex mixture-1 was composed of *Trifolium repens*, *Phleum pratense*, *Lolium perenne*, *Festuca pratensis* and *Poa pratensis*. The complex mixture-2 consisted of *Trifolium repens*, *Festuca arundinacea* and *Phalaris arundinacea*.
The treatments were replicated 4 times and were grazed 4 times with a herd of dairy cows. The botanical composition (grasses, clovers, forbs) of the samples was measured after separation as DM weight. Herbage yield data and its analysis were statistically processed using analysis of variance.

Results and discussion

In PG *Trifolium repens* showed maximum spread when it was sown in the mixture with *Poa pratensis* and *Phleum pratense* (Table 1). In TG, the best companion for *Trifolium repens* was *Phleum pratense*. In the mixture with *Lolium perenne* and *Trifolium repens*/complex mixture-2 the content of clover was 16-9.2 % lower than in the mixture with *Phleum pratense*. Ryegrass was most aggressive towards the clover followed by timothy, meadow fescue and smooth meadow grass (Helgadottir *et al*., 2000).

Table 1. Quality parameters by treatments.

Swards	Grassland type	Proportion of *Trifolium repens* in sward	[1]ME GJ ha^{-1}	Nutritive value	
				[2]CP	[3]CF
Trifolium repens + *Phleum pratense*	PG	25.5	50.4	197	224
Trifolium repens + *Poa pratensis*	PG	29.7	34.0	142	208
Trifolium repens + complex mixture-1	PG	12.2	58.1	171	230
Trifolium repens + *Phleum pratense*	TG	38.3	48.2	183	207
Trifolium repens + *Lolium perenne*	TG	22.3	48.7	163	234
Trifolium repens + complex mixture-2	TG	29.1	54.6	186	223
LSD_{05}		12.5	13.2	21.5	24.9

[1]ME – metabolisable energy, [2]Crude protein content, [3]Crude fibre content.

In PG the highest metabolisable energy (ME) content was produced by complex mixture-1, whilst the lowest ME content was produced by the *Trifolium repens*/*Poa pratensis* sward. In TG, herbage mixtures showed almost the same metabolisable energy content.
A lower content of crude protein was identified in *Trifolium repens*/*Poa pratensis* PG and *Trifolium repens*/*Lolium perenne* TG swards, compared with the other swards. This was determined by a cyclic spread of *Trifolium repens* in the mixture with *Poa pratensis*. The nitrogen rate was sub-optimal for *Lolium perenne* growth. Site fertility determines sward floristic composition of grassland and, therefore, it affects their productivity (Scurtu, 2001).
The highest content of crude fibre was found in the TG *Trifolium repens*/*Lolium perenne* sward. TG *Trifolium repens*/*Phleum pratense* and PG *Trifolium repens*/*Poa pratensis* swards contained 38.3-29.7 % *Trifolium repens*, therefore a lower content of crude fibre was identified in these swards. Forage quality was superior for the mixtures with white clover, with a lower crude fibre and a high protein content (between 25 % and 35 %) on average, for the three years (Fisher and Baker, 1996; Breazu *et al*., 2002). A medium correlation (r = 0.55) was established between white clover content in the sward and crude fibre in dry matter yield.

Coefficients of variation (27.6-83.2 %) suggest that *Trifolium repens* per cent in the dry matter yield is unstable, since clover needs adequate light and favourable weather conditions (Table 2). The better development of white clover in summer and autumn is associated with more favourable temperatures and reduced grass competitiveness (Rogalski and Kryszak, 2001). The most stable clover content in PG swards was found in the mixture with *Poa pratensis*, and in TG swards in the mixture with *Lolium perenne*. TG swards distinguished themselves by the lower variation in the ME content.

Table 2. Variation of forage quality in PG and TG.

Swards	Grassland type	Variation coefficient V (%)			
		[1]TR (%)	[2]ME	[3]CP	[4]CF
Trifolium repens + *Phleum pratense*	PG	83.2	27.0	11.5	7.54
Trifolium repens + *Poa pratensis*	PG	38.7	23.9	13.4	8.81
Trifolium repens + complex mixture-1	PG	50.6	24.1	13.1	15.3
Trifolium repens + *Phleum pratense*	TG	43.6	19.9	18.9	13.7
Trifolium repens + *Lolium perenne*	TG	27.6	21.0	13.4	4.60
Trifolium repens + complex mixture-2	TG	68.9	19.9	18.2	16.0

[1]TR %-*Trifolium repens* per cent. [2]ME – metabolisable energy. [3]Crude protein content. [4]Crude fibre content.

Trifolium repens is notable for a stable chemical composition as well as abundance of minerals. The variation in organic matter content in the DM yield of *Trifolium repens*/grass mixtures was medium and low. However, the variation in crude protein content in the dry matter yield was higher than that for crude fibre. In PG swards the content of crude fibre was more stable than that in TG swards. PG *Trifolium repens*/*Phleum pratense* swards were characterised by the most stable crude protein content. The greatest variation in crude fibre content was determined in both types of *Trifolium repens*/complex mixtures, while the smallest variation was estimated in *Trifolium repens*/*Lolium perenne* TG swards.

We can conclude that for permanent grasslands it is most expedient to compose complex mixtures of herbage. The productivity of such mixtures is determined by the cyclic spread of *Trifolium repens* in the sward. Two-component mixtures are suitable for temporary legume / grass grasslands.

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Botanical composition of permanent grassland in the Stara Planina

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Abstract

Three of the most important meadow associations in Stara Planina Mountain were analysed in order to define initial parameters for determination of grassland potential, as well as natural resources for production of biologically valuable and high quality food and revitalisation of agricultural production in a hilly-mountainous region. Floristic composition of three meadow associations is presented: valley-*Arrhenatheretum elatioris,* hill-*Festuco-Chrysopogonetum grylli* and mountain-*Danthonietum calycinae.* Participation of major meadow species based on their mass is presented in the paper. On the basis of their productivity, the species belong to the associations of useful grasses, useful legumes and other useful species and weeds.

Keywords: botanical composition, productivity, permanent grassland

Introduction

The flora and vegetation of Stara Planina Mount are exceptionally diverse due to the ecosystem whose plant cover produces herbaceous associations of more or less limited composition composed essentially of perennial herbaceous mesophiles. On the meadows and pastures of Stara Planina grow a great number of plant species belonging to different families whose agricultural value is wide. Up to the thirties of the last century, and in some cases even later, only the species from the families of grasses (*Poaceae*) and legumes (*Fabaceae*) were considered desirable and useful, while all other grasses were deemed useless and harmful which was completely wrong (Kojic *et al*., *2001*). The aim of this paper is to determine, on the basis of phytocenological observation of certain plant species, the most common meadow associations, determine the percent of participation of useful grasses, legumes, and other species and weeds and on the basis thereof to determine their quality potential for the nutrition of ruminants. The results obtained can serve as a basis for the measures for quality improvement of meadows by the use of land-reclamation measures.

Materials and methods

Meadow associations were described according to the principles and methods of the Swiss-French Phytocenological School (Braun-Blanquet, 1964). The weeds taken from grasslands and pastures were divided into two categories, i.e., very poisonous species and less poisonous species previously analysed and determined in many research papers (Sostaric-Pisacic and Kovacevic, 1968; Kojic *et al*., 2001). The percentage participation of species was determined by measuring mass yield of each grass in 1 kg sample in 2 repetitions.

Results and discussion

Table 1 shows the botanical composition of three determined meadow associations and the percent of participation of certain plant species.

Table1. Botanical composition of the associations *Arrhenatheretum elatioris, Festuco-Chrysopogonetum grylli* and *Danthonietum calycinae* (mass participation of species in %).

Species	Associations		
	Arrhenatheretum elatioris	*Festuco-Chrysopogonetum grylli*	*Danthonietum calycinae*
Centaurea jacea	3.04	0.92	4.04
Trifolium alpestre	0.80	0.66	0.07
Coronilla varia	-	-	0.93
Minuartia viscosa	-	1.32	0.14
Sanguisorba minor	-	1.71	4.40
Astragalus onobrychis	-	-	8.00
Plantago lanceolata	-	0.40	0.22
Achillea millefolium	-	0.33	1.80
Rhinanthus minor	-	2.10	3.82
Bromus sterilis	-	-	13.43
Lathyrus tuberosus	-	-	0.87
Agrostis capillaris	5.30	4.75	7.30
Festuca rubra	7.34	11.29	14.50
Galium verum	-	2.10	0.36
Lotus corniculatus	0.50	0.20	0.14
Medicago falcata	0.85	-	10.60
Danthonia calycina	-	6.80	18.25
Teucrium chamaedrys	-	-	0.50
Prunella grandiflora	-	-	2.16
Carduus scabiosa	14.41	-	2.56
Melanpyrum arvense	-	0.80	1.87
Poa pratensis	11.07	-	1.23
Anthoxanthum odoratum	7.75	2.45	1.23
Cichorium intybus	-	-	0.80
Briza media	-	4.52	0.14
Fragaria vesca	-	-	0.14
Knautia arvensis	-	0.07	0.50
Carex hostiana	0.10	-	-
Ranunculus repens	0.90	-	-
Agrostis alba	2.85	-	-
Trifolium montanum	0.25	0.07	-
Carex acutiformis	0.10	-	-
Pimpinella saxifraga	0.20	-	-
Taraxacum officinalis	1.05	-	-
Equisetum palustre	1.34	-	-
Silene conica	1.05	-	-
Melilotus officinalis	2.34	-	-
Vicia lutea	0.60	-	-
Cynosurus cristatus	5.70	-	-
Sagina ciliata	4.33	-	-
Arrhenatherum elatius	28.13	-	-
Trifolium resupinatum	-	0.66	-
Roripa pyrenaica	-	0.85	-
Alium vineale	-	0.26	-
Asperulo procumbens	-	0.44	-
Chrysopogon gryllus	-	38.84	-
Filipendula hexapetala	-	3.42	-
Prunella laciniata	-	1.80	-
Sideritis montana	-	0.46	-
Centaurea stenolepis	-	8.10	-
Genista pilosa	-	0.66	-
Echium vulgare	-	0.66	-
Setaria verticilata	-	0.53	-
Dorycnium germanicum	-	2.17	-
Eringium campestre	-	0.66	-

In lowland association *Arrhenatheretum elatioris* 23 species were established among which the most common was *Arrhenatheretum elatioris* with 28 %. In hilly association *Festuco-Chrysopogonetum grylli* the presence of 31 species was established which is lower compared with the same association on Rtanj Mount (Jovanovic-Dunic, 1954). Dominant species in this association are *Festuca rubra* (11 %) and *Chrysopogon gryllus* (39 %). In mountain association *Danthonietum calycine,* 27 species are represented which is less than reported by Cincovic and Kojic 1962. In this association the dominant species is *Danthonia calycina* with 18 %. Table 2 shows the ratio among useful grasses, useful legumes, other useful species, weeds and total useful species in all three associations.

Table 2. The participation of some quality groups in analysed associations (%).

Associations	Useful grasses total	Useful legumes total	Useful sp. other families	Weeds	Useful sp. total
Arrhenatheretum elatioris	25.0	20.8	16.7	37.5	62.5
Festuco-Chrysopogonetum grylli	9.7	16.1	9.7	64.5	35.5
Danthonietum calycinae	18.5	14.8	11.1	55.6	44.4

The data indicate that the participation of weed plants in the plant cover of natural meadows in Stara Planina is rather high. In all analysed meadow plant associations, they range from 37-65 %. The highest percentage of useful grasses and legumes was found for lowland association *Arrhenatheretum elatioris*. The lowest percentage of useful grasses was observed in association *Festuco-Chrysopogonetum grylli*, and of legumes in association *Danthonietum calycinae.* The best ratio of total useful grasses and weeds was observed in the association *Arrhenatheretum elatioris,* while the worst in the association *Festuco-Chrysopogonetum grylli.* The reason for that is bad quality of the species of *Chrysopogon gryllus.*

Conclusions

Botanical structure of the three most present associations was determined on Stara Planina Mountain. In the first, A*rrhenatheretum elatioris,* 23 species are present, of which 62 % are useful. In the second association, *Festuco-Chrysopogonetum grylli,* of 31 existing species only 35 % are useful, whereas in the third association, *Danthonietum calycinae*, of 27 species 44 % are useful and can be used for livestock nutrition and pasture. The established floristic composition of meadows should be improved by adequate measures of fertilisation, which would increase the yield of useful species.

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Feeding value of mountain meadows in the Pieniny National Park managed for nature protection

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Abstract

The meadows in the Pieniny National Park are managed to maintain plant communities of high biodiversity. Traditional extensive management, which consists of a late cut for hay, is necessary to preserve them but provides a low feeding value of fodder. The content of crude protein, crude fibre, neutral fibre, acid detergent fibre, acid detergent lignin were analysed in four different plant meadow communities. The nutritive value was typical for extensively managed mountain meadows and suitable for less demanding stock. In spite of different botanical composition they had similar feeding value, mainly because of the relatively low contribution of grasses. However, the occurrence of poisonous species, often present in multispecies sward, can additionally worsen the feeding value of such fodder.

Keywords: extensive grassland, mountains, protected areas, feeding value

Introduction

Grasslands are often the only place where many plant and animal species occur at the same place. The richest in this respect are traditionally and extensively managed mountain meadows. In the Pieniny National Park (PPN) such communities as Pieniny herbal meadow (*Veratrum lobelianum – Laserpitium latifolium*) and thermophilous Pieniny meadow (*Anthylii-Trifolietum montani*) have the highest natural value. For many years campaigns of active protection have been conducted there (Wróbel, 2000) by simulating traditional meadow management. Thermophilous Pieniny meadows are cut from mid July to August, when most of the species have already ceased flowering. Herbal meadows are cut in 2-3 year intervals. In both cases no fertilisation is used. An important factor affecting an opportunity to use hay from extensively managed meadows is its usefulness for animals (Kostuch, 1997). The purpose of the study was to assess the quality of green forage obtained from the Pieniny meadows managed with the aim of nature conservation.

Materials and methods

Four meadow areas have been selected within PPN at 630-950 m asl The floral composition of the sward of the examined surfaces was determined on the basis of phytosociological releve by the Braun-Blanquet method. In the collected samples of green forage a standard method was used to determine the basic chemical composition, which was used to assess the feeding value of green forage in the INRA system (Normy, 2001).

Results and discussion

The species composition of the sward of the examined meadows was very different (Table 1). The thermophilous Pieniny meadow (sample 2 and 4) was characterised by multi-species swards without any dominating species. Herbal meadows (sample 1) were much more exuberant, but had poorer species composition. The Pieniny herbal meadow (sample 3) contained relatively few grasses and lots of high perennial plants in its composition.

Table 1. Botanical composition of samples (Braun-Blanquet coverage scale).

Plant species	Sample no.				Plant species	Sample no.			
	1	2	3	4		1	2	3	4
Dactylis glomerata	1	3	2	2	*Polygala vulgaris*		+		+
Agrostis capillaris	3	2	+	3	*Ranunculus polyanthemos*		+		1
Centaurea jacea	3	3	+	3	*Tragopogon orientalis*		+		1
Pimpinella major	2	2	+	2	*Rumex acetosa*		+		+
Potentilla erecta	+	1	+	1	*Rhinanthus minor*		+		+
Trifolium medium	3	3	+	2	*Prunella vulgaris*		1		
Hypericum maculatum	+	1	2	2	*Filipendula vulgaris*		+		
Heracleum sphondylium	+	+	+	+	*Luzula multiflora*		+		
Stellaria graminea	+	+	+	+	*Nardus stricta*		+		
Veronica chamaedrys	+	+	+	+	*Phyteuma spicatum*		+		
Astrantia major	4	1		3	*Crepis biennis*		+		
Anthoxantum odoratum	2	1		3	*Leontodon autumnalis*				3
Festuca rubra	2	2		2	*Carlina acaulis*				1
Alchemilla sp.	1	+		+	*Anthyllis vulneraria*				+
Primula elatior	1	1		1	*Carex flacca*				+
Festuca pratensis	+	1		1	*Centaurea scabiosa*				+
Plantago lanceolata	+	+		2	*Cynosurus cristatus*				+
Campanula glomerata	+	+		1	*Gentiana asclepiadea*				+
Achillea millefolium	+	+		+	*Gymnadenia conopsea*				+
Carex pallescens	+	+		+	*Plantago media*				+
Knautia arvensis	+	+		+	*Platanthera bifolia*				+
Taraxacum officinale	+	+		+	*Leontodon hispidus*				+
Vicia cracca	+	+		+	*Linum catharticum*				+
Poa trivialis	2		+		*Myosotis sylvatica*				+
Ranunculus acris	1			1	*Thymus pulegioides*				+
Phleum pratense	+	2			*Viola canina*				+
Carex sylvatica	+	+			*Trisetum flavescens*	+			+
Cruciata glabra	+	+			*Cardaminopsis halleri*	+		1	+
Lathyrus pratensis	+	+			*Galium mollugo*	+		2	+
Lotus corniculatus		1		1	*Chaerophyllum hirsutum*	2		2	
Luzula luzuloides		1		+	*Veratrum lobelianum*			3	
Trifolium montanum		+		2	*Senecio nemorensis*			2	
Trifolium pratense		+		2	*Polygonatum verticillatum*			1	
Briza media		+		1	*Urtica dioica*			1	
Leucanthemum vulgare		+		+	*Rumex alpestris*			1	
Carum carvi		+		+	*Laserpitium latifolium*			+	
Trifolium repens		+		+	*Tanacetum corymbosum*			+	
Crepis mollis		+		+	*Campanula patula*		+	+	+

Analyses of chemical composition reflected floral differentiation only to a small degree (Table 2). The protein content was highest in sample 3 (125.6 g kg^{-1} of dry matter).

Also in terms of protein content estimated to be digested in the small intestine (PDIN and PDIE), sample no. 3 significantly exceeded others, and was the only one with a shortage of energy compared with protein. It was also characterised by the lowest share of crude fibre (273.6 g kg^{-1} of dry matter) and NDF (476.6 g kg^{-1} of dry matter). This is related to the location of the surface about 300 m above other surfaces and different botanical composition.

Table 2. Chemical composition of cut green forage (g kg^{-1} of DM).

Sample no.	1	2	3	4
Dry matter (g kg^{-1} original matter)	197	250	274	281
Crude ash	84	70	50	83
Crude protein	99	100	126	105
Ether extract	39	44	55	40
Crude fibre	316	305	274	336
ADF	398	390	355	431
ADL	66	79	71	87
NDF	568	543	477	552

Assessed in energy units per milk production (UFL) and meat (UFV), particular samples did not show any difference (Table 3).

Table 3. Estimated nutritive value of green forage (kg^{-1} of DM).

Sample no.	1	2	3	4
UFL	0.68	0.69	0.69	0.68
UFV	0.59	0.60	0.60	0.59
PDIN (g)	61.87	62.7	78.9	65.70
PDIE (g)	67.18	67.77	71.35	68.34

The results of the quality analyses of green forage provide average feeding values similar to those achieved in studies conducted in Poland many years ago, where a similar type of grassland is the basic type in the mountainous areas (Filipek, 1965). It is also higher than the value of mountain hay, according to currently used tables of feeding value of fodder used by INRA (Normy, 2001). The protein content is relatively high while the content of fibre is low. Most probably this is caused by a large herb content whose considerable share compensates for the decrease of the value of the sward caused by late mowing (Bruinenberg *et al.*, 2001). Rich floral composition can be, however, be detrimental to the value of the fodder due to presence of species containing poisonous and anti-nutritional substances. In the meadows in PPN that were studied, some species considered poisonous and harmful occurred, generally in small quantities, except for hellebore (*Veratrum lobelianum*),which was more widespread.

Conclusions

Results of analyses show that the fodder from the Pieniny mountains is appropriate for less intensive, traditional livestock systems. It can also be used as an additive improving digestion in cattle intensively fed with highly-digestible fodder (Bruinenberg *et al.*, 2001). However, chemical analysis of fodder should be supplemented by an assessment of botanical composition due to a possible occurrence of poisonous and harmful plants.

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Content of nutrients in selected herb species on natural meadows

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Abstract

In 1998-2000 in the area of the Olsztyn Lake District (north-eastern Poland), 78 plant communities with high herb variation were analysed. The following plant species were examined: *Alchemilla* sp., *Cirsium oleraceum* and *Heracleum sibiricum* which appear with high density in natural meadow communities located on mineral soil. These plants were often accompanied by valuable grass plants; *Alopecurus pratensis*, *Dactylis glomerata*, *Festuca pratensis* and *Poa pratensis*, as well as plant species which indicate plant community and soil degradation: *Deschampsia caespitosa* and *Holcus lanatus*. Analysed herb species appear as valuable components of meadow swards by enriching fodder with valuable nutrients. High levels of Mn and Fe were found in *Achillea* sp., *Cirsium oleraceum* included high contents of K and Ca whilst *Heracleum sibiricum* mostly accumulated P, K, Mg and Ca. *Cirsium oleraceum* and *Heracleum sibiricum* concentrated high levels of total protein and simultaneously low levels of crude fibre.

Keywords: herbs, natural meadow, nutrients, plant communities

Introduction

Meadows and pastures provide valuable bulky feed and green fodder in summer and hay, silage or hay silage in autumn and winter. The fodder value depends mainly on its floristic composition, which is largely determined by the intensity of land utilisation and the level of fertilisation. In the past decade grasslands have been managed extensively, which has led to the modification of the floristic composition of communities. This in turn may result in the deterioration of their productivity and the quality of fodder (Kryszak and Grynia, 2001). The fodder obtained from land cultivated extensively has lower contents of protein and phosphorus, and a higher level of fibre and lower digestibility. Consequently, theories specifying meadow floristic composition requirements as 50-60 % grass, 20-30 % papilionaceous plants and 10-30 % other plant species (Nösberger *et al*., 1994), which contain more protein and mineral compounds than grass are justified (Tiley and Frame, 1990; Trzaskoś, 1998). Species examined at the right stage of development may have a high quality (Filipek, 1973). The aim of the study was to determine the content of nutrients in *Alchemilla* sp., *Heracleum sibiricum* and *Cirsium oleraceum*, found in large numbers in plant communities of permanent grassland.

Materials and methods

In 1998-2000 research was conducted in grasslands within the Olsztyn Lake District (north-eastern Poland), situated on mineral soils. The research involved grasslands with considerable percentage of selected species of herbs and weeds. Thirty-one grasslands with *Alchemilla* sp., 29 with *Heracleum sibiricum* L. and 18 with *Cirsium oleraceum* (L.) Scop. were selected. The species composition of the greenness was evaluated with the Braun-Blanquet method. Soil samples were collected for physical and chemical analyses and plant samples were collected for nutrient analyses. Results were assessed using analysis of variance based on the Tukey test.

Results and discussion

In the greenness of meadows, the examined species were usually accompanied by valuable grass species such as *Poa pratensis*, *Dactylis glomerata*, *Phleum pratense* and *Festuca pratensis*. Of the papilionaceous plants, the following were represented in large numbers: *Lathyrus pratensis* and *Vicia cracca*, and of the herb group: *Taraxacum officinale*, *Achillea millefolium* and *Plantago lanceolata*. Numerous species were found which are proof of negligence in meadow management. The following, undesired species were found frequently and in great numbers: *Holcus lanatus*, *Deschampsia caespitosa*, *Rumex acetosa*, *Ranunculus repens*, *R. acris* and *Galium mollugo.* The examined plant communities grew on mineral soils of various nutrient content. The soils under communities with *Alchemilla* sp. had the lowest content of nutrients, whereas those with *Cirsium oleraceum* proved to be the most favourable with a high amount of organic matter (65.3 g kg^{-1}) and calcium (0.96 g kg^{-1}) as well as a higher soil pH value (5.8). However, the soils of the communities with *Heracleum sibiricum* had a higher potassium content, which with a low index of its variability, 11.5 % (Table 1), should be considered a characteristic feature.

Table 1. Chemical properties of soils in the communities with selected plants.

Specification	Plants communities with:					
	Alchemilla sp.		*Heracleum sibiricum*		*Cirsium oleraceum*	
	Mv	Cv	Mv	Cv	Mv	Cv
pH_{KCl}	5.3 a	15.2	5.5 ab	14.9	5.8 b	6.3
	g kg^{-1}	%	g kg^{-1}	%	g kg^{-1}	%
Organic matter	45.2 a	49.7	37.4 a	43.8	65.3 b	32.3
N	2.5 a	46.6	2.0 a	43.1	3.4 b	44.3
P	0.04 ns	104.5	0.06 ns	90.4	0.07 ns	89.0
K	0.06 a	49.8	0.13 b	11.5	0.07 a	65.7
Mg	0.08 ab	55.4	0.08 a	56.2	0.12 b	81.5
Ca	0.66 ns	49.3	0.84 ns	100.3	0.96 ns	35.4
Na	0.02 a	40.0	0.02 a	43.5	0.03 b	36.2
	mg kg^{-1}	%	mg kg^{-1}	%	mg kg^{-1}	%
Cu	4.1 a	53.3	3.8 a	40.8	5.7 b	53.1
Mn	180.9 ns	70.8	161.4 ns	49.0	207.9 ns	59.6
Zn	14.7 a	40.0	15.0 ab	60.6	21.2 b	57.8
Fe	2072 ns	62.6	2026 ns	71.6	3179 ns	78.5

a, b, c – Homogenous groups; ns – not significant, Mv – Mean value; Cv – Coefficient of variation (%).

Herb and weed plants are an important element of greenness, particularly where their percentage increases to reach even 30 %. They provide valuable specific compounds, vitamins, enzymes and nutrients. One of the most valuable components is protein, contained in *Alchemilla* sp. (112 g kg^{-1}dry matter (DM)), in *Cirsium oleraceum* (138 g kg^{-1} DM), and *Heracleum sibiricum* (153 g kg^{-1} DM). The protein-rich species contained small amounts of fibre – 173 g kg^{-1} in *Heracleum sibiricum* and 175 g kg^{-1} in *Cirsium oleraceum* (Table 2). The quality of fodder is undoubtedly affected by the content of macro- and microelements. The species in question had a high content of P, K, Mg and Ca. The content of Na, Cu and Zn met the optimum requirements for high quality fodder (Falkowski *et al.*, 1990). The species differed significantly in terms of mineral composition, namely: *Alchemilla* sp. contained significantly more Mn and Fe and significantly less K, Ca and Na, *Heracleum sibiricum* contained higher quantities of P, K and Mg, and *Cirsium oleraceum* – very high quantities of Ca.

Table 2. Content of nutrients in plants (in DM).

Specification	Species					
	Alchemilla sp.		*Heracleum sibiricum*		*Cirsium oleraceum*	
	Mv	Cv	Mv	Cv	Mv	Cv
	g kg^{-1}	%	g kg^{-1}	%	g kg^{-1}	%
Crude protein	112 a	12.8	153 c	11.5	138 b	11.7
Crude fibre	229 b	10.0	173 a	15.2	175 a	14.7
P	3.1 a	23.0	4.9 b	19.5	3.2 a	21.9
K	20.9 a	24.5	39.5 c	21.0	30.9 b	24.8
Mg	2.9 a	19.6	5.3 b	30.0	3.1 a	48.4
Ca	15 a	22.5	33.6 b	17.1	40.6 c	11.2
Na	0.9 a	49.6	1.8 b	19.1	1.9 b	21.4
	mg kg^{-1}	%	mg kg^{-1}	%	mg kg^{-1}	%
Cu	6.5 a	11.6	6.8 a	19.7	9.1 b	29.7
Mn	233.2 b	55.3	77.3 a	55.1	74 a	65.2
Zn	48.9 b	20.7	50.2 b	20.3	37.5 a	24.7
Fe	212.7 b	86.5	131.3	50.6	115.8 a	53.8

a, b, c – Homogenous groups, Mv – Mean value; Cv – Coefficient of variation (%).

Conclusions

In plant communities of natural meadows, examined species were accompanied by: *Poa pratensis*, *Dactylis glomerata*, *Phleum pratense, Festuca pratensis, Lathyrus pratensis* and *Vicia cracca* as well as undesirable species such as *Holcus lanatus*, *Deschampsia caespitosa, Rumex acetosa*, *Ranunculus repens*, *R. acris* and *Galium mollugo*.

Valuable species differed significantly in terms of mineral composition, namely: *Alchemilla* sp. contained significantly more Mn and Fe than is considered as optimal, *Heracleum sibiricum* contained higher quantities of P, K and Mg, and *Cirsium oleraceum* very high quantities of Ca. Mentioned species can be desirable supplements of the mineral composition of fodder, particularly with P, K, Mg and Ca, whose concentration is sometimes several times higher than the optimum requirements.

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Harvest management effects on productivity and forage quality of ten lucerne varieties

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Abstract

The aim of the research (carried out in 2000-2003) was to compare the impact of three different cutting schedules on the productivity and forage quality of ten lucerne (*Medicago* sp.) varieties. Harvest management was as follows: traditional three cut schedule (cutting mainly by stage of plant development, providing stand longevity) – treatment 1; three cut schedule using fixed time intervals – treatment 2; and four cut schedule using fixed time intervals – treatment 3. Ten different lucerne varieties differing in origin and fall dormacy were used (3 local Baltic and 7 American). Results of the four years of lucerne usage showed that the best average lucerne dry matter yield was provided using treatment 1 (P < 0,01). Two fall dormant varieties never provided the 4th cut. Varietal effects on DM yield were more substantial if compared with the harvest management effect. Quality of lucerne could be measured as concentration, or yield per unit area, of nutrition elements. Treatments 2 and 3 appeared more preferable, providing substantially higher crude protein concentrations measured in mg kg^{-1} of dry matter ($t > t_{crit}$). Looking on crude protein yield per ha, treatment 2 showed substantially lower crude protein yield in all the cases. Harvest management practices for lucerne have to be chosen depending on the individual characteristics of the variety used and the season.

Keywords: lucerne, variety, harvest management, yield, quality

Introduction

Cutting of lucerne (*Medicago* sp.) may be scheduled using stage of plant development, fixed time intervals, crown bud development, or combinations of these criteria (Scheaffer *et al*., 1988). Traditionally, a 3 cut schedule has been recommended in Latvia, taking the 1st cut in the bud stage, the 2nd cut in the stage of first flower (10 % flower) and the 3rd cut in the bud to first flower stage, but not earlier than 42 days after the 2nd cut. For better wintering and assuring better yield in the next season, October (October 1-10) is a better cutting time if compared with September (after September 20). Our findings in previous years (1994-2000) showed that a 3 cut schedule (1st cut – bud stage or the 1st ten-day period of June, 2nd cut – early to full bloom stage (generally before July 31), 3rd cut – after the October 1) is very good for obtaining high yields and long alfalfa performance, but it does not provide presentable quality of forage in all the cases (Gaile, 2000). Nowadays there is the possibility to use modern alfalfa varieties with a high regrowth potential in spring and for after cuts, and sufficient winter-hardiness. This provides a chance for choice of more frequent cutting schedule, hence obtaining both high yield and excellent quality of forage.

Materials and methods

Field experiments were carried out at Research and Study farm 'Vecauce' of Latvia University of Agriculture (latitude: N 56°28′, longitude: E 22°53′) from 2000 to 2003 (lucerne was sown in 1999). Soil at the site was clay loam altered by cultivation, with pH_{KC} = 6.3 and containing available for plants P 198 mg kg^{-1}, K 224 mg kg^{-1} and with an organic carbon content 15 g kg^{-1} of soil. Before sowing (1999), mineral fertilisers were applied: 17.5 kg ha^{-1}

P and 33.2 kg ha^{-1} K, but in the spring of 2000-2003: 34.9 kg ha^{-1} P and 99.6 kg ha^{-1} K. Ten lucerne varieties were used: seven varieties bred in North America (Vernal, ABT-205, WL-324, Spredor III, Alfagraze, DK-121HQ, Winterstar) and three varieties bred in Baltic States (Skriveru – Latvia, Karlu – Estonia, Birute – Lithuania). That trial was arranged into 3 replicated randomised blocks, with a plot size of 5 m^2. Harvest management was as follows: traditional three cut schedule (1st cut – bud stage; June 5, 2nd cut – early to full bloom stage; July 24-25 depending on a year, 3rd cut – after October 1; October 1-2) – treatment 1; three cut schedule using fixed time intervals (1st cut – May 25-June 1, 2nd cut – July 10, 3rd cut – August 20) – treatment 2; four cut schedule using fixed time intervals – with 3 cuts mentioned above for the treatment 2, and the 4th cut on the October 10 – treatment 3. Meteorological conditions were generally similar in all the wintering periods, but different in vegetation periods: 2000 – cool and wet, suitable for very high yield formation; 2001 – a little warmer if compared with the meteorological norm in region, and rainy; 2002 – atypical hot and very dry in August and September; 2003 – late, cool and dry spring, hot July and first part of August and with the mild temperatures and rainfalls in September. ANOVA procedures were used for processing the obtained experimental data.

Results and discussion

Results show that the best average lucerne dry matter (DM) yield per season was obtained using treatment 1, i.e., traditional three cut schedule, where the cutting is organised mainly by stage of plant development ($P < 0.01$; Table 1). It is in agreement with the findings of other researchers and our previous findings (Sheaffer *et al*., 1988, Gaile, 2000). If treatments 2 and 3 were compared, the 4 cut schedule did not achieve a substantial average DM yield increase. Two fall dormant varieties – Skriveru and Karlu – never provided the completed 4th cut. Plant height on October 10 of these varieties in the 4 cut nursery were 7-22 cm and 7-17 cm respectively depending on year, and were very uneven within the specific year, while the plant height of the other 8 varieties was 23-44 cm and was uniform within a specific year. Harvest management affected DM yield by 10.60 %, but variety affected yield by 50.73 % ($P < 0.01$). It could be explained by the notable differences among varieties in the rate of regrowth, which in turn is connected with the fall in dormancy rating (FD) of a variety (Table 1).

Table 1. Average dry matter yield per season depending on variety characteristics and harvest management, t ha^{-1}, 2000 to 2003.

Variety – factor A	Harvest management – factor B			Average for A	FD (smaller value – marked dormancy)
	Treatment 1	Treatment 2	Treatment 3		
1. Skriveru	15.83	12.24	11.86	13.31	0.5
2. Karlu	15.56	11.76	12.55	13.29	0.5
3. Birute	18.73	17.48	18.00	18.07	1 … 2
4. Vernal	18.39	15.97	15.92	16.76	2
5. ABT-205	18.85	18.34	18.00	18.40	2
6. WL-324	19.37	18.59	19.11	19.02	3
7. Spreador III	18.10	16.95	16.51	17.19	1
8. Alfagraze	18.64	16.00	16.07	16.90	2
9. DK-121 HQ	16.67	15.93	16.91	16.50	2
10. Winterstar	18.96	17.29	16.75	17.66	2
Average for B	17.91	16.05	16.17		

$\gamma_{0.05A} = 1.41$; $\gamma_{0.05B} = 0.77$; $\gamma_{0.05AB} = 2.45$;

Meteorological conditions of the specific year could be the reason for harvest management choice, too, if we speak about varieties with higher FD ratings. Our results show that on average increasing cutting frequency decreases DM yield and increases forage quality, which is in conformity with the results of other scientists (Berardo *et al*., 1994, Porqueddu *et al*., 2003). The main interest of lucerne growers in Latvia is related to protein (CP). Treatments 2 and 3 appear more preferable, providing similar and substantially higher CP concentrations measured in g kg^{-1} of dry matter ($P < 0.001$; Table 2) if compared with the treatment 1. CP yield per ha per season depends mainly on DM yield per ha (De Falco *et al*., 2003), but also on CP concentration. On average during the 4 experimental years, treatment 1 (3.379 t ha^{-1}) and treatment 3 (3.373 t ha^{-1}) showed similar CP yields, but treatment 2 (3.251 t ha^{-1}) had a substantially lower CP yield per ha ($\gamma_{0,05} = 0.05$).

Table 2. Average crude protein and NDF concentration depending on harvest management and number of cut, mg kg^{-1}.

Number of the cut	Harvest management and nutrition quality of lucerne					
	Crude protein, average from 2000-2003			NDF, average from 2000-2002		
	Treatment 1	Treatment 2	Treatment 3	Treatment 1	Treatment 2	Treatment 3
1st cut	196.54	213.24	214.53	436.35	422.10	415.33
2nd cut	188.98	202.40	201.83	482.56	440.98	433.08
3rd cut	178.28	201.67	203.74	457.49	439.64	440.41
4th cut	-	-	257.88	-	-	298.30

Digestibility and dry matter intake of forage is adversely related to ADF (acid detergent fibre) and NDF (neutral detergent fibre) concentration, respectively. NDF concentration is substantially higher ($P < 0.05$) using treatment 1 in all the cuts (Table 2), but ADF concentration using this treatment is substantially higher in the 1st and 2nd cuts. Difference is not proven statistically for the 3rd cut.

Conclusions

Significantly higher average dry matter yields were obtained using the traditional three cut harvest management (treatment 1), but on the other hand, by using treatment 3 for less dormant varieties (WL-324, ABT-205, Birute) it is possible to obtain a similar yield if compared with treatment 1, but with better quality. The average effect of harvest management on stand density during four years was not notable if treatments 1 and 3 were compared. Consequently, harvest managements should be chosen depending on the peculiarities of the variety used and the season.

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Influence of expression of the multifoliolate trait on quantity and quality of lucerne (*M. sativa L.*) forage

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Abstract

In the present research seven populations were included: two of them with trifoliolate leaves (TF) and five multifoliolate (MF) populations with varying degrees of expression of the multifoliolate trait. Using correlative and regressive analysis relationships between quantity, forage quality, and some morphological traits utilising two cutting regimes: bud stage and early flowering were determined.
MF expression on the basis of dry weight of MF leaves was not correlated with dry matter (DM) yield for both harvest regimes but was positively related with the percentage of leaves in the total biomass (r = 0.45), and (r = 0.65) for bud stage and early flowering stage, respectively. There was a positive relationship between DM yield, and stem number (SN) per m^2 (r = 0.54). The coefficient of plural regression for DM yield, and plant height (PH) in the early flowering stage was definitely higher (r = 0.92).
The relationship between crude protein (CP) and dry weight of MF leaves decreased from bud stage to early flowering (r = 0.66) and (r = 0.57), respectively.
In both cutting regimes a negative relationship was found between MF populations height, and expression of MF trait (r = - 0.72), and (r = - 0.77).

Keywords: lucerne, multifoliolate, genotypes, crude protein, leafiness

Introduction

Experimental work over many years with lucerne has confirmed that the proportion of leaf in the herbage is the main indicator for lucerne forage quality. This trait is connected as with the number in the individual plant, as with leaflet number in one regular leaf.
MF lucerne varieties were created as having ability to improve lucerne forage quality in comparison with the standard TF varieties. MF lucernes have a higher CP content (Bingham and Murphy, 1965; Petkova *et al.*, 1996; Vasileva and Ilieva, 1998) and can compete with TF lucerne in CP yield per unit area.
The objective of this study was to determine correlations between forage quantity and quality and some morphological traits to bud and early flowering cutting regimes.

Materials and methods

The experiment was carried out from 1995 to 1998 at the experimental field of the Institute of Agriculture and Seed Science 'Obraztsov chiflik' – Rousse. Two TF varieties (Nadezhda 2 and Obnova 10) and five MF genotypes (Ax 93/3, Ax 93/5, 4782, 4906, 4910) were subjected to bud and early flowering cutting regimes.
The experiment was a randomized block design with four replications. DM yield, yield components, CP content and MF expression during the four trial years were estimated from four and three cuts to the bud and early flowering stage, respectively. Twenty-five stems were randomly selected from each replication before yield determination. Stems and TF and MF leaves were separately dried and weighed to determine leaf concentration (leafiness) on a dry weight basis. Expression of the MF trait was also quantified on a dry weight of MF leaves per

total leaf dry weight basis. The crude protein content was determined using the Kjieldahl method.

Results and discussion

DM yield and its components varied across the years due to different climatic conditions. Our results showed that the average DM yield for the early flowering harvest regime was higher than for the bud harvest regime. There were no consistent differences between TF varieties and MF genotypes concerning DM yield for both harvest regimes, but DM genotypes had better leafiness (Table 1, Table 2).

MF genotypes were shorter than TF varieties, but MF genotypes produced the same stem number per m^2 as TF lucerne. MF lucerne has been previously found to be shorter (Ferguson and Murphy, 1973) than TF lucerne. Our results showed that within MF genotypes, the MF expression was negatively correlated with plant height (PH) for both harvest regimes ($r = -0.72$ and $r = -0.77$ respectively).

MF expression on a dry weight basis (MF leaf dry weight / total leaf dry weight) was not correlated with DM yield for both harvest regimes but positively correlated with the percentage leaves in the total biomass for bud stage ($r = 0.45$) and early flowering stage ($r = 0.65$), respectively. Within MF genotypes, DM yield was positively associated with stem number (SN) m^{-2} ($r = 0.54$) for the bud harvest regime. For the early flowering harvest regime, SN m^{-2} was not correlated with DM yield. The coefficient of plural regression for DM yield, and PH in early flowering stage was definitely higher ($r = 0.92$). For the bud harvest regime, DM yield was not correlated ($r = 0.19$) with PH.

MF lucerne genotypes had the potential to produce higher quality forage than TF varieties. CP concentration in the total herbage of the MF genotypes was greater than the TF varieties for both harvest regimes. The correlation between CP and dry weight of MF leaves decreased from bud stage ($r = 0.66$) to early flowering ($r = 0.57$). For the early flowering harvest regime, CP concentration was positively correlated with leafiness ($r = 0.58$), but there was no correlation for the bud harvest regime.

Table 1. Average dry matter (DM) yield, MF expression, crude protein (CP), plants height (PH), stem number (SN) m^{-2} and leafiness of two TF varieties and five MF genotypes harvested at bud stage.

Genotypes	DM yield (kg ha^{-1})	MF expression (g kg^{-1})	CP (g kg^{-1})	PH (cm)	SN (m^{-2})	Leafiness (g kg^{-1})
Nadezhda 2	14450	-	206	57	542	424
Obnova 10	14230	-	207	58	548	416
Ax 93/3	14690	301	221	51	567	458
Ax 93/5	14500	390	221	50	553	445
4782	14310	412	223	52	548	431
4906	14860	350	220	52	549	444
4910	14670	340	224	51	579	456

Table 2. Average dry matter (DM) yield, MF expression, crude protein (CP), plants height (PH), stem number (SN) m^{-2} and leafiness of two TF varieties and five MF genotypes harvested at early flower stage.

Genotypes	DM yield (kg ha^{-1})	MF expression (g kg^{-1})	CP (g kg^{-1})	PH (cm)	SN (m^{-2})	Leafiness (g kg^{-1})
Nadezhda 2	20150	-	187	76	514	346
Obnova 10	19380	-	190	78	538	350
Ax 93/3	19980	313	201	70	512	403
Ax 93/5	19320	361	203	68	510	388
4782	18950	369	203	72	512	377
4906	17610	332	200	71	511	384
4910	20200	305	202	71	529	393

Conclusions

MF expression on a dry weight basis (MF leaf dry weight / total leaf dry weight) was not correlated with DM yield for both harvest regimes.

The relationship between CP and dry weight of MF leaves decreased from the bud stage (r = 0.66) to early flowering (r = 0.57).

MF expression was negatively correlated with plant height for both harvest regimes (r = -0.72 and r = -0.77 respectively).

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Forage quality and production in domestic cultivars of alfalfa and red clover

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Abstract

In this paper the production and main quality parameters of domestic cultivars of legumes, 7 cultivars of alfalfa and 2 cultivars of red clover are presented, in comparison to their standards NS-Medijana and Kolubara. The trial was carried out on the experimental field of the Institute for Animal Husbandry, Belgrade-Zemun in 2002, and the results refer to 4 cuts in the first and 4 cuts in the second year of production. In samples taken during the second investigation year the main quality parameters were determined using standard laboratory methods: organic matter, ash, moisture, content of crude protein, crude celulose, crude lipid and NFE. Results were processed and differences determined using LSD test. All domestic cultivars were similar in yield and nutrient composition compared to the standard cultivars.

Keywords: cultivars, alfalfa, red clover, production, quality

Introduction

Alfalfa and red clover are important forage crops. They are used for obtaining good quality livestock and feeds rich in proteins, vitamins and minerals. In the nutrition of animals these two most important species of legumes are used in different forms either fresh (pasturing) or conserved (hay, silage, hay silage, alfalfa meal or pellets). Hay is one of the most commonly used forms of conserved alfalfa and red clover since silage making is more difficult due to lower content of sugars. For successful silage making additives should be used. Besides their importance in animal nutrition they also have a great significance in supplying the soil with nitrogen. The part of the nitrogen, after the removing of these plants, remains in the soil and increases its fertility. In Serbia greater emphasis had been given to red clover but today it has almost been pushed out of production by alfalfa because of its greater production of dry matter, better resistance to drought and longevity.

Materials and methods

The cultivars of alfalfa and red clover were examined on the experimental field of the Institute for Animal Husbandry, Belgrade-Zemun. The trial was arranged according to the random block system in five replicates. We have tested seven cultivars of alfalfa and two cultivars of red clover in relation to their standards. The standard cultivar of alfalfa is NS-Medijana (8), while for red clover it is Kolubara (2). During the first year fertiliser was applied twice by standard agrotechnical norms for degraded black soil. The phenological and morphological characteristcs were monitored. In both years we have measured the production of green mass and dry matter in 4 cuts. The basic parametres of quality were determined by standard laboratory analyses. The results obtained were processed statistically by analysis of variance and the evaluation of significant differences by the LSD test.

Results and discusion

The results obtained for production of alfalfa and red clover for all 4 cuts and total annual production in both years processed in t ha^{-1} are shown in table 1.

Table 1. Dry matter yield of alfalfa and red clover in 2002/2003 per cuts and in total (t ha^{-1}).

Species	Cultivars No.	Icut 2002 - 2003	IIcut 2002 - 2003	III cut 2002 - 2003	IV cut 2002 - 2003	Total 2002 - 2003
Medicago sativa	1	1.30 - .53	1.19 - 3.58	1.63 - 3.28	0.96 - 2.31	5.10 - 13.70
	2	1.28 - 4.80	1.55 - 4.14	2.04 - 3.70	0.88 - 2.54	5.80 - 15.18
	3	1.47 - 4.43	1.09 - 3.75	1.77 - 3.05	0.72 - 2.07	5.10 - 13.31
	4	1.12 - 4.57	1.35 - 3.88	1.88 - 3.52	0.83 - 2.71	5.20 - 14.70
	5	0.85 - 5.26	1.11 - 3.62	1.76 - 2.86	0.87 - 2.15	4.60 - 13.90
	6	1.4 - 4.98	1.40 - 4.01	2.06 - 3.74	0.89 - 2.44	5.73 - 15.16
	7	1.28 - 5.04	1.31 - 3.59	1.92 - 3.10	0.88 - 2.10	5.40 - 13.82
	8	1.43 - 5.19	1.32 - 4.24	2.16 - 3.80	0.98 - 2.93	5.90 - 16.17
	X	1.27 - 4.85	1.29 - 3.85	1.90 - 3.38	0.88 - 2.40	5.34 - 14.49
	$LSD_{0.05}$	1.52 - 1.02	0.15 - 0.66	0.24 - 0.45	0.16 - 0.42	0.51 - 1.83
	$LSD_{0.01}$	2.04 - 1.38	0.20 - 0.90	0.33 - 0.61	0.21 - 0.57	0.68 - 2.46
	Cv (%)	9.28 - 16.41	9.23 - 3.46	9.94 - 10.36	13.93 - 13.70	7.37 - 9.80
Trifolium pratense	1	1.32 - 3.47	1.52 - 2.68	1.18 - 0.89	0.91 - 1.10	4.94 - 8.15
	2	1.10 - 3.71	1.48 - 2.86	1.22 - 1.18	0.99 - 1.30	4.80 - 9.06
	3	1.24 - 4.06	1.43 - 2.76	1.26 - 1.08	1.18 - 1.16	5.12 - 9.07
	X	1.22 - 3.75	1.48 - 2.77	1.22 - 1.05	1.03 - 1.19	4.95 - 8.76
	$LSD_{0.05}$	1.12 - 0.70	0.23 - 1.07	0.20 - 0.22	0.16 - 0.33	0.37 - 1.64
	$LSD_{0.01}$	1.57 - 0.98	0.33 - 1.50	0.27 - 0.30	0.22 - 0.47	0.52 - 2.31
	Cv (%)	6.66 - 13.55	11.5 - 28.04	11.37 - 14.97	10.99 - 20.44	5.42 - 13.63

The results for the yield of dry matter of alfalfa and red clover in 2002/2003 are different regarding the annual yields, as well as the differences among cultivars and their standards. All differences regarding the amount of yield appearing between the cultivars and standards are not statistically significant. All cultivars of alfalfa and red clover had significantly higher yields in the second year of utilisation. In the first year the highest yield was achieved by the cultivars of alfalfa in the third cut, being 1.9 t ha^{-1} on average, and red clover cultivars in the second cut being 1.48 t ha^{-1}. In the second year of utilisation the cultivars of alfalfa had best results in the first cut, that is 4.85 t ha^{-1} on average, while the cultivars of red clover achieved 4.06 t ha^{-1}. Analysing the individual cultivars the highest total yield in the first year of utilisation in alfalfa cultivars had cv. No. 2 being 5.80 t ha^{-1}, and among the cultivars of red clover the cv. No. 3 being 5.12 t ha^{-1}. In the second year the same cultivar of alfalfa achieved highest yield of 15.18 t ha^{-1}. This is lower in relation to the trials of Lukic and Kraljevic (2001), who achieved yields of 18.3 t ha^{-1} dry matter with the cv. NS Slavija. The highest yield among the cultivars of red clover was achieved by the cv. No. 3 (9.07 tha^{-1}).

Table 2. Nutrient contents of the cultivars of alflafa and red clover in the second year of trial (average value for 4 cuts in g kg^{-1}).

Species	Cv. No.	DM	Ash	OM	CP	CC	NFE	CF
Medicago sativa	1	897.5	87.9	809.6	200.6	243.2	301.3	29.8
	2	901.3	81.2	822.5	205.0	264.8	314.1	29.8
	3	900.3	91.8	808.5	200.5	257.6	321.4	29.7
	4	900.6	83.1	817.6	205.2	245.6	318.6	32.5
	5	901.2	87.8	813.4	211.5	245.5	305.2	33.8
	6	906.7	88.6	818.2	195.6	262.7	305.7	33.0
	7	898.7	83.2	815.6	210.4	247.4	316.0	31.2
	8	899.0	81.1	818.0	199.0	275.5	306.5	30.3
Trifolium pratense	1	894.3	91.9	802.4	183.6	196.3	383.5	38.9
	2	892.5	97.8	794.7	181.0	169.2	407.1	37.4
	3	894.4	92.5	801.9	181.4	197.3	384.1	39.2

By chemical analyses we have established the parameters of quality and observed some differences in tested cultivars in relation to their standards.

The highest content of crude protein (CP) in the alfalfa cultivars was found in cv. No. 5 being 211.5 g kg^{-1}, while the lowest CP was found in cv. No. 6 with 195.6 g kg^{-1} DM. The highest content of CP was found in cv. Vertus 195 g kg^{-1} DM (Halling *et al.,* 2002). In red clover cultivars the highest content of CP was found in cv. 1 (183.6 g kg^{-1} DM). The content of CP in Northern European red clover cv. Vivi was 209 g kg^{-1} DM (Halling *et al*., 2002). By the analysis of another significant quality parametre, that is, crude celulose (CC), the highest content was found in cv. No. 2 of alflafa being 264.8 g kg^{-1} and cv. 3 of red clover being 197.3 g kg^{-1} DM. The lowest content of CC occurred in cv. No. 1 of alfalfa (243.2 g kg^{-1} DM) and in the red clover cv. No. 1 (196.3 g kg^{-1}). The content of crude fat (CF), was greatest in the alfalfa cv. No. 5 (33.8 gkg^{-1} DM), considerably higher in relation to the cultivars investigated by Katic *et al*. (2001) who obtained 24.8 g kg^{-1} on average. The cv. No. 3 of red clover had highest content of CF, being 39.2 g kg^{-1}.

Conclusions

In the course of two years of trials all the tested cultivars achieved total yields of dry matter equivalent to those of standard cultivars of alfalfa and red clover. The differences found were not statistically significant. Furthermore, no significant differences were found between newly selected cultivars regarding quality when compared with standard ones.

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Effect of mineral nutrition on red clover forage production

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Abstract

A one-factorial two-year field trial (2000, 2001) was undertaken in order to optimise red clover (cv. Kolubara) mineral nutrition. The effect of phosphorus and potassium fertilisation on dry matter yield and yield components (plant height and leaf area index) was examined. Fertiliser rates were determined according to the Al-method based on soil supply of specific elements and their removal by yield (Ubavić, 1996). The soil nitrogen content was 45 kg ha^{-1}. There were three different phosphorus (P_1, P_2 and P_3, 40, 80 and 120 kg P ha^{-1}, respectively) and three different potassium levels (K_1, K_2 and K_3, 60, 120 and 180 kg K ha^{-1}). The total number of treatments/combinations was 13. In year 1 of the study, the greatest dry matter yield from three cuts was obtained by the NP_1K_2 treatment (16.4 t ha^{-1}), followed by NP_1K_3 and NP_2K_2 (15.7 t ha^{-1} in each case). The lowest DM yield was recorded by the NP_3K_3 treatment (12.2 t ha^{-1}). In year 2, the highest DM yields from three cuts were obtained by the NP_1K_2 and NP_1K_3 treatments (14.5 t ha^{-1} and 14.4 t ha^{-1}, respectively) and the lowest DM yields were obtained by the control treatment (12.2 t ha^{-1}).

Keywords: red clover, mineral nutrition, dry matter yield

Introduction

In the agro-ecological conditions of the Vojvodina Province, particularly on acid soils, red clover (*Trifolium pratense* L.) is an important substitute for alfalfa, the most common and the most important forage crop in the province (Vasiljević *et al*., 2001).
Red clover is a leguminous plant with the ability to fix N and so should receive fertiliser nitrogen at a rate determined by the supply of N from the soil. There is no recent data in domestic literature concerning the rates of P and K fertiliser required for the production of red clover. As a result the rates recommended to farmers are often either inadequate or excessive. Recommendations found in foreign literature cover a wide range of P and K rates. Taylor and Quesenberry (1996) reported that red clover mineral nutrition is significantly affected by particular soil and weather conditions.
The objective of our two-year study was to monitor the affect of different rates of P and K fertilisers on red clover establishment (cv. Kolubara), to enable rational recommendations of fertiliser rates in accordance with particular soil type and agro-ecological conditions.

Materials and methods

The field trial was undertaken during two years (2000 and 2001) using red clover swards (cv. Kolubara). The experiment was a randomised block design with four replicates. Soil analyses showed slight acidity (pH 6.64), mean nitrogen content (0.20 %) and phosphorus and potassium content of 12.10 and 14.0 mg^{-1} 100 g^{-1} of soil, respectively. Fertiliser rates were determined according to the Al-method based on the soil supply of these elements and their removal by yield (Ubavić, 1996). The soil nitrogen content was 45 kg ha^{-1} (determined by the N-min method). There were three different phosphorus (P_1, P_2 and P_3, 40, 80 and 120 kg P ha $^{-1}$, respectively) and three different potassium levels (K_1, K_2 and K_3, 60, 120 and

180 g K ha $^{-1}$). The total number of treatments/combinations was 13 (Control, NP_2, NK_2, P_2K_2, NP_1K_1, NP_2K_1, NP_3K_1, NP_1K_2, NP_2K_2, NP_3K_2, NP_1K_3, NP_2K_3, NP_3K_3).
Experimental unit size was 10 m^2. At technological maturity, dry matter yield (t ha^{-1}) was measured and samples for determining leaf area index-LAI (m^{-2} m^{-2}) and plant height (cm) were taken. LAI was determined on the basis of leaf dry matter weight and leaf area (Sarić *et al*., 1986). The results were statistically analysed using analyses of variance and regression and correlations.

Table 1. Monthly precipitation (mm) and average monthly temperature (°C) for 2001 and 2002 (Rimski Sancevi).

Parameter	Year	Month						Winter	Growing	Annual
		IV	V	VI	VII	VIII	IX	(X-IV)	season	sum
Precipitation	2001	127	75	233	56	30	162	237	683	920
	2002	26	87	27	33	55	46	191	284	465
Long-term average		48	59	83	62	55	39	255	346	601
Temperature	2001	11.2	17.8	18.3	22.3	22.7	16.1	-	18.1	11.9
	2002	11.7	18.1	21.8	23.6	22.2	17.1	-	19.1	14.6
Long-term average		11.3	16.6	19.7	21.4	20.9	16.9	-	17.8	11.0

Results and discussion

During the trial years, the red clover cv. Kolubara achieved high dry matter yields, confirming that the species has a high genetic yield potential under the agro ecological conditions of the Vojvodina Province (Ćupina *et al*., 1997). In year 1 of study, three cuts produced an average dry matter yield of 14.5 t ha^{-1}. In year 2, the average yield was 13.8 t ha^{-1} (Table 2). These results were influenced by the weather conditions during the trial years, most notably by the sum and distribution of precipitation (Table 1).

Table 2. Dry matter yield (t ha^{-1}) on plots receiving various levels of P and K fertiliser.

Treatment	Year						Total yield	
	2001			2002				
	Cut						2001	2002
	I	II	III	I	II	III		
N-Control	7.4	4.0	1.8	7.7	4.5	1.0	13.2	13.2
NP_2	7.7	4.8	2.2	8.2	4.5	1.0	14.7	13.7
NK_2	7.5	4.7	2.0	9.1	4.1	0.9	14.2	14.1
P_2K_2	7.7	4.4	1.8	8.8	4.3	1.0	13.9	14.1
NP_1K_1	7.6	4.7	1.9	8.3	4.3	0.8	14.2	13.4
NP_2K_1	7.6	4.4	1.8	8.6	4.2	0.6	13.8	13.4
NP_3K_1	8.0	5.0	2.3	8.2	4.3	0.8	15.3	13.3
NP_1K_2	8.3	5.5	2.6	8.9	4.8	0.8	16.4	14.5
NP_2K_2	7.6	5.4	2.7	8.8	4.5	1.1	15.7	14.4
NP_3K_2	8.2	5.0	2.3	8.2	4.0	0.7	15.5	12.9
NP_1K_3	8.0	5.2	2.5	9.2	4.5	0.8	15.7	14.5
NP_2K_3	8.0	4.7	2.2	7.9	4.2	0.9	14.9	13.0
NP_3K_3	6.3	4.0	1.9	8.2	4.5	0.6	12.2	13.3
Average	7.6	4.7	2.1	8.5	4.4	0.9	14.5	13.8
LSD 1 %	1.42	1.31	0.47	1.16	0.73	0.06	1.78	1.70
LSD 5 %	2.08	1.93	0.66	1.73	0.93	0.12	2.00	1.85

In the first year of the study, the highest dry matter yield was obtained from the NP_1K_2 treatment (16.4 t ha^{-1}), followed by the NP_1K_3 and NP_2K_2 treatments (15.7 t ha^{-1} in each case). The lowest yield was recorded on the NP_3K_3 treatment (12.2 t ha^{-1}). Highly significant differences were recorded between the control treatment and treatments 7, 8, 9, 10 and 11. In

year 2, the highest yield was obtained by the NP_1K_2 and NP_1K_3 treatments (14.5 t ha^{-1} and 14.4 t ha^{-1}, respectively) and the lowest by the control treatment (12.2 t ha^{-1}), but there were no statistical differences among the applied fertiliser treatments. In all treatments, in both years, the highest yields were recorded in the first cut (7.6 and 4.4 t ha^{-1}), followed by the second cut (4.7 and 4.4 t ha^{-1}) and the very lowest from the third cut (2.1 and 0.9 t ha^{-1}).
Taking the two years together, a significant correlation coefficient (r = 0.69) was found between plant height and dry matter yield. The coefficient between LAI and dry matter yield (r = 0.25) was not significant.

Conclusions

The average dry matter yield in the first and the second year of study were 14.5 t ha^{-1} and 13.8 t ha^{-1}, respectively. In year 1 of study, the highest dry matter yield was obtained by the NP_1K_2 treatment (16.4 t ha^{-1}), and the lowest yield by the NP_3K_3 treatment (12.2 t ha^{-1}).
In year 2, the highest yield was obtained by the NP_1K_2 and NP_1K_3 treatments (14.5 t ha^{-1} and 14.4 t ha^{-1}, respectively), and the lowest by the control treatment (12.2 t ha^{-1}).
A significant correlation coefficient (r = 0.69) was found between plant height and dry matter yield. The coefficient between LAI and dry matter yield was not significant.

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Forage yield and quality of perennial legumes grown for different purposes

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Abstract

Different perennial legumes can be successfully grown in agroecological conditions of the Vojvodina Province, but only lucerne is grown in large-scale production and considered as the most important forage crop in the province. A comparative analysis of yield and forage quality of four perennial legumes grown for forage (15 cm row spacing) and both forage and seed (25 cm row spacing) has been performed in field conditions over a period of three years. Lucerne (*Medicago sativa* L.), sainfoin (*Onobrychis sativa* L.), red clover (*Trifolium pratense* L.) and birdsfoot trefoil (*Lotus corniculatus* L.) have been included in the trial on the basis of previous results.
The obtained results indicated that in the conditions of the Vojvodina Province all of the studied perennial legumes and not just lucerne can produce high yields of quality forage. In the first year of the trial, the highest dry matter yield (an average of three cuts) was achieved with red clover (9.95 t ha^{-1}), followed by sainfoin (9.82 t ha^{-1}) and birdsfoot trefoil (8.32 t ha^{-1}). The lowest yield was produced by lucerne (8.00 t ha^{-1}).
All of the tested species produced a slightly higher dry matter yield in the dense stand (15 cm) compared with the 25 cm row-to-row spacing. Dry matter quality (crude protein, crude fibre, crude fats, crude ash) was determined in the second year.

Keywords: lucerne, sainfoin, red clover, birdsfoot trefoil, yield, quality

Introduction

In the Vojvodina Province, lucerne is the only perennial forage legume in cultivation. It is mostly grown for hay. In recent years, however, lucerne has produced low forage yields significantly below the biological yield potential of the crop. The reasons for these low yields were the lack or unfavourable distribution of rainfall. For successful production of forage lucerne under the climatic conditions of the Vojvodina Province (semiarid climate), the annual precipitation should be higher by 200-250 mm (Bosnjak, 1991).
Most perennial forage legumes produce high yields of high quality forage, with high protein content. Therefore, it seems natural to seek a substitute for lucerne among legumes. Previous results (Cupina *et al*., 1997) directed us to sainfoin and birdsfoot trefoil because of their high drought resistance, while goat's rue was excluded from further study. The aim of this paper was to establish which of the perennial legumes could, if not entirely substitute then at least compensate for the shortage of lucerne forage in dry years.

Materials and methods

The trial was carried out under rainfed conditions on the low-carbon chernozem soil. The experimental design was a two factorial randomized block with four replicates.
Factor A – comprised four plant species: lucerne – *Medicago sativa* L. (cv. NS Banat ZMS-V); sainfoin – *Onobrychis sativa* L. (cv. Makedonka); red clover – *Trifolium pratense* L. (cv. K-17) and birdsfoot trefoil – *Lotus corniculatus* L. (cv. Bokor).
Factor B – comprised two aims for cultivation: for forage (sowing at 15 cm row-to-row spacing) and for forage-seed (sowing at 25 cm row-to-row spacing). The seed rates used were: lucerne – 13.3 kg ha^{-1} for forage and 8.0 kg ha^{-1} for forage-seed, sainfoin – 150 kg ha^{-1} (one-

seed pods) and 90 kg ha^{-1}, red clover – 11.3 kg ha^{-1} and 6.8 kg ha^{-1} and birdsfoot trefoil – 8.0 kg ha^{-1} and 4.8 kg ha^{-1}. Sowing was performed on March 24, 2000. In the course of the trial, dry matter yields (t ha^{-1}) were determined and chemical analyses of forage quality were done (crude protein, crude fibre, crude fat, crude ash and N-free extract matter). The climatic conditions in the three years of the trial (2000-2003) were different.

Results and discussion

Forage yield: The highest dry matter yield in the year of sowing (an average of three cuts) was produced by red clover (11.67 t ha^{-1}), followed by sainfoin (9.82 t ha^{-1}), birdsfoot trefoil (8.32 t ha^{-1}) and lucerne (8.00 t ha^{-1}) (Table 1). The high yields of red clover and sainfoin can be explained by their rapid initial development and, thus, by a high production of forage in the year of sowing (Ivanova-Bandžo and Fidanovski, 1973).

All of the tested legumes achieved the highest yield in the first cutting: 8.32 t ha^{-1} with sainfoin, 6.74 t ha^{-1} with red clover, 5.15 t ha^{-1} with lucerne and 4.35 t ha^{-1} with birdsfoot trefoil. On the three-year average, the largest portion of dry matter (DM) in the yield at the first cut was found for red clover (58.05 %), then for sainfoin (52.79 %), birdsfoot trefoil (44.43 %) and lucerne (41.90 %) (Table 1). Lucerne had the best distribution of forage yield among the cuts over the year.

Table 1. Dry matter yields (t ha^{-1}) of perennial legumes per years of trial (2000-2002), cuts and aims of usage, i.e., per row spacing.

Species	Year			Cut				Row spacing	
	2000	2001	2002	I	II	III	IV	forage 15 cm	forage-seed 25 cm
Lucerne	8.00	12.96	12.00	5.15	3.12	2.06	1.95	12.85	11.73
Sainfoin	9.82	20.87	13.06	8.32	3.90	1.69	1.85	16.09	15.43
Red clover	9.95	20.79	4.29	6.74	3.50	1.37	-	12.23	10.98
Birdsfoot trefoil	8.32	11.08	7.55	4.35	2.68	1.54	1.22	10.44	9.16
Average	9.02	16.42	9.22	6.14	3.30	1.44	1.22	12.95	11.25

In the agroecological conditions of the Vojvodina Province, seed production of forage legumes is more dependent on climatic conditions, primarily the sum and distribution of rainfall during the growing season, than on cultivation practices. Thus, although higher seed yields are obtained with a wide row spacing (50 cm), the growers prefer denser rows (12.5 or 15 cm) because, in the case of bad climatic conditions for seed production, forage yield ensures profitability of the crop.

The results show that the difference between forage yields obtained with 15 and 25 cm row spacings is not significant. The 25-cm row spacing provides better conditions for lucerne seed production. In the thin stand, plants produce more shoots which partially compensate for the smaller number of plants per hectare, and this is significant for forage yield. Therefore, it is recommended that the seed crops of perennial forage legumes in the Vojvodina Province are established for combined use (forage-seed) in 25-cm spacing, and not for the production of forage (15-cm spacing) or seed (50-cm spacing).

Forage quality: For forage production, apart from high yield, high forage quality, i.e., high content of nutrients is important. The perennial forage legumes are known for high content of nutrients and good digestion (Ocokoljic, 1975). All of the tested species had high crude protein content. Lucerne had the highest (19.45 %), then sainfoin (18.08 %), birdsfoot trefoil (17.22 %) and red clover (16.60 %) (Table 2). At the beginning of flowering lucerne had the highest crude fibre content, 26.60 %. An increased portion of crude fibre significantly decreases the nutritive value of lucerne, as a result of fast lignification, especially in the first

cut. Birdsfoot trefoil had the lowest fibre content (25.00 %), then red clover (25.08 %), which is around 6 % less than the content of fibres in lucerne.
Lucerne had the highest mineral nutrient content. Although the quantity of minerals depends on the climatic and soil conditions of the cultivation area, it is evident that lucerne represents the richest source of minerals for the feeding of domestic animals.

Table 2. Chemical composition of forage of perennial legumes.

Species	Content in dry matter (%)				
	Crude protein	Crude fibre	Crude fats	Crude ash	N-free extract
Lucerne	19.45	26.60	1.28	10.36	38.50
Sainfoin	18.08	25.72	1.57	7.16	44.05
Red clover	16.60	25.08	1.41	8.76	43.02
Birdsfoot trefoil	17.22	25.00	2.01	7.88	42.60
Average	17.84	25.60	1.57	8.54	42.04

Conclusions

The highest dry matter yield was achieved with sainfoin, followed by lucerne and red clover. The lowest was achieved with birdsfoot trefoil. Lucerne has the best distribution of forage yield over the year and red clover the worst.
There was no significant difference in yield performance between the sowing at 15 cm and the sowing for combined usage (forage-seed) at 25-cm row spacing.
Chemical analyses showed that the perennial legumes had a high forage quality, but it was the best in lucerne. Sainfoin, except for the relatively high crude protein content, had much N-free extract, i.e., sugars, which enables ensiling and produces high-quality silage.
Generally, sainfoin can substitute lucerne, not only because of its yield height and quality of forage but also because of its adaptability to the agroecological conditions of the Vojvodina Province.

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Hay and silage making losses in legume-rich swards in relation to conditioning

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Abstract

This work aimed to define the effects of mixture composition and determine techniques to reduce qualitative and quantitative losses during silage or haymaking in legume-rich, mixed swards. To do so, drying losses were determined in the 1st and 2nd cuts of different legume-grass mixtures (perennial ryegrass-white clover, perennial ryegrass-red clover, timothy-red clover and cocksfoot-lucerne). The impact of mower type (with or without conditioner) and tedder rotation speed (270 vs. 540 rotations min^{-1} at the power plug) were tested during the 1st and the 2nd cut. Losses, in term of dry matter (DM), were 41 % and 27 %, respectively during hay and silage making. The results highlighted the absence of mower type effect and the importance of tedder rotation speed. Increasing the rotation speed from 270 to 540 r min^{-1} increased protein losses by 11.5 %, without any impact on the final DM content. Grass-legume mixture type had also a significant impact on losses, in terms of quantity and quality, but this factor integrated parameters such as difference in initial DM yield and different leguminous-grass ratio. These preliminary results should be taken into consideration when promoting the use of legume-rich swards, for example in organic farming systems.

Keywords: drying losses, clover, lucerne, mowing method, tedding speed

Introduction

The use of legume rich mixed swards is a way of combining a low level of nitrogen input with a good level of production of protein-rich forage. Thus, in grazed swards, each percent of white clover present has the same impact as fertilisation at the rate of, on average, 2 kg N ha^{-1} y^{-1}. This produces a protein-rich forage with 154 and 127 g of Digestible Crude Protein kg^{-1} DM, obtainable from swards with or without white clover, respectively, but in this later case with a nitrogen fertilisation of 100 kg N ha^{-1} y^{-1} (Limbourg, 2001). As a result, the use of legume-rich swards offers advantages for organic farms.
Nevertheless, although the production potential of legume-rich swards are well known, some questions remain about the effects of mixture composition and the best techniques to employ in order to reduce qualitative and quantitative losses during haymaking. It is well known that legume species easily lose their leaves during drying. Such losses could reach more than 40 % on a dry matter basis, and 50 % on a protein basis, when a pure lucerne sward is balled at a 70 % dry matter content (Ciotti and Cavallero, 1979). These are much greater than the 10 to 15 % losses observed by these authors for pure cocksfoot swards.
The aim of the present work was to quantify field losses during silage and hay making for different legume-grass mixtures, using different conditioning treatments, in order to define the best practices for producing high quality forage in legume-rich grasslands.

Materials and methods

Haymaking losses were determined in the first and second cuts in mixed swards sown on 27 March 2003, after a cereal crop (spelt). Manure, applied at the rate of 30 t ha^{-1} before ploughing, was the only fertilisation. A cleaning cut was done at the end of June. Four mixtures were compared: tetraploid perennial ryegrass (*Lolium perenne* L.) (35 kg ha^{-1}) with a large-leaved white clover (*Trifolium repens* L.) (5 kg ha^{-1}) [LP-TR], tetraploid perennial ryegrass (35 kg ha^{-1}) with red clover (*Trifolium pratense* L.) (5 kg ha^{-1}) [LP-TP], timothy (*Phleum pratense* L.) (20 kg ha^{-1}) with red clover (5 kg ha^{-1}) [PP-TP] and cocksfoot (*Dactylis glomerata* L.) (15 kg ha^{-1}) with lucerne (*Medicago sativa* L.) (20 kg ha^{-1}) [DG-MS].

The first cut was carried out on 4 August (day temperatures, 30-35 °C), to compare two mower materials (management factor), with and without conditioner. Forage was balled 73 hours after cutting. Samples were tedded at 7, 28 and 53 hours after cutting, except for DG-MS, which was tedded at 7 and 28 hours as it already reached 83 % DM content after 28 hours of drying. The second cut was carried out on 24 September (cold night, day temperatures, 20-24 °C), to test the impact of tedder rotation speed on silage making losses. Two speeds were compared: 270 and 540 rotations min^{-1} [r min^{-1}] at the power plug. Forage samples were balled 52 hours after cutting. Samples were tedded after 22, 26 and 46 hours.

The experimental design was a split-plot design with four replicates. The 'mixture' factor formed the main plots, while the 'management' procedures were randomly assigned to sub-plots of 120 m^2. In order to measure changes in forage quality (protein content, enzymatic digestibility (De Boever *et al.*, 1986)), a sample was removed daily until balling, while dry matter (DM) loss was obtained by the difference between DM yield observed before cutting (cut of a 9 m^2 area with an Haldrup harvester) and after balling. Legume leaf, legume stem and grass proportions were measured on a sample taken following initial yield measurement.

Results and discussion

At the first cut (mower comparisons), the DM yields before drying were 3, 5 and 7 t ha^{-1} for lucerne, white and red-clover based mixtures, respectively. The highest DM losses (almost 45 %), were obtained in red clover and cocksfoot-lucerne mixtures. The perennial ryegrass-white clover mixture showed the lowest DM losses (29 %). This difference was significant at P = 0.1 (Table 2). On a protein basis, these losses reached 61 and 39 % for red-clover-lucerne based mixtures and the LP-TR mixture, respectively (Table 1).

Table 1. Mean values of legume proportion in the sward, DM and quality losses during drying in relation to mixture composition and type of management for the first and the second cut. Standard Deviation is given in parentheses.

	Yield (t DM ha^{-1})	Leguminous (% DM)	Leaf (% Leguminous)	Final DM Content (%)	DM losses (%)	Protein losses (%)	Digestibility (% DM)
			1st Cut				
LP-TR	5.0 (0.5)	53.6 (6.0)	35.0 (3.0)	83.0 (0.8)	29.0 (12.5)	39.5 (10.2)	73.2 (1.8)
LP-TP	6.9 (0.7)	75.2 (11.9)	18.2 (3.6)	83.8 (1.1)	43.6 (12.7)	56.4 (14.3)	59.6 (3.7)
PP-TP	6.8 (1.1)	83.6 (5.7)	17.4 (1.9)	83.8 (1.4)	44.3 (14.5)	65.6 (7.0)	52.6 (3.0)
DG-MS	3.0 (0.3)	53.1 (11.5)	37.7 (2.5)	84.4 (0.5)	45.9 (6.8)	62.6 (8.8)	54.7 (3.8)
Without Conditioner				83.6 (0.9)	39.3 (12.9)	55.2 (14.3)	60.4 (9.8)
With Conditioner				84.0(1.3)	42.6 (13.6)	57.4 (14.4)	59.3 (7.5)
			2nd Cut				
LP-TR	3.0 (0.2)	87.2 (5.6)	51.4 (3.5)	41.3 (5.1)	32.5 (9.2)	28.0 (7.4)	86.7 (0.8)
LP-TP	3.1 (0.2)	88.2 (4.7)	45.3 (3.8)	46.4 (6.9)	20.1 (5.6)	24.5 (7.7)	78.7 (0.8)
PP-TP	3.2 (0.3)	90.4 (3.2)	44.8 (3.7)	43.5 (8.3)	30.4 (11.1)	32.8 (12.6)	77.9 (0.9)
DG-MS	2.8 (0.1)	62.5 (9.9)	49.6 (2.0)	61.4 (5.1)	21.0 (11.9)	21.1 (16.8)	71.6 (2.1)
270 rot. m^{-1}				46.0 (10.5)	22.9 (11.6)	21.9 (11.9)	78.7 (6.3)
540 rot. m^{-1}				49.8 (9.6)	30.5 (8.9)	32.4 (9.8)	79.1 (5.2)

These differences were not only linked to the higher legume content of red-clover based mixtures (Table 1), but also to a greater sensitivity of lucerne (tedded only twice) and red-clover leaves to forage manipulation during drying. For red-clover mixtures, characterised by high yields and low clover leaf proportion, such sensitivity may be due to a higher ‘maturity-senescence’ of red clover when compared to white clover. No significant differences were observed between the conditioner treatments, under the conditions specific to this trial (Table 2). However conditioners are used for silage production more than for hay making, so this approach will be performed for the second cut of the year 2004 with silage making.

Table 2. Impact of grass and legume species ‘mixture’ and of forage ‘management’ practices during mowing (1st cut) and tedding (2nd cut) on quantity and quality losses from mowing until balling. df = degrees of freedom. ns = not significant. °, *, ** and *** is significant at *P* = 0.1, 0.05, 0.01 and 0.001, respectively.

	Cut 1		Cut 2	
	$F_{Mixture}$ (3 df, 9 df)	$F_{Management}$ (1 df, 9 df)	$F_{Mixture}$ (3 df, 9 df)	$F_{Management}$ (1 df, 9 df)
Dry Weight Losses	3.2 °	0.1 ns	2.5 ns	8.4 *
Protein content evolution	3.8 *	0.1 ns	2.9 °	2.0 ns
Digestibility evolution	12.3 **	0.0 ns	0.5 ns	1.4 ns
Protein Losses	8.6 **	0.0 ns	1.1 ns	10.8 **
Final Dry Matter content	2.3 ns	0.6 ns	36.0 ***	1.5 ns
Final Protein content	8.2 ***	0.1 ns	45.9 ***	2.4 ns
Final Digestibility	71.9 ***	0.6 ns	256.3 ***	0.1 ns

$F_{Mixture*Management}$ (3df, 9df) values not significant.

In the second cut, testing the impact of tedder rotation speed, DM yields, before drying, were close to 3 t ha^{-1} whatever the mixture. Once again the DG-MS mixture, with a final DM content of 61.4 %, lost moisture significantly (Table 2) more rapidly than the other mixtures (final DM of 43.7 %). For this cut, management factor had a significant impact on DM losses, and on protein and metabolisable energy losses (Table 2). Thus, increasing the rotation speed from 270 to 540 r min^{-1} increased DM and protein losses from 7.6 % and 11.5 % respectively (Table 1). Protein losses at 540 r min^{-1} were more than 30 % higher than those observed at 270 r min^{-1}, with no significant final DM increase (+4 % for the 570 r min^{-1}). From the association point of view, LP-TR and PP-TP showed a ten percent higher (Table 1), even if not significant (Table 2), loss than the two other mixtures. The lower DM losses of DG-MS mixture could be linked to its lower leguminous content (Table 1) while the lower losses of the LP-TP is more difficult to explain.

Conclusions

These were preliminary observations, as this trial will last for another 3 years. The results obtained for the first cut, under very specific conditions (high temperature, high yield), underline the high losses that could be observed during drying in legume-based mixtures. These losses should be taken into consideration in extensive farming systems, like organic ones, where such forages represent the main feedstuffs.

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Annual legumes as green fodder crops

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Abstract

Cultivars of blue, white and yellow lupins, peas, broad beans and vetch were tested for production and feed quality in field trials in Eastern and Central Norway. The lupins all produced less DM and protein than pure stands of peas, vetch and broad beans and their herbage quality was not higher. For example, the concentration of crude protein at fourteen weeks after sowing was below 16.5 % in lupins and about 19 % in peas. The results of the experiments did not indicate any potential for lupins in Norwegian fodder production. Even if the tested legumes produced higher yields of crude protein than that normally obtained from grass/clover leys, there is not much evidence that these legumes will be a high-grade source of protein to ruminants. However, there is no doubt that the net N yield of the investigated legumes is substantially higher than for grass/clover swards.

Keywords: Broad beans, crude protein yield, herbage quality, lupins, N yield, peas, vetch

Introduction

Purchased concentrates constitute about 35 % of the feed used in Norwegian milk production. If this proportion is to be lowered, one option might be to produce more protein locally by including more clover in leys, or by growing annual legumes. Peas in mixture with barley or oat are to some extent used as a fodder crop, whereas lupins and broad beans are not commonly grown in Norway. Due to an increasing interest for alternative protein crops, field trials with annual legumes were carried out in 2001. The aim was to investigate the yield potential and the feed quality of these crops, and in particular to examine whether the yield of protein could be higher than normally obtained from grass/clover leys.

Materials and methods

'Nelly' white lupin (*Lupinus albus*), 'Prima' (Pr) and 'Borweta' (Bor) blue lupin (*L. angustifolius*), 'Juno'' yellow lupin (*L. luteus*), 'Julia' (Jul) and 'Bohatyr' (Bo) peas (*Pisum sativum)*, 'Nitra' vetch (*Vicia sativa*) and 'Aurora' broad beans (*V. faba*) were seeded in pure stand with two replicates in 7 field trials in Eastern and Central Norway. The seeding rates were 150, 150, 100 and 200 kg ha^{-1} for lupins, peas, vetch and broad beans, respectively. Suspensions of *Rhizobium* were mixed into the topsoil just before sowing, one strain for lupins and another strain for beans, peas and vetch. The N fertilisation ranged from 0 to 30 kg ha^{-1}, either supplied from cattle slurry or mineral fertilisers. The corresponding figures for P, K and S were about 30, 100 and 50 kg ha^{-1}, respectively. The field trials were harvested 9 to 14 weeks after seeding.

In vitro digestibility of dry matter (IVDDM) in dried samples (pooled from replicates 1 and 2) was estimated after incubation for 48 h using the ANKOM DAISY^{II} at Vaagones Research Station. The estimates were adjusted according to *in vivo* digestibility of four standard grass samples. Content of ashes, Kjeldahl N, neutral detergent fibre (NDF), water-soluble carbohydrates (WSC) and P, K, S, Mg, Ca, Na, Zn, Fe and Mn were analysed in dried samples by wet chemistry at Holt Research Centre. The content of crude protein (CP) was calculated as Kjeldahl N × 6.25, and a measure of energy concentration (feed units (FU) per kg of DM) was determined according to Lunnan and Marum (1994).

Results and discussion

In tables 1 and 2 data on yields and feed quality for the trial at Kvithamar Research Centre in Central Norway in 2001 are presented. This field trial was infected by fewer weeds and the yields were higher for most legumes than in the six other trials. Peas and broad beans returned considerably higher yields of DM, feed units and crude protein at Kvithamar than the other species (Table 1). The yields from lupins were low in most trials, and the content of crude protein and visual observations of nodulation indicated that N fixation had been low (data not shown). For peas there was great variation between trials. At some sites the plots with peas were severely damaged by diseases or by birds eating the seeds. The yield and feed quality of vetch was as high as for broad beans in trials harvested less than 13 weeks after seeding (data not shown). The high yield of broad beans presented in table 1 was only found in the trial at Kvithamar. The yield of nitrogen, determined as the difference between N harvested and N supplied by fertilisers, was positive for all legumes (Table 1). For beans, peas and vetch the N yield was considerably higher than normally obtained in grassland with optimal clover content (Lunnan, 2000). In a similar experiment at Kvithamar Research Centre in 2002 the yields of yellow and white lupin were higher than in 2001, whereas the growth of the blue lupin 'Borweta' failed completely due to insects and drought. However, more experiments on how to achieve a sufficient nodulation and N fixation are needed before a final conclusion is reached on the yield potential of lupins. No data on feed quality is available from this field trial.

Table 1. Yields of dry matter (DM), feed units (FU) and crude protein (CP) and net yield of N (harvested N - N applied in fertilisers) of legumes grown in pure stand at Kvithamar Research Centre in 2001. The harvest was taken 14 weeks (1237 day degrees, base temperature 0 °C) after seeding. Means marked with different letters were significantly different ($P < 0.05$) according to a Ryan-Einot-Gabriel-Welsch multiple-range test.

Legume	DM yield (kg ha^{-1})	FU ha^{-1}	Yield of crude protein (kg ha^{-1})	N yield (kg ha^{-1})
Yellow lupin	2580 a	2240	340	23
Blue lupin (Pr)	2830 a	2490	470	44
Blue lupin (Bor)	2540 a	2130	350	25
White lupin	3150 a	2770	250	9
Peas (Jul)	7230 bc	7230	1360	187
Peas (Bo)	6820 bc	6620	1270	172
Vetch	4120 ab	3910	830	102
Broad beans	7880 c	6780	1350	184

The content of crude protein and the digestibility of the investigated legumes (Table 2) were not particularly higher than in grass / clover harvested at a recommended stage. The quality and the degradation of the protein during ensiling and in the rumen have not been investigated to any great extent. This would be crucial for deciding whether production of protein in annual legumes is a more profitable strategy than growing perennial grassland. Studies in Great Britain revealed that the protein in red clover has particular qualities, which the leaf protein in beans, lupins and peas do not have, and that the former therefore is less degradable in silage and in the rumen (Jones, 2000).

The contents of minerals in the investigated legumes (Table 3) were in some ways better suited for ruminants than what is normally obtained from grass / clover (Bakken, 1999). Even though the content of S was rather low, the relatively low concentration of K in relation to Ca and Mg together with a high content of Na might be favourable. However, the higher concentration of most minerals in the lupins compared to the other legumes could be caused by lower yields and thus less dilution rather than by specific abilities to retrieve minerals from the soil.

Table 2. Contents of dry matter (DM), CP, WSC, NDF and feed units per kg of DM and in vitro digestibility of dry matter (IVDDM) of legumes grown in pure stand at Kvithamar Research Centre in 2001. The harvest was taken 14 weeks (1237 day degrees, base temperature 0 °C) after seeding. Means marked with different letters were significantly different ($P < 0.05$) according to a Ryan-Einot-Gabriel-Welsch multiple-range test.

Legume	DM (%)	CP (%)	WSC (%)	NDF (%)	FU (kg^{-1})	IVDDM (%)
Yellow lupin	13.8 abc	13.0	14.0	41	0.87	73.1
Blue lupin (Pr)	12.3 a	16.5	16.1	39	0.88	72.9
Blue lupin (Bor)	13.4 ab	13.8	15.2	40	0.84	71.2
White lupin	16.6 bc	7.9	24.1	42	0.88	73.8
Peas (Jul)	17.1 bcd	18.8	18.8	37	1.00	78.2
Peas (Bo)	20.0 de	18.6	23.0	33	0.97	74.8
Vetch	22.0 e	20.1	18.2	34	0.95	74.7
Broad beans	14.9 abc	17.1	17.3	42	0.86	69.0

Table 3. Contents of minerals in legumes grown in pure stands given as LSMEANS for six sites in Eastern and Central Norway. There were significant differences ($P < 0.001$) between species for all minerals except Fe. For P, K, S, Mg, Ca and Na the values are per cent of DM, and the values of Zn, Fe and Mn are given in ppm of DM.

Legume	P	K	S	Mg	Ca	Na	Zn	Fe	Mn
Yellow lupin	0.35	2.4	0.18	0.22	0.78	0.33	41	155	140
Blue lupin (Pr)	0.34	2.2	0.20	0.26	1.32	0.23	28	169	131
Blue lupin (Bor)	0.35	2.1	0.20	0.27	1.44	0.24	32	182	144
White lupin	0.27	2.2	0.13	0.16	0.71	0.27	20	118	428
Peas (Jul)	0.27	1.7	0.09	0.18	0.85	0.19	17	101	22
Peas (Bo)	0.25	1.5	0.08	0.15	0.70	0.18	16	104	17
Vetch	0.32	2.0	0.12	0.21	1.06	0.27	24	105	50
Broad beans	0.27	1.9	0.09	0.18	0.80	0.33	22	118	41

Conclusions

The investigated cultivars of white, blue and yellow lupins all produced less DM, FU and protein yields than pure stands of peas, vetch and broad beans. Neither was the herbage quality any higher. The results did not indicate any potential for lupins in Norwegian fodder production. However, crops as peas, vetch and broad beans should be further investigated.

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Changes in chemical composition and ruminal degradation of whole crop fodder peas with increasing maturity

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Abstract

Whole crop forage peas were harvested at full blooming (H1), when 30 % of the pods had reached full size (H2) and when most pods were fully developed (H3), corresponding to stages 65, 73 and 79 on the BBCH-scale. The DM yield increased from 2.9 to 4.9 t DM ha^{-1} and the proportion of seeds from 0 to 36 % from H1 to H3. The crude protein content was relatively low (118, 149 and 144 g kg DM^{-1} respectively). Although the rumen by-pass fraction of protein decreased with increasing growth stage, the protein value was probably the highest at H3 due to significantly more energy for microbial protein synthesis caused by a higher rate of rumen degradation of NDF compared with what was found at the earlier growth stages. According to the present study, separately grown whole crop fodder peas should not be harvested until most pods are fully developed in order to maximise the yield and nutritive value. However, more studies are needed before final conclusions can be drawn.

Keywords: *Pisum sativum*, growth stage, protein, starch, NDF, rumen degradation

Introduction

Fodder peas are known as palatable and protein-rich crops with a high intake potential due to their low resistance to particle break down during eating and rumination (Dewhurst *et al*., 2000). In Norway, peas are to date most commonly grown in mixtures with barley or oats, and fed as whole crops either fresh or ensiled. The optimal growth stage for harvesting these crops is so far rather poorly defined and might vary according to how yield and quality aspects are weighted. In the study presented here, we have focused on changes in chemical composition and rumen degradability of whole crop peas alone. The overall aim is to use these results together with knowledge of changes in the quality of the cereal component to give guidelines for the appropriate growth stage to harvest the bi-crops.

Materials and methods

A white-flowering forage pea (*Pisum sativum*, cv. 'Bohatyr') was grown in a pure stand with two replicates at Kvithamar Research Centre, Stjørdal (63°30'N, 10°52'E) in 2002. The crop was sown on 8 May (180 kg seed ha^{-1}), fertilised (30 kg N, 25 kg P and 100 kg K ha^{-1}), and harvested on three occasions (H1, H2 and H3) every second week between 3 July and 31 July during a warm and dry summer. The mean temperatures in June and July of 15.8 and 16.1 °C were on average 3.3 °C above normal for the site. The first harvest was taken when open flowers were visible at 50 % of the side stems.

At harvest, growth stage was determined according to the BBCH-scale (Meier, 1997) and dry matter (DM) yield of the whole crop recorded. Samples were separated into leaves, flowers, stems and tentiles, pods and seeds before drying. Other samples of the whole crop from both replicates were mixed, and frozen at -25 °C and thereafter freeze-dried. Rumen degradation measurements were conducted at the Norwegian Agricultural University, Ås, with three cows, applying incubation times of 0, 2, 4, 8, 16, 24, 48 and 72 hours as described by Prestløkken (1999). The feed samples and their residues after rumen incubation were analysed for contents of nitrogen according to the principle of Dumas (968.06, AOAC, 2002), starch (including free glucose) as described by McCleary *et al*. (1994) and neutral detergent fibre (NDF) as described by van Soest *et al*. (1991) using the ANKOM 220 Fibre Analyser (ANKOM Technol. Corp., Fairport, NY, USA) with use of sodium sulphide and α-amylase.

Results and discussion

The first harvest (H1) was taken eight weeks after seeding. No seeds were then developed. Two weeks later (at H2) 30 % of the pods had reached full size, but seeds constituted only 8 % of DM. After 12 weeks of growth (at H3), most pods were fully developed and seeds constituted 36 % of the DM. The whole crop yield was higher after 12 weeks of growth than that obtained by Nesheim and Bakken (2004) in an experiment conducted the year before. On the other hand, the content of CP (Table 1) was generally lower than reported in other studies (Fraser *et al*., 2001; Rondahl and Martinsson, 2002; Salawu *et al*., 2002; Nesheim and Bakken, 2004). As our method for starch determination differs from most of them referred to in other studies on pea composition, it is not straight forwards to compare our results with those obtained by other authors. Still, it was expected that contents of starch in the whole crop would increase with increasing proportion of seeds (Åhman and Graham, 1987).

Table 1. Dry matter content (DM), DM yields and composition of whole crop peas harvested at three growth stages. Standard deviations are given in parentheses.

Harvest	H1	H2	H3
Growth stage on BBCH-scale	65	73	79
DM (g kg^{-1})	143 (6.3)	184 (3.3)	192 (2.4)
DM yield (t ha^{-1})	2.9 (0.25)	4.6 (0.66)	4.9 (0.43)
Seeds (% of DM yield)	0 (0)	8 (0)	36 (0)
Leaves (% of DM yield)	46 (4)	28 (1)	17 (1)
Stems (% of DM yield)	48 (4)	39 (0)	26 (0)
Crude protein (g kg DM^{-1})	118	149	144
Starch (g kg DM^{-1})	192	146	244
Neutral detergent fibre (NDF) (g kg DM^{-1})	317	362	308
Ash (g kg DM^{-1})	59	63	41

The decrease in the whole crop NDF from H2 to H3 may partly reflect the reduction of the proportion of leaves and stems. On the other hand, the proportion of pods was higher at H3 than H2, and contents of non-starch polysaccarides are found by others to be relatively high in pods (Åhman and Graham, 1987). Åhman and Graham (1987) have also shown that both chemical composition and the proportions of the different fractions of the plants may differ significantly between years. The extraordinary weather during the growth period in the present study might have caused the elevated yields and lowered CP contents.

Stage of maturity at harvesting affected the extent of rumen degradation of protein and NDF (Table 2). The protein degradation increased with increasing maturity at harvesting, with the effects most pronounced for the water soluble and rapidly degradable fraction (0 h) and after 4 h rumen incubation. There were no significant differences between H1 and H2 after 16 h of incubation. The degradation rate as well as the extent of rumen degradation of NDF was highest for H3 and lowest for H2. In contrasting crude protein and NDF, only minor effects of harvesting time on rumen degradation characteristics of the starch fraction were found. The fact that water soluble and easily degradable glucose was included in the starch fraction may partly explain why more than 78 % of the starch was degraded already after 4 h incubation.

Table 2. Extent of *in situ* rumen degradation of crude protein, starch (including free glucose) and neutral detergent fibre (NDF) of whole crop peas harvested at three growth stages. Mean values obtained from three cows.

Incubation time (h)	Rumen degradation (g kg^{-1} crude protein, starch or NDF)								
	Crude protein			Starch			NDF		
	0	4	16	0	4	16	8	24	48
H1	457	561	828	645	869	961	297	491	506
H2	532	644	813	695	857	976	265	354	421
H3	646	723	871	682	785	764	112	589	612

Thus, the highest extent of carbohydrate (starch, glucose and NDF) degradation in the rumen, imply that the highest energy value was obtained at the latest harvesting time (H3). Although the rumen by-pass fraction of protein decreased with increasing growth stage at harvesting, the protein value is probably also the highest at H3 due to significantly more energy for microbial protein synthesis.

Conclusions

According to the present results, separately grown whole crop peas should not be harvested until most pods are fully developed in order to maximise DM yield and nutritive value. When bi-cropped with barley or oats, the energy and protein values of the cereals at the same stage of growth must also be taken into consideration. It is also possible that the optimal stage of harvest will be different for other pea varieties, other sites and weather conditions. It is important to note that chemical analyses and rumen degradation measurements were based on only one sample from each harvest. The final conclusions from this study will therefore not be drawn until more data from the study, which also included a semi-leafed variety of fodder peas as well as barley and oat, are analysed.

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Qualitative characteristics of sulla (*Hedysarum coronarium* L.) at different development stages

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Abstract

The effects of development stage on qualitative characteristics of a commercial variety of sulla (Grimaldi) were evaluated. The crops were grown in a calanchive area of the hills of Bologna (North Italy) at 300 m above sea level. During the second year of cultivation, the crop was harvested at four development stages: early flowering, full flowering, seed pod and ripe seed pod to evaluate the qualitative characteristics of the forage. The analyses evidenced a decrease of protein content (from 217 to 156 g kg^{-1} DM) and water soluble carbohydrates (from 106 to 70 g kg^{-1} DM) and an increase of crude fibre (from 217 to 312 g kg^{-1} DM) with the advancing of plant maturity.
Detailed studies on phenolic composition, performed by HPLC and pyrolysis/gas chromatography/mass spectrometry, showed that the content of total free phenols significantly increased at ripe seed pod stage (from 0.55 to 0.91 g kg^{-1} DM) as did that of the alkali labile lignin (from 2.60 to 3.76 g kg^{-1} DM), whereas the total content of alkali resistant lignin significantly increased at each development stage (2.37, 3.99, 7.48 and 9.32 g kg^{-1} DM, respectively). Changes from simpler to more complex phenolic structures were also observed with the advancing of plant maturity.

Keywords: chemical composition, development stage, fibre, *Hedysarum coronarium* L., pyrolysis/gas chromatography/mass spectrometry, sulla

Introduction

In North Italy, in marginal hilly areas where intensive cultivations of traditional forages do not fit suitable environmental conditions, sulla (*Hedysarum coronarium* L.) can represent a valuable alternative crop for its adaptability to grow under unfavourable conditions, such as clay and calcareous soils, and semi-arid climate. As with all legume forages, sulla is characterised by high protein and lignin contents and relatively low sugar percentage. Lignin exerts negative effects on forage digestibility, depending on its amount and monomeric composition (Reeves, 1985). Low molecular phenolic compounds may be another factor responsible for low quality of forages reducing the growth of fibre digesting bacteria and fungi (Chesson *et al*., 1982). In our work, qualitative analyses and detailed studies of phenolic composition, by HPLC and pyrolysis/gas chromatography/mass spectrometry, were performed on cultivated sulla.

Materials and methods

A commercial variety of sulla (Grimaldi) was sown at the beginning of March 1997 in the hills of Bologna (North Italy) at 300 m asl The trial used a factorial design with two replicates. The plants were harvested at the second year of cultivation at the following development stages: early flowering, full flowering, seed pod and ripe seed pod (12^{th}, 18^{th}, 27^{th} of May and 1^{st} of June, respectively). Part of the samples of green forages were oven dried at 60 °C and ground to be analysed for crude fibre (CFb) by Weende method, crude fat (CF) by Soxhlet extraction, ash as residue after 2 h at 550 °C, fibrous fractions (NDF, ADF, ADL) by the Goering and Van Soest method, free phenols, alkali labile and alkali resistant lignin by HPLC, lignin constituents by PY-GC/MS .The other part was stored frozen prior to being analysed for dry matter (DM) by oven drying at 105 °C, for crude protein (CP) by Kjeldahl method and water soluble carbohydrates (WSC) by HPLC. Statistical analysis of variance and Duncan's test were performed.

Results and discussion

The development stage greatly affected sulla composition (Table 1). From the first to the fourth harvest, in a period of about three weeks, DM varied from 105.6 to 193.7 g kg^{-1}. Early flowering sulla showed a good CP content (217.3 g kg^{-1} DM), which significantly decreased with maturity; while the CFb amount increased from the first to the last harvest with significant differences (from 217.0 to 311.6 g kg^{-1} DM). Earlier harvested sulla contained a relatively high WSC content (106.2 g kg^{-1} DM), that decreased between the first and the second harvest and then remained constant. Fibrous fractions were found at high percentages and scarcely influenced by the developmental stage of the plants. These findings are in good agreement with those reported for wild sulla grown in the same area (Piccaglia *et al*., 2003) and relatively high in comparison with the values obtained in other studies (Borreani *et al*., 1999).

Table 1. Chemical composition of fresh sulla at four development stages[s].

Stage of harvesting	DM (g kg^{-1})	On DM (g kg^{-1})							
		CP[x]	CF	CFb	ash	WSC	NDF	ADF	ADL
Early flowering	105.6^{cC}	217.3^{aA}	33.6	217.0^{c}	140.6	106.2^{a}	509.0^{c}	361.4	150.7
Full flowering	144.3^{bBC}	196.6^{bAB}	28.4	256.5^{bc}	129.3	70.0^{b}	533.5^{bc}	376.8	142.5
Seed pod	155.5^{bAB}	180.6^{bBC}	27.0	288.7^{ab}	122.7	53.9^{b}	569.1^{ab}	411.7	145.8
Ripe seed pod	193.7^{aA}	155.7^{cC}	28.3	311.6^{a}	110.4	69.9^{b}	580.0^{a}	416.1	138.0

[s] Means within columns with common superscripts are not different (a, b, c: $P \leq 0.05$; A, B, C: $P \leq 0.01$) according to Duncan's multiple range test.
[x] CP-crude protein, CF-crude fat, CFb-crude fibre, WSC-water soluble carbohydrates, NDF-neutral detergent fibre, ADF-acid detergent fibre, ADL-acid detergent lignin.

Table 2. Free and lignin phenols characterized by HPLC[s].

Stage of harvesting	Free phenols (g kg^{-1} DM)				Alkali labile lignin (by HPLC) (g kg^{-1} DM)				Alkali resistant lignin (by HPLC) (g kg^{-1} DM)			
	H[x]	G	S	Total	H	G	S	Total	H	G	S	Total
Early flowering	0.27^{A}	0.17^{b}	0.36^{B}	0.60^{B}	1.05^{A}	0.72	0.77^{cB}	2.54^{B}	0.38^{a}	1.07^{D}	0.93^{C}	2.37^{D}
Full flowering	0.21^{B}	0.14^{b}	0.33^{B}	0.53^{B}	0.73^{B}	0.83	1.03^{bcB}	2.59^{B}	0.41^{a}	2.01^{C}	1.57^{B}	3.99^{C}
Seed pod	0.15^{C}	0.19^{b}	0.33^{B}	0.52^{B}	0.45^{C}	1.04	1.17^{bB}	2.65^{B}	0.23^{b}	3.39^{B}	3.86^{A}	7.48^{B}
Ripe seed pod	0.28^{A}	0.30^{a}	0.58^{A}	0.91^{A}	0.27^{D}	1.30	2.19^{aA}	3.76^{A}	0.25^{b}	5.18^{A}	3.90^{A}	9.32^{A}

[s] Means within columns with common superscripts are not different (a, b, c: $P \leq 0.05$; A, B, C: $P \leq 0.01$) according to Duncan's multiple range test.
[x] H-p-hydroxyphenyl units; G-guaiacyl units; S-syringil units.

The studies on phenolic composition gave very interesting results. In particular, HPLC analyses (Table 2) showed important changes in the total amount and in the distribution of phenolics at the four development stages. The content of total free phenols remained quite constant in the first three development stages (about 0.55 g kg^{-1} DM) while it significantly increased at the ripe seed pod stage (0.91 g kg^{-1} DM). The same trend was observed for the alkali labile lignin (from about 2.60 to 3.76 g kg^{-1} DM). The total content of alkali resistant lignin, the 'core' lignin, negatively correlated with digestibility (Buxton and Russel, 1988), significantly increased at each development stage (2.37, 3.99, 7.48 and 9.32 g kg^{-1} DM,

respectively) and was characterized by a continuous increase of guaiacyl (G) and syringyl (S) moieties. These trends were also observed for free phenols and alkali labile lignin, indicating that all the phenolics are subjected to structural changes from simple to more complex forms.
Also the PY/GC/MS analyses, known to be faster and cheaper than the HPLC ones, evidenced significant differences in the relative abundance of C, G and S derivatives (Table 3) and, on the whole, confirmed the increases of guaiacyl (G) and syringyl (S) units during the sulla growth in samples having very similar lignin contents.

Table 3. Sulla characterized by PY/GC/MS[s].

Stage of harvesting	Sulla constituents (by PY/GC/MS) (area %)			
	C[x]	H	G	S
Early flowering	26.1^{aA}	2.5	56.2^{B}	14.9^{b}
Full flowering	21.9^{bAB}	2.4	57.2^{B}	18.6^{ab}
Seed pod	18.7^{bBC}	1.9	61.1^{A}	18.4^{ab}
Ripe seed pod	13.8^{cC}	2.2	61.8^{A}	22.3^{a}

[s] Means within columns with common superscripts are not different (a, b, c: $P \leq 0.05$; A, B, C: $P \leq 0.01$) according to Duncan's multiple range test.
[x] C-carbohydrate units; H-p-hydroxyphenyl units; G-guaiacyl units; S-syringyl units.

Conclusions

The results showed that the determination of total lignin content alone, is not sufficient to evaluate sulla forage quality, but there is the need for more detailed information of all the phenolic compounds.
HPLC and PY/GC/MS analyses provide results in good agreement: the first with specific characterizations of phenolics, and the second with very rapid information on the trends of these compounds.

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Diurnal fluctuations in vertical distribution of chemical composition in a perennial ryegrass *(Lolium perenne* L.) sward during the season

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Abstract

The quantity and quality of milk is related to the amount and quality of ingested herbage, which is a function of the chemical composition of the grass and of factors such as herbage allowance and bite depth. The objective of this study was to compare the concentrations of protein, water-soluble carbohydrates (WSC) and neutral detergent fibre (NDF) of two cultivars of perennial ryegrass (*Lolium perenne* L.) at different canopy heights during the day, and during the growing season. On 17 July, 9 August and 4 September, the total aboveground biomass of two cultivars was harvested at 8:00, 15:00 and 20:30 h. The canopy was cut into layers at 5, 10 and 15 cm from ground level in the laboratory. Concentrations of protein, NDF and WSC were determined and no differences among cultivars were observed. The protein concentration did not differ during the day, but the NDF and WSC concentrations did fluctuate, NDF being higher and WSC lower in the morning compared to the evening. The protein concentration had a steep gradient with canopy height, being highest in the top layer. The WSC concentration also had a gradient with canopy height, but there was an interaction with season. In July the WSC concentration was highest in the stubble, but in September it was lowest in the stubble (0-5 cm). The largest increase in WSC concentration during the day was observed in the top layer (> 15 cm).

Keywords: diurnal fluctuation, seasonal variation, perennial ryegrass, canopy height

Introduction

Grass is an important cattle feed, and an insight into changes in grass quality is needed to optimise grazing management. Variation in the quality of fresh grass is a problem in modern farming systems. Farmers try to optimise the diets of dairy cows as much as possible, to maximise the conversion of feed to milk. Fresh grass quality is very variable and depends on many factors such as weather conditions and fertilisation. The summer diet of Dutch dairy cows consists mainly of fresh grass. Most Dutch farmers use a rotational grazing system, in which a paddock is grazed down in 3 or 4 days. Because cows graze in layers, or so-called horizons (Wade, 1989), it is important to know the vertical distribution of chemical composition of the sward. The objective of this study was to compare the concentrations of protein, water-soluble carbohydrates (WSC) and neutral detergent fibre (NDF) of two cultivars of perennial ryegrass at different canopy heights during the day, and during the growing season.

Materials and methods

In the summer of 2001, herbage of two diploid perennial ryegrass cultivars (Agri and Barnhem) was harvested in a field trial in Wageningen, the Netherlands. Herbage was harvested in the morning between 7:00 and 9:00h, in the afternoon between 14:00 and 16:00h, and in the evening between 19:30 and 21:30h on 17 July, 9 August and 4 September. These were the third, fourth and fifth cut respectively. Grass was harvested after 20 days regrowth. The total aboveground biomass was harvested from two 0.5 × 0.215 m quadrates per plot using a knife. The samples were collected in a plastic bag, taking great care to preserve the vertical structure of the sward. The samples were stored in a cool box until the harvest was finished. In the laboratory the harvested material was cut using a paper cutter into four layers (0-5, 5-10, 10-15 and > 15 cm). The material was weighed and stored at -20 °C. In total, 144 samples were freeze-dried, ground through a 1 mm mill and analysed by near infrared reflectance spectroscopy (NIRsystem5000, FOSS Benelux ltd., Amersfoort) for protein, NDF and WSC. Data were statistically analysed using a four-way ANOVA, with 4 layers, 2 cultivars, 3 dates and 3 sampling-moments as factors.

Results

As no differences in chemical parameters between the two cultivars were observed, mean values are presented. Figure 1 shows the effect of time of the day on protein concentration, NDF and WSC. The protein concentration (Figure 1a) did not have a diurnal pattern, but there was a steep gradient with canopy height. The lowest ($P < 0.001$) protein concentration (78 g kg^{-1} DM) was found in the stubble (0-5 cm) and the highest concentration (208 g kg^{-1} DM) in the top layer (> 15 cm). NDF (Figure 1b) and WSC concentrations (Figure 1c) fluctuated during the day, NDF being highest ($P < 0.001$) in the morning and WSC highest ($P < 0.01$) in the evening. This effect was observed in every layer. The largest ($P < 0.001$) diurnal fluctuations were observed in the top layer, where the NDF concentration decreased from 519 to 460 g kg^{-1} DM and the WSC concentration increased from 62 to 133 g kg^{-1} DM.

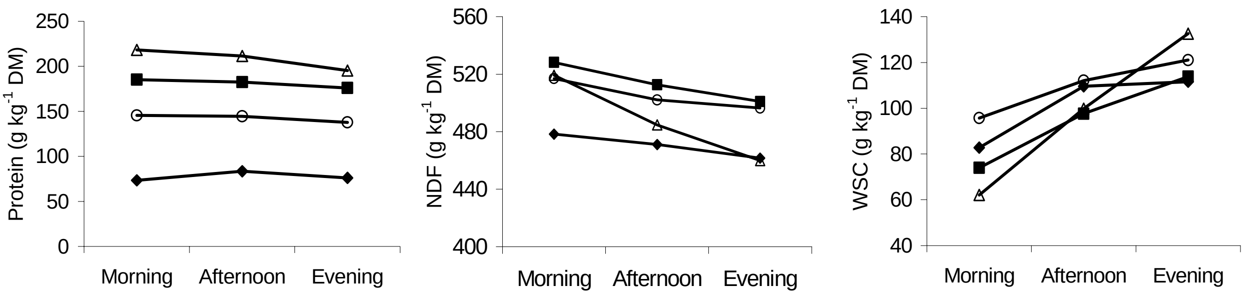

Figure 1. Protein (A), NDF (B) and WSC (C) concentration (g kg^{-1} DM) in four canopy layers of perennial ryegrass sward during the day. ♦: 0-5 cm, ○: 5-10 cm, ■: 10-15 cm, Δ: >15 cm.

The effect of season on protein concentration, NDF and WSC is shown in figure 2. The protein concentration (Figure 2a) increased ($P < 0.001$) from July to September. The largest ($P < 0.001$) increase, from 188 to 229 g kg^{-1} DM, occurred in the top layer. The NDF concentration (Figure 2b) did not show a clear trend during the season. The WSC concentration (Figure 2c) decreased ($P < 0.001$) from July to September in all layers, but the decrease was strongest ($P < 0.001$) in the stubble. In July, the WSC concentration was highest in the stubble (147 g kg^{-1} DM), but in September it was lowest in the stubble (58 g kg^{-1} DM).

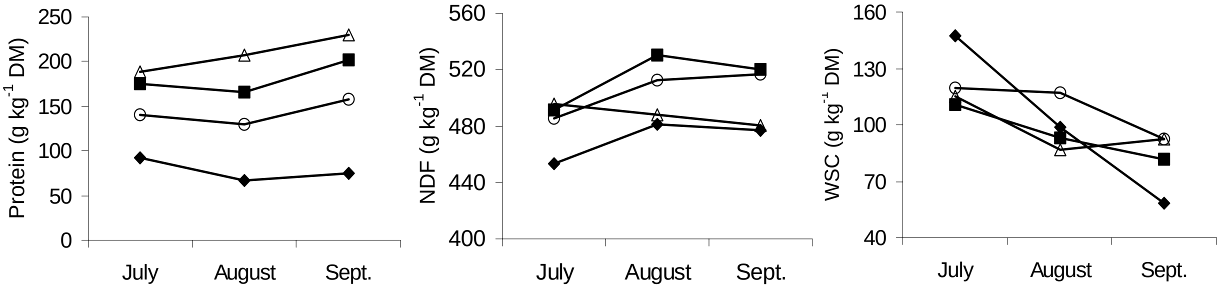

Figure 2. Protein (A), NDF (B) and WSC (C) concentration (g kg^{-1} DM) in four canopy layers of perennial ryegrass sward during the season. ♦: 0-5 cm, ○: 5-10 cm, ■: 10-15 cm, Δ: >15 cm.

Discussion and conclusions

Contrary to expectation, no difference between cultivars was found. In a cutting trial in 2000 (unpublished results), the two cultivars did differ in the WSC concentration, but during 2001 this difference was diminished. The strongest diurnal increase in WSC occurred in the top layer of the sward, where most radiation is intercepted. Delagarde *et al.* (2000) found similar results and noted that in rotational grazing systems it could be beneficial for dairy nutrition to turn cows into a new paddock in the evening. This would increase the ingestion of soluble sugars and synchronise the energy to nitrogen balance, especially with the high protein concentration present in the upper layer of the sward. The lower sward horizons have decreased protein concentrations. This could have nutritional implications such as effects on fermentation end products when cows graze down into the sward (Taweel *et al.*, 2003). In rotational grazing systems, protein availability decreases dramatically over the 3 or 4 days that cows are grazing down the sward. Nutritional feeding schemes do not take this into account, but by feeding dairy cows increasing protein levels in supplementary concentrates during the course of the grazing cycle, nitrogen utilisation may be increased. There was a seasonal trend towards an increase in protein concentration and a decrease in WSC concentration, while the NDF concentration showed little change. This effect agreed with observations by Delagarde *et al.* (2000). NDF and WSC are energy sources for herbivores, while protein is the nitrogen source. Increasing protein and decreasing energy might affect the nutritional status of the dairy cow. The largest decrease in WSC during the season occurred in the stubble. Frequent defoliation can deplete the WSC concentration in the stubble (Donaghy, 1998) and this along with decreasing intensity of radiation may have caused the WSC decrease in the stubble.

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Accumulation of water soluble carbohydrates in two perennial ryegrass cultivars at nine European sites

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Abstract

Yields of dry matter (DM) and water soluble carbohydrates (WSC) were determined in two varieties (AberDart and Fennema) of perennial ryegrass (*Lolium perenne* L.) grown in small-plot field experiments at a total of nine sites in Norway, Sweden, Germany, UK and Ireland. AberDart, which had been bred to accumulate high levels of WSC and Fennema, which was a standard variety which accumulates normal levels of WSC, were investigated in a three- or four-cut silage system in the first year of ley. Trials were established in 2000 or 2001. Compared to Fennema, AberDart had significantly lower total DM yields at five sites and a significantly greater DM yield at one site. A strong interaction ($P < 0.0001$) between variety and site was found. The WSC content of AberDart averaged 14 % greater (25 g kg^{-1} DM) than that of Fennema across sites and harvests. Compared to DM yield, there was a reduced differential between the two varieties in terms of total WSC yield per hectare. Thus the WSC yield of AberDart was significantly greater than that of Fennema at two sites, but significantly lower than Fennema at only one site ($P < 0.01$). A strong interaction ($P < 0.0001$) between variety and site was also observed for total WSC yield. It was concluded that Aberdart did not accumulate significantly greater yields of WSC than Fennema under all conditions, as evidenced by the strong genotype × environment interaction.

Keywords: forage grass, *Lolium perenne*, water soluble carbohydrates (WSC), genotype × environment

Introduction

The water-soluble carbohydrate (WSC) fraction is the primary source of readily available dietary energy in temperate grasses and the discovery that grasses with high levels of WSC could be used more efficiently by livestock lead to the development of novel perennial ryegrasses varieties which accumulate elevated levels of WSC (Humphreys, 1989). These varieties have been shown to enhance milk production (Miller *et al*., 1999). Humphreys (1989) found that WSC was consistently positively correlated with dry matter digestibility and feed intake, but negatively correlated with crude protein and showed little correlation with dry matter production. The appeal of the high WSC grasses lies in their potential to make protein synthesis in the rumen more efficient through matching protein and energy supply more closely, and so help reduce nitrogen losses to the environment. However, it is not known whether the genetic potential to accumulate high levels of WSC is expressed under all conditions. The objective of this study was to determine the effect of temperature, light intensity and photoperiod under field conditions on the DM yield and accumulation of WSC in grasses with elevated and normal WSC contents.

Materials and methods

Nine small-plot field experiments were established in the spring of 2000 or 2001 at three sites in each of Norway (Kvithamar, Fureneset and Saerheim) and Sweden (Ultuna, Rådde and Tvååker) and one site in each of Germany (Völkenrode), Great Britain, Wales (Trawsgoed) and Ireland (Grange). The experiments were of a single-factor randomised block design with two to eleven varieties and four replicates, except at Grange, which had six replicates. At all sites, the perennial ryegrass varieties AberDart, bred for high WSC accumulation and the control variety Fennema, were established. Plots were fertilised with a total of 295, 357, 240, 170 and 265 kg N ha^{-1} in Wales, Ireland, Sweden, Germany and Norway, respectively. P and K were applied according to the plant available levels in the soil. Three cuts were taken, except for Wales and Ireland were four were taken, by using plot mowers. The date of first cut was based upon growth stage of Fennema when it was in stage of early booting. On each harvest date, plots were mown at the same time during the day in each cut, 1300 h or at some sites 1400 h. The weight of fresh biomass from each plot was thereafter recorded. Immediately upon cutting, 1 kg sub-samples were taken, placed on ice and transported to the laboratory whereupon the samples were dried at 60 ^{o}C, or stored at -20 ^{o}C prior to oven drying at 60 ^{o}C. Dried samples were milled through a 1 mm steel mesh and analysed for dry matter (DM) and WSC. WSC analyses were done on all plots at each harvest. NIRS was used for determination of WSC in each country, except for Ireland where a phenol / sulphuric acid assay was used. The NIRS WSC results are preliminary and not yet calibrated between the countries. The SAS procedure Mixed was used (SAS, 1997) for the statistical analysis of data where variety and site were set as fixed factors and the effect of replicate was set as a random factor in the model.

Results and discussion

The total yields of DM and WSC for AberDart and Fennema in the first year of ley across the nine sites are shown in table 1. There was a significant difference between AberDart and Fennema in DM yield at seven sites and in WSC yield at three sites. At the more northern sites in Norway and Sweden, AberDart had significantly lower DM yields than Fennema.

Table 1. Total yield of DM and WSC at nine sites in the first year of ley.

	Site								
Variety	Kvit-hamar	Fure-neset	Saer-heim	Ultuna	Rådde	Tvååker	Völken-rode	Traws-goed	Grange
	DM (kg ha^{-1})								
Aberdart	10064	7321	10171	7648	9574	12356	12595	14320	14014
Fennema	12183	8973	10676	8344	10673	13931	11984	12313	14272
CV %	5.2	5.8	4.1	5.8	5.2	4.9	4.6	7.0	4.9
LSD	886	760	633	680	806	902	832	2,090	832
	WSC (kg ha^{-1})								
Aberdart	2733	1863	2914	1189	2281	2702	2836	2864	1389
Fennema	3096	2229	2922	1123	2131	2649	2459	1771	1296
CV %	9.2	6.8	6.4	8.4	8.6	6.6	5.0	7.9	6.7
LSD	388	224	269	135	280	251	190	318	113

LSD = least significant difference at $P < 0.05$

Only at the site in Wales, did AberDart have a significantly greater DM yield than Fennema. At the sites in Germany and Ireland, there were no significant differences in yield between the two varieties. In terms of dry matter yield, a strong interaction was found between variety and site ($P < 0.0001$), which to some extent reflected the lower yield of AberDart compared to Fennema, presumably as a consequence of the reduced winter hardiness of AberDart.

Due to an average 14 % greater (25 g kg^{-1} DM) WSC content of AberDart than Fennema found in all harvests in the trials, the calculated total yields of WSC per hectare (WSC content × DM yield) for the two varieties were much more similar than their total DM yields. At two sites the total WSC yield of AberDart was significantly greater than that of Fennema and only at one site, did Fennema have a significantly greater total WSC yield. At the remaining five sites, total WSC yields were not significantly different between the two varieties. A strong interaction ($P < 0.0001$) between variety and site was found for total WSC yield. The sites were situated from latitude 63° N in mid-Norway to latitude 52° N in Wales and from longitude 6° W in east Ireland to 17° E in mid-Sweden, and as such represented a wide range of climate conditions with differences in temperature, radiation, photoperiod and precipitation, all of which can influence the sugar content in grasses. More detailed analysis and modelling are required to try to explain these effects further.

Conclusions

At more northern sites in Norway and Sweden, AberDart had lower DM yield and winter hardiness than Fennema. In more southern sites in Wales, Ireland and Germany, AberDart had similar or greater DM yield than Fennema. A greater WSC content of AberDart than Fennema resulted in a much more similar total yield of WSC than total DM yield. Interactions between varieties and sites, which represented a wide range of climate conditions, need more detailed analysis to explain these effects further. It was clearly demonstrated that AberDart did not accumulate significantly greater yields of WSC than Fennema under all conditions, which was shown by the strong genotype × environment interaction.

Acknowledgements

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Development of leaf-stem ratio and qualitative values of timothy in subarctic growing conditions

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Abstract

Qualitative values of timothy (*Phleum pratense* L.) at different stages of development were studied in 1999-2001 at the Lapland Research Station of MTT Agrifood Research Finland in Rovaniemi (66°35´N). The aim of the study was to observe the growth habit and to analyse the yields and quality components of timothy in spring and late summer. The dry matter yield and leaf-stem ratio were measured from the crop samples, and the contents of crude protein and crude fibre and organic matter digestibility of leaves and stems were analysed.
In timothy, on average, the first heads were visible on 23 June and full heading was seen on 3 July, i.e., ten days later. During this period the dry matter yield increased from 3169 to 5033 kg ha^{-1}, the crude protein content decreased from 15.2 to 10.0 %, the crude fibre increased from 29.2 to 35.9 % and organic matter digestibility decreased from 74.2 to 63.8 % in dry matter. The principal reason for the drop in forage quality was the rapidly increased ratio of stems to leaves in the yield. During two weeks, from the grazing stage to full heading, the contribution of stems to the yield increased from 58 to 74 %. In the aftermath, in the vegetative phase of timothy, the decrease in crude protein content followed the increase in dry matter yield, but the organic matter digestibility also remained high in the stems. In the last cut, the measured dry matter yield was 3852 kg ha^{-1}, leaf-stem ratio in percentages was 49:51, crude protein content averaged 10.5 % and organic matter digestibility 75.3 % in dry matter.

Keywords: timothy, leaf-stem ratio, dry matter, digestibility, crude protein, crude fibre

Introduction

Close to the Arctic Circle the growing period (mean daily temperature above +5 °C) begins 1-2 weeks after melting of the snow in the middle of May and averages 134 days and 834 °C effective day degrees. However, only about 100 days can be exploited for yield production because the ley requires the last third of the growing period and the last quarter of the temperature sum to accumulate reserve nutrition and reach winterhardiness.
In northern conditions the most rapid growth phase of timothy in early summer is difficult to utilise for silage due to rapid changes in chemical composition. On the other hand, retarded growth in late summer decreases the total dry matter yield during the short growing season.
The right timing of the harvest is important both for the quantity and the quality of the yield. Mostly, leys are cut twice during the growing season. Although the primary aim is to exploit the high growth of early summer, the timing of the first cut also affects the yield and the quality of aftermath and, consequently, the total yield during the short growing period.

Materials and methods

The present investigation is based on field trials carried out during 1999-2001 at the Lapland Research Station of MTT Agrifood Research Finland in Rovaniemi (66°35' N). The study consisted of first to third year timothy (*Phleum pratense* L., cv. Iki) stands established in 1998. Both spring yield and aftermath were fertilised with 100 kg nitrogen per hectare. The development of the first yield was followed over a period of three weeks from the grazing stage to full heading of the timothy. The yield and quality changes in aftermath were followed

for a month from the end of July to the last harvest at the end of August. In early summer, crop samples were taken at five-day intervals. There were three samplings from the aftermath at two-week intervals before the last cut. The quantity of the yield was measured and the dry matter, crude protein and fibre contents, as well as organic matter digestibility were analysed. For every yield sample the leaf-stem ratio in percentage terms was also determined in order to explain the background of the changes in quality features.
At harvesting the stage of development of the timothy was observed visually. The plant samples were analysed for total nitrogen with the Kjeldatherm system (Gerhardt, Germany) and for fibre content with the Fibertec system (Tecator, Sweden). The digestibility of the organic matter was tested in vitro by the cellulase-enzyme method of Friedel (1990).
The data were analysed using repeated measurements analysis of variance model for split-plot design. The analyses were performed by the MIXED procedure of SAS software.

Results and discussion

A summary of dry matter yields and forage quality is shown in table 1. In early summer, dry matter yield and its qualitative values were highly related to the stage of development of the timothy. Within a period of ten days from the beginning of heading to full heading, dry matter yield increased from 3169 to 5033 kg ha^{-1}, crude protein decreased from 15.2 to 10.0 %, crude fibre increased from 29.2 to 35.9 % and organic matter digestibility decreased from 74.2 to 63.8 % in dry matter on an average. The crude protein content decreased 0.7 and organic matter digestibility 1.0 percentage unit per day. At the grazing stage, about one week before the first visible heads, the leaf-stem ratio in percentages was 47:53. Ten days later, when half of the timothy heads were visible, the leaf and stem percentages were 29 % and 71 %, respectively. At the end of July the aftermath yielded 1399 kg dry matter per hectare, contained 18.5 % crude protein, 22.0 % crude fibre and organic matter digestibility was 77.8 %. Four weeks later the dry matter yield was 3852 kg ha^{-1}. The organic matter digestibily was still 75.3 % but crude protein content was only 10.5 %. However, all these changes in quality were very slow, with the crude protein decreasing 0.3 and organic matter digestibility less than 0.1 percentage point per day.
The period from the beginning of the growing season, 15 May, to the date of first visible heads, 23 June, averaged 39 days and around the first cut the accumulated effective temperature sum was about 250 °C. For the growing of the aftermath, 57 days and 515 effective day degrees were needed. In early summer, with a 24-hour photoperiod, high temperature speeds up the already fast regenerative development of main shoots and also lowers the forage quality in respect of the amount of dry matter. Although the effective day degrees had a significant effect on the date of first visible heads and at that time also on the amount of dry matter and organic matter digestibility, the changes in yield and forage quality occurring during the actual heading stage are not influenced by weather conditions. During heading the rapid increase in the proportion of stems in yield affects most the quality features of the timothy.
In the second cut the dry matter yield was as high as in first cut, the leaf-stem ratio in percentages was 50:50 and the organic matter digestibility in stems was about 10 percentage point higher than in the spring yield. Despite the same nitrogen fertlization, both the leaves and the stems in the aftermath had a markedly lower crude protein content than that in the first cut in relation to the amount of the dry matter yield.

Table 1. Dry matter yield and forage quality of first- to third-year timothy stands at different stages of development in 1999-2001.

Sampling date	Dry matter yield		Crude protein			Organic matter digestibility		
	Mean (Range) (kg ha^{-1})	Leaf-stem ratio (%)	Mean (Range) %	Leaves Mean (%)	Stem Mean (%)	Mean (Range) (%)	Leaves Mean (%)	Stem Mean (%)
1st cut								
14 June	1336 (854-1915)	53:47	22.5 (20.5-24.8)	26.7	17.7	79.8 (77.5-82.4)	80.9	79.0
18 June	2047 (1853-2198)	42:58	18.6 (16.2-20.1)	24.2	14.2	78.7 (74.9-81.1)	78.5	75.8
23 June [a)]	3169 (2095-4099)	32:68	15.2 (14.1-15.8)	21.9	10.4	74.2 (72.1-77.9)	77.2	71.8
28 June	4034 (3381-4464)	29:71	11.8 (10.6-12.5)	20.2	8.2	68.2 (65.4-72.2)	73.8	62.4
3 July [b)]	5033 (3703-5698)	26:74	10.0 (9.0-10.7)	19.2	7.4	63.8 (62.7-64.6)	73.3	58.9
Aftermath (1st cut 28 June)								
27 July	1399 (939-1921)	74:26	18.5 (16.8-21.8)	20.9	12.5	77.8 (76.6-79.4)	79.1	77.9
9 Aug.	2942 (2621-3266)	61:39	14.7 (11.3-18.1)	18.0	9.5	76.0 (74.4-78.0)	77.4	75.2
24 Aug.	3852 (3656-4133)	49:51	10.5 (9.3-11.9)	14.4	6.0	75.3 (73.1-78.8)	76.7	72.9
1st cut:								
SE	103		0.17			NA		
P value	< 0.001		< 0.001			< 0.001		
Aftermath:								
SE	152		0.28			NA		
P value	< 0.001		< 0.001			< 0.001		

[a)] first heads visible, [b)] full heading

Conclusions

There is a great variation in e.g., the organic matter digestibility of timothy in the different vegetative phases and under different photoperiods. When variation in quality traits affecting the feed value of timothy also exists between different varieties, variation in quality factors, including the speed of quality decline during maturity, can be utilised in variety breeding.
A rapid decrease in crude protein content and organic matter digestibility follows from the increasing proportion of stems in the yield. In breeding timothy varieties, just improving the digestibility of stem fibre would be one way to take better advantage of the growth potential in the spring yield. In the aftermath the timothy plants are in the vegetative phase and also the digestibility of the stems remains high. However, in relation to the amount of the dry matter yield, both leaves and stems have a very low crude protein content in the aftermath. This cannot be affected by cultivation technique or variety breeding.

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Nutrient elements in herbage and extracts of perennial grasses at differing stages of maturity

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Abstract

Distribution of macro (N, P, K, Ca and Mg) and trace (Mn, Zn and Fe) elements was assessed in herbage, water and ethanol extracts of meadow grass, perennial ryegrass, timothy grass and tall fescue at different stages of maturity. Amounts of elements soluble in water and 80 % ethanol were assessed by analysis of water and alcohol insoluble fraction. N, P and K decreased generally with increasing maturity. Percentages of total herbage content of elements soluble in water were: 32-63 % N, 70-88 % P, 52-80 % Ca, 68-86 % Mg, 89-95 % K, 42-77 % Zn, 63-76 % Mn and 18-61 % Fe. Differences in proportions of elements soluble in water and ethanol were generally small.

Keywords: perennial grasses, macro elements, trace elements, water extract, ethanol extract

Introduction

The association of certain minerals with fibre or other insoluble plant components could decrease the rate and extent of mineral release from forages in the gastrointestinal tract (Spears, 1994). For elements that are associated with various components of the plant tissue,

Table 1. Concentrations (g kg^{-1} or *mg kg^{-1} DM) of elements in the herbage at different stages.

Species	Stage	N	P	K	Ca	Mg	Fe*	Mn*	Zn*
Meadow grass	1	37.1	4.50	25.5	2.65	2.60	123	44	28
	2	23.4	4.57	24.9	3.05	2.80	95	51	24
	3	17.6	4.20	19.4	3.40	3.00	96	44	22
	4	13.1	3.25	17.2	3.50	2.45	96	32	23
	5	11.8	2.87	17.0	3.50	2.15	77	25	18
	6	12.4	3.25	23.5	3.40	2.80	102	33	20
	7	12.1	2.72	18.1	2.25	1.35	78	28	19
Perennial ryegrass	1	28.2	4.61	24.3	3.60	2.20	152	43	28
	2	19.6	4.20	19.2	2.75	1.80	146	29	26
	3	16.6	3.85	18.3	2.05	1.65	106	28	29
	4	12.5	3.60	15.2	2.40	1.75	90	26	27
	5	10.9	2.82	15.4	1.75	1.35	76	26	23
	6	12.4	4.50	14.5	2.35	1.65	66	25	28
	7	11.6	2.82	12.9	2.45	1.80	102	32	26
Timothy grass	1	30.5	3.75	22.1	2.80	2.30	126	48	40
	2	21.5	3.10	20.2	2.65	1.95	87	36	29
	3	18.5	3.10	22.5	2.40	1.60	94	36	28
	4	15.0	2.60	18.9	2.90	1.45	80	27	22
	5	13.4	2.72	18.4	2.00	1.25	86	24	20
	6	15.1	2.82	21.2	2.45	1.55	174	37	26
	7	10.6	2,30	25.4	2.75	2.45	147	37	34
	8	7.9	1.40	20.4	1.70	1.10	67	15	26
Tall fescue	1	23.2	3.37	21.7	1.60	1.90	124	28	26
	2	16.1	2.75	20.9	1.65	1.80	80	26	20
	3	14.5	2.75	18.4	1.90	1.85	81	22	19
	4	13.0	1.85	16.4	2.00	1.65	74	22	16
	5	10.0	2.50	18.0	2.40	2.65	107	32	23
	6	10.0	2.00	19.1	2.00	1.95	95	22	15
	7	8.0	2.50	17.3	1.35	2.25	90	20	13

extraction with different solvents provides some evidence of their forms of occurrence. The aim of this investigation was to evaluate changes with maturation of mineral content in herbage and distribution of N, P, K, Ca and Mg and trace elements (Fe, Mn and Zn) in different fractions (fraction insoluble in water and fraction insoluble in 80 % ethanol) of meadow grass, perennial ryegrass, tall fescue and timothy grass.

Materials and methods

Meadow grass (*Festuca pratensis* L.) cv. K-21, perennial ryegrass (*Lolium perenne* L.) cv. Naki, timothy grass (*Phleum pratense* L.) cv. K-15 and tall fescue (*Festuca arundinacea* Schreb.) cv. K-20 were grown as pure stands. Sampling began on April 26 when all grasses were in the vegetative phase and continued at 7 day intervals until June 7 (for timothy grass 14 June), the phase of seed development. Separation of fractions insoluble in water was conducted according to Whitehead *et al.* (1985). Herbage was extracted with deionised water for 2 h. After centrifugation, the residue was re-extracted twice with water for 1 h. The residue insoluble in ethanol was obtained by boiling under reflux in 80 % ethanol for 30 min. After centrifugation the residue was refluxed again two times for 15 min. The proportion of elements soluble in water and ethanol was assessed by analysis of insoluble fractions. Analyses of elements were in duplicate and the mean value is shown.

Results and discussion

The content of elements in herbage, water and alcohol extracts are shown on tables 1, 2 and 3.

Table 2. Concentrations (g kg^{-1} DM and *mg kg^{-1} DM) of elements in the water-insoluble fraction (in parenthesis the proportion of the total content of elements soluble in water).

Species	Stage	N	P	K	Ca	Mg	Fe*	Mn*	Zn*
Meadow grass	1	40.7 (26)	1.2 (82)	3.7 (92)	1.8 (64)	1.1 (77)	157 (31)	28 (65)	20 (62)
	2	25.7 (31)	1.1 (85)	2.9 (94)	2.1 (65)	1.1 (80)	125 (34)	30 (71)	12 (74)
	3	19.4 (30)	1.1 (83)	1.6 (96)	1.8 (73)	0.9 (84)	101 (46)	24 (72)	14 (66)
	4	13.1 (30)	1.0 (79)	2.3 (93)	1.5 (76)	0.8 (83)	99 (42)	18 (70)	14 (67)
	5	10.9 (34)	0.8 (80)	1.8 (94)	1.4 (78)	0.7 (82)	94 (31)	14 (68)	10 (67)
	6	9.8 (41)	0.9 (81)	1.6 (96)	1.4 (75)	0.7 (84)	81 (52)	14 (75)	10 (68)
	7	9.2 (45)	0.7 (81)	1.9 (94)	1.3 (67)	0.7 (67)	102 (23)	14 (70)	13 (61)
Perennial ryegrass	1	31.5 (28)	1.1 (85)	3.9 (92)	1.6 (77)	1.1 (74)	168 (43)	23 (73)	20 (54)
	2	20.2 (37)	1.1 (84)	3.1 (92)	1.4 (76)	0.9 (76)	115 (62)	18 (69)	15 (72)
	3	17.0 (34)	0.8 (86)	2.0 (94)	1.2 (70)	0.8 (75)	109 (26)	19 (65)	19 (66)
	4	11.8 (34)	0.6 (88)	1.6 (94)	1.0 (77)	0.7 (77)	90 (44)	16 (67)	18 (63)
	5	9.3 (40)	0.8 (80)	1.4 (95)	0.9 (71)	0.6 (75)	86 (36)	14 (69)	13 (69)
	6	8.9 (47)	1.0 (84)	2.5 (90)	1.2 (67)	0.7 (75)	104 (6)	14 (69)	12 (73)
	7	8.9 (42)	0.8 (78)	2.0 (91)	1.1 (74)	0.9 (69)	94 (44)	19 (65)	17 (59)
Timothy grass	1	35.1 (22)	0.7 (87)	2.3 (94)	1.4 (74)	1.0 (77)	141 (39)	26 (70)	33 (55)
	2	22.8 (31)	0.5 (89)	2.0 (95)	1.4 (72)	0.8 (68)	115 (30)	18 (73)	21 (62)
	3	20.2 (27)	0.9 (81)	2.8 (93)	1.2 (72)	0.8 (72)	102 (42)	21 (70)	33 (35)
	4	16.5 (25)	0.8 (79)	2.6 (92)	1.0 (80)	0.4 (87)	88 (41)	14 (72)	15 (63)
	5	15.5 (27)	0.5 (88)	2.9 (92)	1.3 (66)	0.7 (74)	125 (27)	15 (68)	20 (48)
	6	13.6 (38)	0.5 (88)	3.5 (91)	1.5 (67)	0.9 (69)	205 (35)	21 (68)	19 (61)
	7	18.2 (21)	0.6 (82)	2.2 (95)	0.9 (81)	0.6 (85)	119 (55)	14 (78)	14 (77)
	8	7.2 (38)	0.3 (86)	1.9 (95)	1.0 (69)	0.1 (70)	101 (19)	10 (63)	12 (59)
Tall fescue	1	23.4 (27)	0.7 (85)	2.4 (94)	1.2 (58)	0.8 (85)	140 (34)	18 (68)	14 (67)
	2	15.0 (32)	0.5 (87)	2.4 (93)	1.0 (65)	0.7 (78)	106 (22)	14 (68)	12 (65)
	3	14.0 (30)	0.7 (82)	1.8 (94)	1.0 (68)	0.7 (78)	85 (39)	13 (65)	11 (67)
	4	12.5 (29)	0.5 (80)	2.1 (93)	1.2 (64)	0.7 (76)	97 (23)	14 (64)	12 (56)
	5	7.6 (44)	0.7 (80)	1.5 (95)	1.0 (75)	0.6 (86)	119 (35)	13 (77)	10 (73)
	6	7.7 (43)	0.8 (70)	2.4 (93)	1.1 (66)	0.7 (78)	96 (40)	12 (67)	9 (65)
	7	5.4 (49)	0.8 (75)	2.2 (92)	1.0 (53)	0.7 (80)	136 (5)	13 (60)	12 (42)

N, P and K decreased generally with increasing maturity while Ca and Mg were not greatly altered by the stage of maturity. Proportion of N soluble in water was around 30 % and higher in older plants (40-49 %) (Table 2). This may be due to a greater proportion of stems in mature plants as Whitehead *et al*. (1985) reported that the proportion of N soluble in water in lucerne stems was much higher than in the leaf. The solubility of Ca in water for all grasses and maturity stages was in the range 53-80 % which is in agreement with the results of Emanuele and Staples (1990) for release of Ca after 72 h of incubation in rumen. Among the trace elements examined, water solubility for Mn was greatest (60-78 %). Smaller proportions of N, P, Ca and Mg were soluble in 80 % ethanol than in water (Table 3) as reported by Whitehead *et al.* (1985). K had extremely high solubility (99 %) in boiling ethanol. Differences in proportions of trace elements soluble in water and ethanol were generally small.

Table 3. Concentrations (g kg^{-1} DM and *mg kg^{-1} DM) of elements in the ethanol-insoluble fraction (in parenthesis the proportion of the total content of elements soluble in ethanol).

Species	Stage	N	P	K	Ca	Mg	Fe*	Mn*	Zn*
Meadow grass	1	44.9 (20)	2.9 (57)	0.2 (99)	1.9 (53)	1.8 (54)	161 (13)	45 (32)	27 (38)
	2	27.6 (23)	3.0 (58)	0.2 (99)	1.9 (59)	1.8 (57)	120 (17)	51 (35)	17 (54)
	3	20.3 (20)	2.1 (66)	0.8 (97)	1.5 (70)	0.6 (87)	100 (28)	33 (49)	14 (56)
	4	13.9 (25)	2.0 (56)	0.1 (99)	1.7 (65)	0.7 (67)	86 (36)	29 (36)	21 (37)
	5	12.0 (25)	1.0 (76)	0.4 (98)	1.0 (79)	0.2 (93)	77 (28)	18 (50)	11 (54)
	6	10.9 (35)	0.9 (79)	0.4 (98)	1.0 (79)	0.3 (93)	84 (39)	16 (64)	22 (20)
	7	10.3 (36)	1.9 (48)	0.3 (99)	1.6 (48)	1.4 (26)	96 (9)	26 (32)	16 (39)
Perennial ryegrass	1	34.4 (21)	2.0 (72)	0.2 (99)	1.8 (67)	1.3 (62)	169 (28)	31(53)	23 (47)
	2	23.3 (24)	3.2 (52)	0.3 (99)	1.6 (62)	1.5 (47)	122 (47)	28 (39)	18 (56)
	3	18.3 (26)	2.8 (53)	0.3 (99)	1.5 (51)	1.3 (47)	130 (17)	27 (34)	33 (24)
	4	12.7 (25)	2.6 (46)	0.2 (99)	1.3 (61)	1.2 (49)	86 (29)	23 (34)	25 (31)
	5	10.9 (27)	2.0 (47)	0.2 (99)	1.2 (50)	1.0 (46)	94 (9)	22 (41)	20 (36)
	6	10.1 (40)	1.9 (68)	0.2 (99)	1.2 (63)	0.9 (60)	70 (21)	19 (44)	21 (42)
	7	10.5 (30)	2.0 (45)	0.1 (99)	1.4 (54)	1.2 (47)	97(27)	28 (33)	26 (22)
Timothy grass	1	38.9 (13)	3.4 (38)	0.3 (99)	1.7 (58)	1.7 (49)	134 (28)	47 (33)	39 (34)
	2	25.7 (16)	2.4 (46)	0.3 (99)	1.6 (58)	1.1 (60)	98 (21)	32 (39)	25 (39)
	3	21.7 (17)	2.4 (46)	0.3 (99)	1.4 (59)	1.1 (53)	98 (26)	32 (38)	25 (35)
	4	17.0 (19)	2.9 (21)	0.2 (99)	2.4 (41)	0.6 (72)	85 (24)	24 (35)	23 (23)
	5	15.6 (18)	3.1 (19)	0.2 (99)	2.3 (19)	0.5 (72)	76 (38)	22 (35)	25 (15)
	6	15.3 (24)	3.2 (16)	0.2 (99)	2.3 (30)	0.6 (70)	201 (13)	33 (32)	24 (32)
	7	10.1(30)	2.6 (16)	0.1 (99)	2.1 (43)	0.4 (89)	95 (53)	20 (62)	32 (10)
	8	9.0 (18)	1.4 (28)	0.1 (99)	1.1 (53)	0.6 (59)	198 (23)	15 (31)	15 (31)
Tall fescue	1	24.5 (22)	2.7 (41)	0.2 (99)	1.3 (40)	1.5 (42)	131 (22)	31 (19)	17 (50)
	2	16.0 (27)	2.4 (37)	0.3 (99)	1.1 (51)	1.3 (47)	80 (27)	24 (33)	20 (28)
	3	15.0 (23)	2.6 (28)	0.3 (98)	2.3 (10)	1.6 (35)	80 (26)	22 (28)	19 (24)
	4	13.8 (22)	2.0 (20)	0.2 (99)	1.4 (48)	1.2 (48)	80 (21)	22 (28)	18 (29)
	5	9.7 (28)	1.4 (60)	0.2 (99)	1.4 (57)	0.9 (75)	81 (44)	22 (51)	15 (52)
	6	9.4 (30)	2.0 (19)	0.2 (99)	1.3 (52)	1.2 (51)	75 (41)	20 (32)	13 (33)
	7	7.0 (34)	1.8 (44)	0.2 (99)	1.1 (37)	1.1 (63)	83 (30)	20 (27)	16 (9)

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Modelling of water-soluble carbohydrates in forage maize

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Abstract

Over the last decades, maize (*Zea mays* L.) has become a key to high production on livestock farms, mainly based on its proven ability to produce high quality silage. Fermentation, however, may be limited due to low water-soluble carbohydrate (WSC) content under some environmental conditions such as low temperature and irradiation, or heavy rainfall during growth, which is typical for the maize growing regions in northern Europe. The main objective of the present study was to adapt the weather-based, dynamic model FONSCH to forage maize. FONSCH was originally developed for WSC prediction in forage grasses. Data on WSC content were collected in a 2-year field experiment conducted in northern Germany. Eight varieties covering a wide maturity range (early, mid-early, mid-late) and different maturation types, were harvested during each vegetation period six times and separated into ear and stover. A comparison of model output with observed data showed a good performance indicating the potential of the FONSCH model to predict WSC content not only for grass but also for forage maize.

Keywords: forage maize, water soluble carbohydrates, modelling, variety

Introduction

In forage maize, varietal differences with respect to fodder quality are partly due to a varied maturation of ear and stover. Apart from genotype, assimilate translocation from the stover into the ear is influenced by environmental conditions. In northern Europe, environmental constraints, i.e., low irradiation intensities paralleled by low temperatures and high amounts of rainfall particularly during the grain filling period, may decelerate maturation, hamper the achievement of optimum harvest date, and cause significant monetary losses. In order to tackle this problem, a Germany-wide project was initiated, aiming to develop a model for harvest time prediction in forage maize. In addition to dry matter (DM) content, maturation was characterized by other meaningful forage quality parameters such as WSC content. High WSC contents in the maize crop are important for the fermentation process and for the aerobic stability of silages. The objectives of the present study were (i) to analyse the impact of variety and stage of maturity on the WSC content of ear and stover, and (ii) to investigate whether the influence of environmental conditions on WSC content of the whole crop can be quantified by using an appropriate model. For this purpose, the weather-based, dynamic FONSCH model (Wulfes *et al*., 1999), originally developed for forage grasses, was adjusted to forage maize.

Materials and methods

The study was based on data collected in a 2 year (2001, 2002) field experiment conducted at the experimental farm 'Hohenschulen' of the Christian-Albrechts University of Kiel on a sandy loam soil. An one-factorial block design was used for the field trial, where eight varieties (Arsenal, Oldham, Symphony, Probat, Attribut, Fuego, Clarica, Benicia), covering a wide maturity range (early, mid-early and mid-late) and different maturation types (normal, dry-down and stay-green), were investigated. Growth and quality change of the maize crop was recorded at six dates throughout the vegetation period. Sampling dates were chosen in order to be in line with developmental stages of Probat, scheduled to BBCH 32 and an ear DM content of 20, 30, 40, 50, and 55 percent. At each sampling date, 10 adjacent plants were harvested per plot by hand clipping, separated into ear and stover, chopped, and subsequently freeze-dried. WSC content of the plant fractions was estimated by NIRS, with calibration and validation being based on a modified anthron method. Statistical analysis was conducted using PROC MIXED (SAS 8.2), by assuming a heterogeneous, auto-regressive covariance structure for repeated measurements. Comparison of means was performed by t-test with a Bonferroni-Holm adjustment. The WSC content of the whole crop was calculated from the corresponding values of ear and stover, and served then as input for the FONSCH model.

Results and discussion

WSC concentrations of stover and ear: Prior to the onset of intensive grain filling, WSC accumulation in the stover indicates that assimilate supply of the plant exceeded its demand (Figure 1A). After silking, with an ear DM content of approximately 20 %, the WSC content of the stover decreased, caused by a translocation of assimilates from stover into the ear. A comparison of the three maturation groups revealed a more pronounced decline of WSC content in the early group, which may have been induced by an interaction between the source-to-sink ratio and the environmental conditions in the early grain filling period. Statistical analysis showed significant interactions of maturity group and harvest date (Table 1). Significant lower WSC contents of the early compared to the mid-early and mid-late groups were detected for the 3rd to 5th sampling date (ear DM content of 30 to 50 %). Within the maturation groups, varieties differed significantly at the 3rd to 5th date for the early and mid-early group, but for the mid-late group at the 4th date only. To provide a better overview, figures 1A and 1B do not show each individual variety, but display the maturity groups.

Table 1. Statistical analysis of the ear and stover WSC content.

	Num DF		F-Value		Pr > F	
Effect	Stover	Ear	Stover	Ear	Stover	Ear
year	1	1	1.57	115.60	0.3531	0.0041
variety (maturity)	5	5	9.53	19.15	<.0001	<.0001
maturity	2	2	54.34	135.86	<.0001	<.0001
harvest date	5	4	270.54	848.33	<.0001	<.0001
maturity*harvest date	10	8	15.05	13.83	<.0001	<.0001
variety (maturity)*harvest date	25	20	2.36	1.44	0.0091	0.1691
year*maturity	2	2	0.15	43.28	0.8622	<.0001
year*variety (maturity)	5	5	0.67	2.83	0.6493	0.0415
year*harvest date	5	4	32.55	44.76	<.0001	<.0001

During the early stages of grain filling, ear WSC contents reached values of up to 35 %, indicating that assimilate supply exceeded kernel demand. With intensifying starch accumulation, WSC contents decreased markedly to 4 to 7 % at silage maturity (Figure 1B). For all sampling dates, the mid-late group achieved significantly higher WSC values compared to the early group. Within the mid-early and mid-late maturity groups, WSC contents (averaged across dates) differed significantly among varieties.

Model calibration of whole crop WSC content: The impact of the year on ear and stover WSC content was substantial, as indicated by significant main effects and interactions (Table 1). The modelling of the WSC contents should therefore clarify whether these effects can be explained mainly by environmental conditions, i.e., temperature, radiation, and plant-available soil water. Figure 2 presents the observed and calculated data of the 2001 and 2002 growing season for two selected cultivars. While Oldham belongs to the early maturity group and has a synchronous maturation of ear and stover, Fuego (mid-early group) can be classified as a stay-green type.

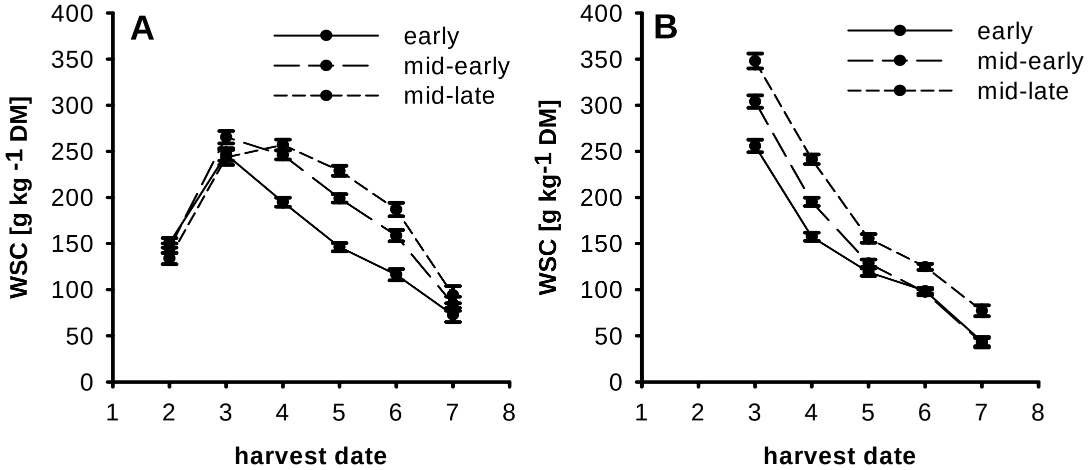

Figure 1. Stover (A) and ear (B) WSC content of the early, mid-early, and mid-late maturity group; means of two years (I: standard error).

The calculated WSC values demonstrate that the significant year effects could largely be explained by climatic conditions. Compared to 2002, WSC accumulation was delayed in 2001, with the maximum occurring about 20 days later. In the later grain filling period, however, WSC contents decreased at higher rates in 2001. At silage maturity, WSC values differed markedly between years, ranging from less than 5 % in 2001 (date 6) to 10 % in 2002 (date 5). In the simulations, varietal effects emerged in the post-silking phase only. Overall, the model performed well, as indicated by coefficients of determination above 0.80 and prediction errors of approximately 2 %. Slight deviations appeared in the presilking period. The present model calibration thus provides a sound basis for the ongoing modelling work and will be supplemented by additional data from another site and a third experimental year.

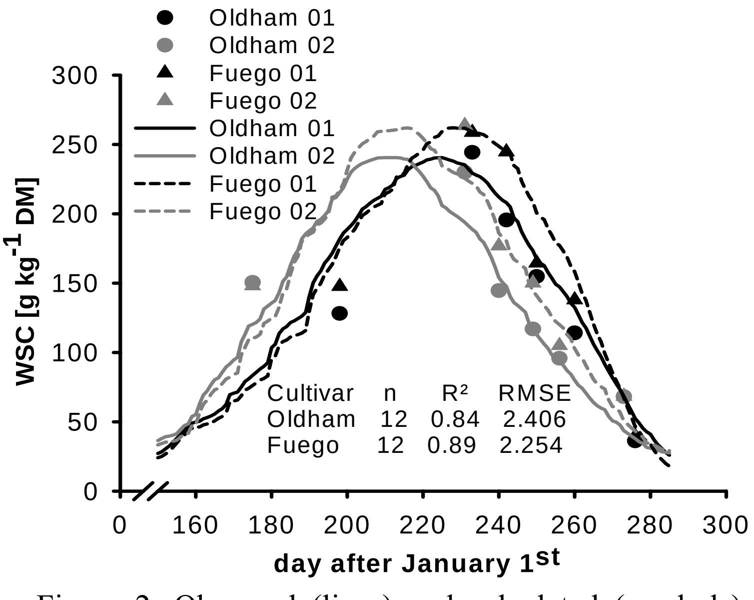

Figure 2. Observed (lines) and calculated (symbols) WSC values of two selected cultivars.

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Ensilability of different grass/clover mixtures

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Abstract

In Switzerland, grass/clover mixtures are sown for leys. Pure sown grass stands are not common. White and red clover play a central role in Swiss mixtures. They are highly palatable, well digestible and exhibit high energy, protein and mineral contents. On the other hand, legumes are regarded as being unsuitable for ensiling.
In 2001 and 2002 we carried out ensiling trials with different grass/clover mixtures from the first and third cut.
The results of the trial showed that nutrient contents and fermentation quality of different grass/clover mixtures varied significantly. Growth number proved to be a major influencing factor. Botanical composition also influenced silage quality. Ryegrass had a positive and cocksfoot a negative effect on quality. However, the influence of clover (red and white) on silage quality was limited and slightly negative.

Keywords: grass/clover mixtures, ensilability, silage, fermentation quality

Introduction

Various factors determine the ensilability of plant crops. In addition to dry matter content, sugar and protein content, buffering capacity, plant structure, soil contaminations and epiphytic microflora are also of importance. Many of these factors are a direct consequence of the botanical composition.
The various mixtures available in Switzerland are continuously revised on the basis of results from variety testing programmes, mixture trials on field plots and results of pilot scale studies under farm conditions (Kessler and Lehmann, 1998). Concerning the ensilability of the different mixtures, no systematic tests are carried out. For this reason, we tested in 2001 and 2002 different grass/clover mixtures.

Materials and methods

In 2001 and 2002, we ensiled different mixtures in laboratory silos. The mixtures were sown in 2000 as part of the testing programme of the Swiss Federal Research Station for Agroecology and Agriculture in Zürich-Reckenholz. The mixtures 1 to 4 contained white and partially red clover as well as different grasses. These mixtures were cut 5 times a year. The mixtures 5 and 6 contained red clover and various grasses. They were only cut 4 times a year. For our experiment, we used the first and third cut. The forage was pre-wilted to attain DM contents of 25 to 30 %, short chopped and ensiled in laboratory silos each having a volume of 1.5 litres. The silos were stored at room temperature (approx. 20 °C) and weighed regularly to measure gaseous losses. Chemical parameters were analysed before ensiling and after a storage period of five months. pH, fermentation acids, ethanol and ammonia were also analysed in the silage.
Furthermore the fermentability coefficient was calculated. This parameter summarizes the potential effects of dry matter as well as the ratio of sugar content and buffering capacity on the fermentation.

Results and discussion

In the leys, the proportion of clover was in all cases higher at the third cut compared to the first cut (Figure 1). In the mixtures 5 and 6 the proportion of red clover (*Trifolium pratense*) reached nearly 90 % in the third growth. The proportion of ryegrass (*Lolium perenne* and *multiflorum*) increased from mixture 1 to 5. The mixtures 1, 2, 5 and 6 contained cocksfoot (*Dactylis glomerata*), contrary to the mixtures 3 and 4. Except for the mixture 6, ryegrass and cocksfoot were the dominant grasses. Both together made up more than 70 % of the grasses present.

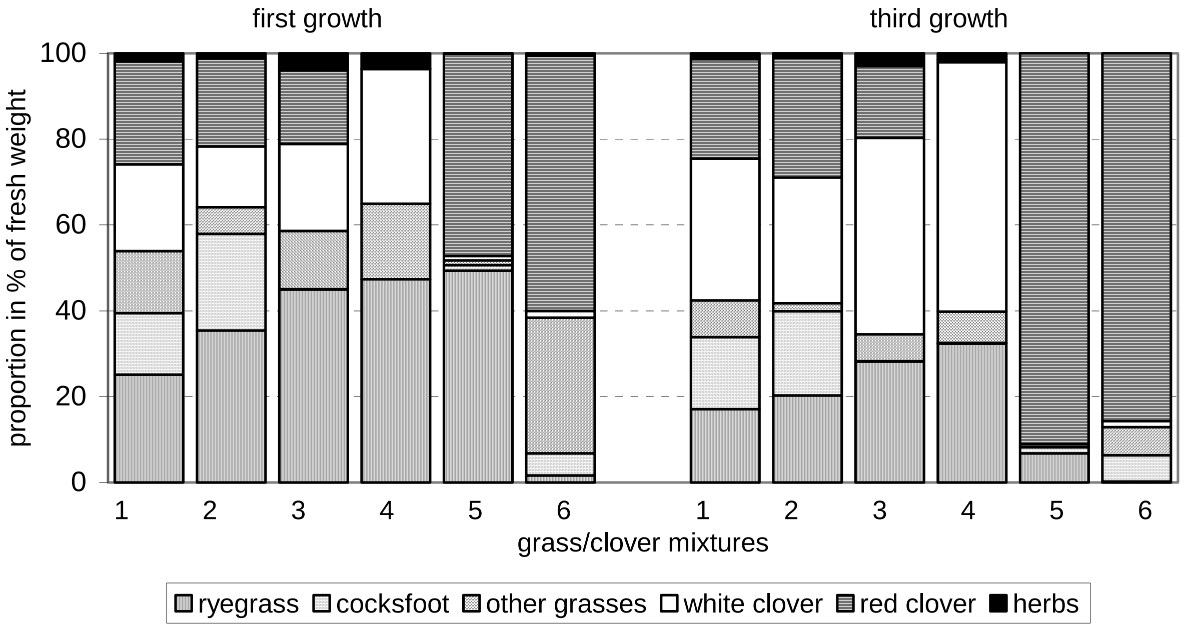

Figure 1. Botanical composition of the six grass/clover mixtures of the first and third cut (growth).

Concerning the nutrient contents, the mixtures at the third cut had a higher crude fibre and lower sugar contents than the first cut (Table 1). The fermentability coefficients varied between 39 and 50. The nitrate contents were < 0.5 g per kg DM in all treatments.

Sugar was strongly reduced during the fermentation process. This caused higher ash, crude protein and crude fibre contents along with lower sugar contents following ensiling.

Except for butyric acid, the fermentation parameters significantly differed between the six mixtures. But also growth number and year contributed to significant differences in fermentation parameters. In spite of higher DM contents, the fermentation quality of third cut silages was worse than of first cut silages. This can be explained by the lower sugar and the higher crude fibre contents of the green forage. According to the DLG evaluation scheme developed by Weissbach and Honig (1997) the silages attained scores between 51 and 95 out of a maximum of 100. Differences were observed between mixtures and especially between growth number. Mixtures with cocksfoot had lower DLG scores. Wyss and Vogel (1998) showed that silage quality with cocksfoot as pure stand or in mixtures was always lower compared to ryegrass.

The correlation between DLG scores and the proportion of grasses was 0.23, between DLG scores and proportion of ryegrass 0.47. On the other hand cocksfoot had a negative effect on quality (-0.35). White and red clover had a small negative impact on silage quality. The corresponding correlations with DLG scores amounted to -0.14 and -0.08, respectively.

Higher correlations were found between DLG scores and sugar (0.66), crude fibre content (-0.61) as well as fermentability coefficient (0.54) of the green forage.

Table 1. DM, nutrient contents and fermentation parameters of six green and ensiled grass/clover mixtures of the first and third growth (mean values of 2001 and 2002).

	Mixtures, first cut						Mixtures, third cut						Factors		
	1	2	3	4	5	6	1	2	3	4	5	6	M	C	Y
Green forage															
DM, g kg^{-1}	254	248	245	253	252	252	294	294	278	302	284	273	NS	**	**
Ash, g kg^{-1} DM	102	100	98	95	85	92	105	108	112	103	91	85	**	*	NS
Crude protein, g kg^{-1} DM	184	171	171	165	131	159	163	164	182	177	163	169	**	**	**
Crude fibre, g kg^{-1} DM	213	214	208	204	229	255	275	274	256	252	264	269	**	**	**
Sugar, g kg^{-1} DM	108	112	116	118	145	118	70	68	72	77	103	109	**	**	NS
Fermentability coefficient	42	42	43	45	50	43	41	41	39	43	44	44	**	**	*
Silages															
DM, g kg^{-1}	248	236	235	245	239	242	282	280	266	289	269	260	NS	**	**
Ash, g kg^{-1} DM	107	109	106	100	89	97	114	115	116	109	96	89	**	*	*
Crude protein, g kg^{-1} DM	196	187	185	179	138	165	173	174	189	185	170	174	**	NS	**
Crude fibre, g kg^{-1} DM	225	229	231	224	247	279	296	296	269	269	288	291	**	**	**
Sugar, g kg^{-1} DM	37	29	29	44	52	28	19	16	20	25	27	23	**	**	**
pH	4.5	4.6	4.2	4.3	4.3	4.6	4.8	4.7	4.6	4.5	4.6	4.5	**	**	*
Lactic acid, g kg^{-1} DM	25	23	46	46	50	34	13	14	20	31	35	53	**	*	**
Acetic acid, g kg^{-1} DM	16	14	20	21	29	11	12	11	12	10	8	10	**	**	**
Butyric acid, g kg^{-1} DM	2	6	2	1	0	8	8	10	10	6	6	6	NS	**	NS
Ethanol, g kg^{-1} DM	8	11	12	9	6	10	6	6	6	5	5	6	**	**	*
NH_3-N/N total, %	7	9	7	7	5	8	8	9	9	9	8	9	**	**	**
Gas losses, %	3.2	4.9	4.1	3.8	2.8	3.8	4.0	4.0	3.7	3.3	3.4	3.4	*	NS	**
DLG scores	82	69	95	93	95	63	51	53	57	64	59	66	*	**	NS

M = mixtures, C = cut, Y = year; Statistical significances: ** $P < 0.01$, * $P < 0.05$

Conclusions

The results of the trial showed that nutrient contents and fermentation quality of six different grass/clover mixtures varied significantly. Cut number proved to be a major influencing factor. But also the botanical composition influenced silage quality. Ryegrass had a positive and cocksfoot a negative effect on quality. However, the influence of clover (red and white) on silage quality was limited and slightly negative.

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Suitability to ensiling of sulla (*Hedysarum coronarium* L.) cultivated in North Italy

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Abstract

A commercial variety of sulla (Grimaldi), cultivated in the hills of Bologna (North Italy) at 300 m above sea level in a calanchive area, was evaluated for its suitability to ensiling. The crop was harvested, during the first year of cultivation, at three development stages (early flowering, full flowering and seed pod) and, after wilting, was ensiled for six months in 3 L experimental silos. Fresh sulla was characterised by a marked decrease in crude protein and water soluble carbohydrate content with the maturity of the plants (from 166 to 129 g kg^{-1} and from 111 to 64 g kg^{-1} respectively) whereas few changes were observed in the other parameters. The ensiling process seemed to be more influenced by the forage dry matter content reached by the wilting process than by the qualitative characteristics of the forage at harvesting. In fact, sulla harvested at early and full flowering stages, with 370-390 g kg^{-1} of dry matter after wilting, produced silages with good qualitative characteristics, whereas sulla cut at the seed pod stage, with a shorter wilting time and only 300 g kg^{-1} of dry matter, was less suitable for the ensiling process.

Keywords: *Hedysarum coronarium* L., sulla, development stage, wilting, ensiling.

Introduction

Sulla (*Hedysarum coronarium* L.) is a Mediterranean short-lived perennial legume, suitable for clay and calcareous soils and warm and drought environments. In the past, it was largely cultivated in Central and Southern Italy for pasture and haymaking (Bullitta and Sulas, 1998; Stringi *et al*., 1997; Talamucci, 1998). The evolution of cattle-breeding, which resulted in a great concentration of farms in the valleys of North Italy, where maize silage and lucerne hay were the forages of choice, resulted in declining interest in other kinds of forages. This gave rise to consideration of growing sulla, a crop that represents one of the few forages which can be proposed for marginal and neglected land, where intensive cultivations of usual forages can not be performed, and where the presence of crops contributes also to environment protection. However, to support the role of forage sulla, it is necessary to find new approaches to its utilisation and to increase its competitiveness towards other forages. The ensiling process could offer the possibility to reduce losses and costs of conservation in comparison with those of haymaking, but sulla, as a legume, with a high protein content could reduce the natural acidification process; interesting results were obtained with this technique in our previous work on wild sulla (Piccaglia *et al*., 2003).

In this work, a commercial variety of sulla (Grimaldi), cultivated in the hills of Bologna (North Italy) at 300 m asl in a calanchive area, and harvested during the first year of cultivation at three development stages, was evaluated for its suitability to ensiling after wilting.

Materials and methods

Sulla (Grimaldi) was sown at the beginning of March 1997; the experimental trial was performed adopting a factorial design with two replications. The crop was harvested at three different development stages (early flowering, full flowering and seed pod) with three successive cuts (7th, 17th and 29th of July). A part of the cut forage was left to dry in the field for different periods of time (24 h at the first and the second cut and 3 h at the third one), then chopped into 2-3 cm lengths and ensiled in 3 L laboratory silos for six months at 25 °C. Samples of green forage were in part oven dried at 60 °C and ground to be analysed for crude fibre (CFb) by the Wende method, crude fat (CF) by Soxhlet extraction, ash as residue after 2 h at 550 °C, fibrous fractions (NDF, ADF, ADL) by the Goering and Van Soest method and in part stored frozen prior to being analysed for dry matter (DM) by oven drying at 105 °C, for crude protein (CP) by Kjeldahl method and water soluble carbohydrates (WSC) by HPLC. Samples of fresh silage were analysed for DM (by oven drying at 105 °C and correction on the basis of fermentation compounds according to Fatianoff and Gouet, 1969), CP, fermentation acids by GC (Galletti and Piccaglia, 1983), ammonia by enzymatic method and pH. Forage quality was evaluated by the Flieg method. Statistical analyses were performed using analysis of variance and Duncan's multiple range test.

Results and discussion

The developmental stage of sulla at harvesting greatly influenced its chemical composition (Table 1). In fact from the first to the third cut, in a period of 22 days, the CP and the WSC contents significantly decreased from 165.8 to 128.5 g kg^{-1} and 110.5 to 63.5 g kg^{-1} respectively, whereas the other parameters did not show relevant differences and only slight increases in ash and fibrous fractions were observed.

Table 1. Chemical composition of fresh sulla at three developmental stages[s].

Stage of harvesting	DM, g kg^{-1}	On DM, g kg^{-1}							
		CP[x]	CF	CFb	ash	WSC	NDF	ADF	ADL
Early flowering	197.2^{b}	165.8^{A}	23.0	181.9	181.0^{bAB}	110.5^{a}	405.8	304.0	141.3
Full flowering	245.7^{ab}	156.5^{A}	20.7	180.6	171.3^{cB}	74.3^{b}	406.1	305.6	136.8
Seed pod	295.9^{a}	128.5^{B}	21.6	197.1	190.8^{aA}	63.5^{b}	418.5	321.9	146.4

[s] Means within columns with common superscripts are not significantly different (a, b, c: $P \leq 0.05$; A, B, C: $P \leq 0.01$) according to Duncan's multiple range test.
[x] CP-crude protein, CF-crude fat, CFb-crude fibre, WSC-water soluble carbohydrates, NDF-neutral detergent fibre, ADF-acid detergent fibre, ADL-acid detergent lignin.

The sulla harvested at early flowering stage and at full flowering were wilted for 24 h and, during this period, their DM reached values of 395.1 g kg^{-1} and 374.4 g kg^{-1} respectively, while the sulla cut at the seed pod stage was wilted for a shorter time (about 3 h), and was ensiled with 300.1 g kg^{-1} DM (Table 2).
These differences in DM content, and consequently the length of the wilting periods, strongly affected the ensiling process probably more than the qualitative characteristics of forage at harvesting. In fact, the best ensiling results were obtained with sulla harvested at the early flowering stage and having, after wilting, the higher contents of DM, producing silage characterised by a quite high critical pH fast reached with little acid production. The silages from forages obtained with later cuts, and having lower DM contents, showed less favourable fermentation parameters, particularly that of the last cut characterized by a relevant amount of butyric acid, a quite high pH probably higher than the critical value and by the presence of

ammonia nitrogen significantly higher than the other silages. This indicates that this last silage was still unstable (after 6 months of conservation) and subjected, in the late stages of the process, to a fermentative activity mainly carried out by *Clostridium* bacteria.

Table 2. Composition of sulla wilted silage[s].

Stage of harvesting	DM, g kg^{-1}	Crude protein on DM, g kg^{-1}	Acids on DM, g kg^{-1}			Lactic acid, g kg^{-1} of total acids	Flieg		pH	Ammonia-N, g kg^{-1} of total-N
			lactic	acetic	butyric		score	quality		
Early flowering	395.1^{A}	176.8^{a}	7.2^{b}	2.7^{cB}	0.2^{cB}	705^{aAB}	69^{A}	good	5.14^{aA}	21.6^{bB}
Full flowering	374.4^{B}	158.2^{b}	26.9^{a}	4.2^{bA}	2.1^{bB}	810^{aA}	60^{A}	medium	4.76^{cC}	27.2^{bAB}
Seed pod	300.1^{C}	137.0^{c}	23.1^{a}	5.4^{aA}	17.4^{aA}	502^{bB}	28^{B}	bad	4.83^{bBC}	37.7^{aA}

[s] Means within columns with common superscripts are not different (a, b, c: $P \leq 0.05$; A, B, C: $P \leq 0.01$) according to Duncan's multiple range test.

Conclusions

The results of this research confirmed the possibility to ensile sulla forage with no account of the development stage of the crop at harvesting, taking care to adopt a wilting period suitable to reach a DM content of about 400 g kg^{-1}.
With a shorter wilting time, it is possible to determine conditions favouring unwanted fermentations.

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Silage quality of tall fescue in comparison with other grass species

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Abstract

Year-round-grazing is one interesting extensive grassland system in low mountain ranges. In strong winters tall fescue is one of the important species with good forage quality. Because of the low acceptance by cows as fresh forage in summer, silage making is one alternative to hay production. Therefore the ensilability and silage quality from growth, harvested at the beginning of June of *Festuca arundinacea*, x *Festulolium* and *Lolium perenne*, were analysed over four years. The results show that tall fescue tends to have lower concentrations of water-soluble corbohydrates than x *Festulolium* and *Lolium perenne*; the WSC / BC-ratio is in all years higher than two. The nitrate concentrations are too low, so that a supplementation of nitrate / nitrit-additives is necessary. In most cases the critical pH-value of 4.5 and lower was arrived; butyric acid and NH_3-N-proportion of the crude protein-N-content appeared only in some cases. Consequently the silage quality of *Festuca arundinacea* is comparable to the other grasses and therefore the use of tall fescue silage as forage for cows is possible.

Keywords: silage quality, tall fescue, *Lolium perenne*, x *Festulolium*, nitrate, butyric acid

Introduction

In peripheral regions of low mountain ranges extensive farming systems like non-seasonal outdoor stock keeping of suckler cows are interesting 'low-input-systems'. *Festuca arundinacea* is across the world the most important frost resistant winter forage grass in the temperate climate. Under cold conditions and long snow periods *Festuca arundinacea* has higher dry matter yields with better forage quality than x *Festulolium* and *Lolium perenne*. Short length of accumulation before winter and late restained N fertilisation has a positive influence on forage quality (Wolf and Opitz v. Boberfeld, 2003). Because of high lignin and SiO_2 contents the acceptance of *Festuca arundinacea* as fresh forage is not very high. Therefore it is necessary to find an alternative when tall fescue is a major component of yield. Schrader and Kalthofen (1987) found that chopped *Festuca arundinacea* silage has a higher acceptance by cows. Therefore the ensilability and silage quality of *Festuca arundinacea*, x *Festulolium* and *Lolium perenne*, harvested at the beginning of June, were analysed.

Materials and methods

For analysing the ensilability and silage quality, primary growth from grass monocultures harvested at the beginning of June were analysed over four years. The trial was a latin rectangle with three replications and the following variants (Table 1).
The forage was dried to dry matter of 30 %, ensilaged and opened after 90 days. To characterize the ensilability the watersoluble carbohydrate content (Yemm and Willis, 1954), the buffering capacity (Weissbach, 1967) and the nitrate concentration (Anonymus, 1997) were analysed. After that the WSC / BC-ratio was calculated. On the other hand the pH-value (Anonymus, 1997), the volatile fatty acid concentrations (Theune, 1979), the milk acid concentrations (Haaker *et al.*, 1983) and the NH_3-N-proportion of the crude protein-N-content (Honold and Honold, 1991) were examined to get information about the silage quality. All data were tested separately for every year by analysis of variance. The LSD-test was made and the significance level was 5 %.

Table 1. Variants, designed as latin rectangle.

Factor	Level
1. Species	*Festuca arundinacea* ELFINA + MALIK
	x Festulolium PAULITA
	Lolium perenne ARABELLA + WEIGRA
2. Year	2.1 1998
	2.2 1999
	2.3 2000
	2.4 2001

Results and discussion

In all years *Festuca arundinacea* had the lowest WSC / BS-ratios (Figure 1); x *Festulolium* and *Lolium perenne* had comparable ratios. The reason for that was the lower content of watersoluble carbohydrate of *Festuca arundinacea*, which confirms the results from Cunderlikova *et al.* (2002). Because of lower buffering capacities in 2000 the WSC / BC-ratios were higher; in all years the ratio was higher than 2.0 in DM. The nitrate concentration was in all years lower than 0.05 % in DM; only in 1998 *Festuca arundinacea* had a higher nitrate concentrations of 0.03 % in DM (Figure 2). In comparison to Chestnut *et al.* (1988) and Pinosa *et al.* (1995) there were no great differences between the quality of *Festuca arundinacea*, x *Festulolium* and *Lolium perenne* silages. In most cases the pH-values of the silages were similar and lower than 4.5 (Figure 3). Because of lower concentrations of milk acid and higher concentrations of butyric acid, (Figure 4), in 1998 the pH-values were higher. This effect was also described through the higher concentrations of volatile fatty acids. The concentrations of butyric acid were between 2.3 and 5.2 % in DM; x *Festulolium* had the lowest, *Lolium perenne* and *Festuca arundinacea* silages the highest contents. The highest NH_3-N-proportion of the crude protein-N-content was found in tall fescue silages, but the concentrations were lower than the critical 8 % in DM, from which we can talk about as a relevant decomposition of crude protein through bacteria (Wierenga, 1961). Consequently *Festuca arundinacea* silages showed comparable qualities to silages from x *Festulolium* and *Lolium perenne*. Therefore these could be fed to cows, confirming the results of Murphy *et al.* (1987).

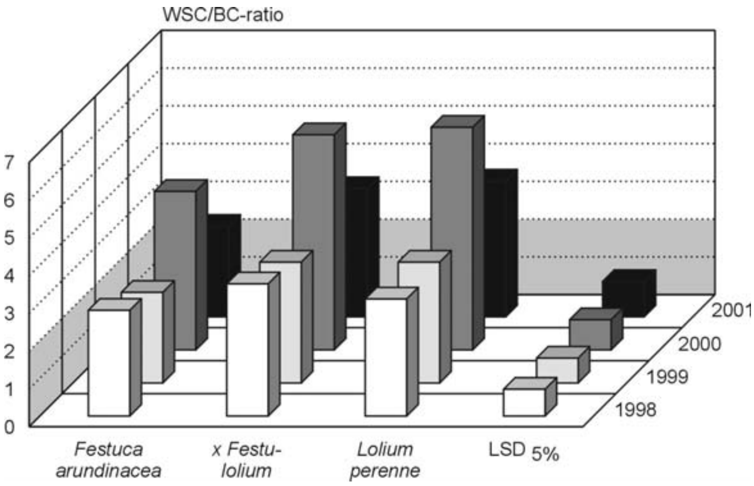

Figure 1. WSC / BC-ratio as influenced by species and year.

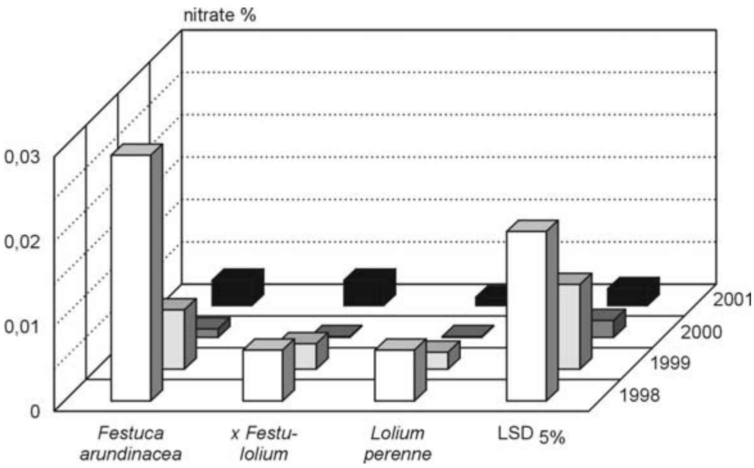

Figure 2. Nitrate-concentration as influenced by species and year.

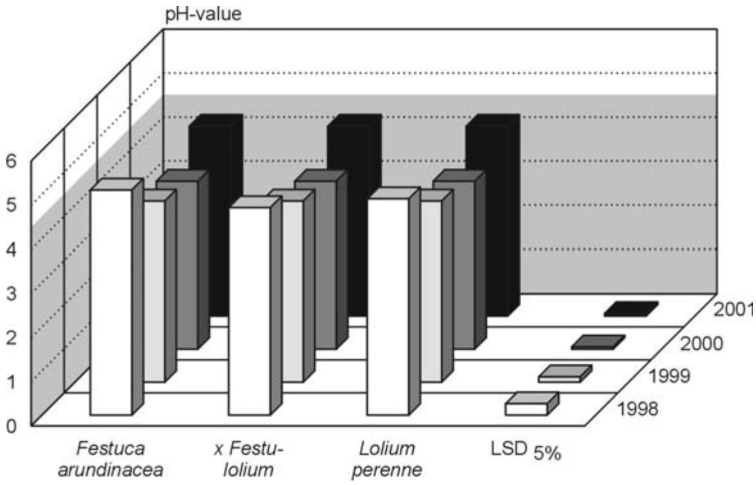

Figure 3. pH-value as influenced by species and year.

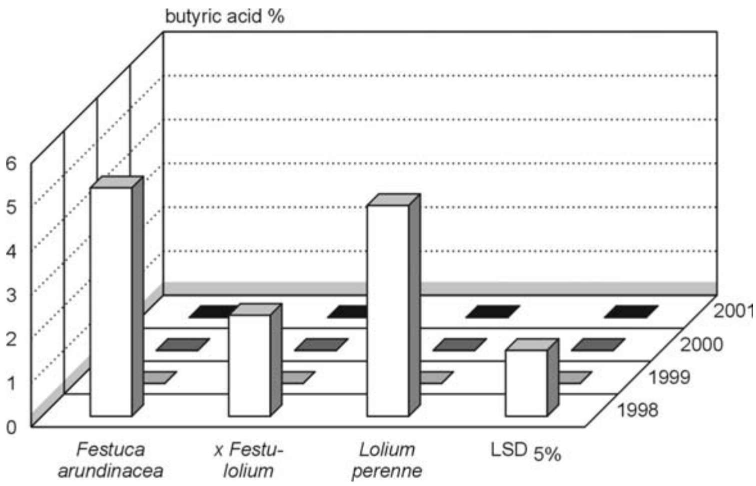

Figure 4. Butyric acid concentration as influenced by species and year.

Conclusions

Based on the data obtained feeding of tall fescue silages to cows is possible. The silage quality is comparable to other grass silages. Because of the low nitrate concentrations it is advisable to use nitrate / nitrite additives to reduce the risk of butyric acid fermentation.

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Aerobic stability of silages from high sugar grasses (EU-Project ‘SweetGrass’)

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Abstract

Pure stands of *Lolium perenne* and *Medicago sativa* were established within the EU-funded project ‘SweetGrass’ at the Federal Agricultural Research Centre (FAL) in Braunschweig, Germany. Both crops were cut with a plot harvester, wilted to a target dry matter (DM) content of 400-450 g DM kg^{-1} and chopped. In Experiment A, grass was ensiled with 2 bacterial inoculants and either sorbate or benzoate (4 treatment combinations of additives). In a separate experiment (Exp. B), lucerne was ensiled together with wilted grass in different ratios. The crops at the time of ensiling were analysed for numbers of yeasts and moulds, and their chemical composition, i.e., pH, fermentation losses, residual water-soluble carbohydrates (WSC), and the degree of aerobic stability.

All additive treatments were successful in inhibiting fungal development, delaying heating and aerobic spoilage after opening of the silos, and in reducing ensiling losses by 75 %. Aerobic stability was increased and fermentation losses were considerably reduced in the grass-legume silages provided a minimum of 50 % lucerne was contained in the mixture. Additives as well as the admixture of lucerne resulted in higher concentrations of residual WSC in the silages.

Keywords: *Lolium perenne*, *Medicago sativa*, silage, WSC, aerobic instability, additives

Introduction

Novel varieties of *Lolium perenne* with WSC contents up to 300 g kg^{-1} DM offer the potential, either on their own or in combination with protein-rich forage legumes, to improve the efficiency of ruminant production in sustainable livestock systems. However, silages prepared from these grasses may contain elevated amounts of residual fermentable carbohydrates. These provide a particular risk for silage stability after opening the silo. In grass silages the aerobic deterioration is initiated primarily by yeasts, which can assimilate lactic acid and consequently raise the pH. The overall objective of this study was to investigate techniques for the conservation of grasses with high WSC contents that maximise the quantity of residual fermentable carbohydrates in the ensiled crop and to determine the effect of co-ensilage with lucerne, which is generally stable upon exposure to air (Pahlow *et al.*, 2000).

Materials and methods

The grass cultivars ‘Aberdart’ (ABD) and ‘Fennema’ (FEN) as well as the lucerne variety ‘Planet’ (LUC), were established in 850 m^2 plots. The sowing density was 35, 30 and 30 kg ha^{-1}, respectively. All plots received a mineral fertiliser treatment of 700 kg ha^{-1} Thomas phosphate (7-21-3 P K Mg) on February 21, 2003; and nitrogen fertilisation (60 kg ha^{-1} on March 20 and June 24, 2003 respectively), except lucerne which received no nitrogen. Cleaning cuts of the plots were made with a Haldrup plot harvester on June 18 and October 27, 2003.

In Exp. A (May 27, 2003) the grass 'Fennema' was cut and wilted to achieve a target DM concentration of 400 g DM kg^{-1}. Plant material was precision-chopped (1.5 cm theoretical particle length). The 4 additive treatments (2 *Lactobacillus plantarum* inoculants with either sodium benzoate or potassium sorbate), were sprayed as liquid preparations in a volume of 10 ml (bacteria) and 5 ml (chemicals) per kg FM of the crop. The control silage received the equivalent amount of water. The additive concentrations applied were 10^5 colony forming units (cfu) per g of the crop as ensiled, and 400 g per ton of the crop for the chemical compounds, which were added separately, prior to the respective inoculants. In both experiments three replicate 1.5 l silos per treatment were ensiled and stored at 25 °C ambient temperature for 90 days. In addition two 0.5 l mini silos were filled in replicate for Exp. A, to determine the acidification rate and the reduction of enterobacteria 3 days after ensiling.

For Exp. B (June 13, 2003) the grass 'Aberdart' and the lucerne were cut and wilted separately to achieve target DM concentrations of 450 g DM kg^{-1} for both crops. After chopping (see above) they were combined on a fresh matter basis in grass : lucerne ratios of 100 : 0; 75 : 25 and 50 : 50.

The initial material was characterised by analyses for dry matter (DM), pH value, crude protein (CP), WSC (g WSC kg^{-1} DM) and epiphytic lactic acid bacteria (LAB), yeasts and enterobacteria (Exp. A only), as given in table 1.

Table 1. Chemical and microbial composition of the wilted crops at ensiling.

Exp.	Crop / Mixture	DM	WSC	CP	LAB	Yeasts	Enterobact.
		g DM kg^{-1}	g kg^{-1} DM		log cfu x g-1 FM		
A	FENNEMA	423	220	145	4,2	1.8	< 3
B	100 % ABD + 0 % LUC	460	161	118	< 2	3.7	not determ.
B	75 % ABD + 25 % LUC	478	142	152	< 2	3.2	not determ.
B	50 % ABD + 50 % LUC	484	127	166	< 2	3.4	not determ.

The silages were analysed for fermentation losses, DM, pH, residual WSC and yeasts. The aerobic stability of all silages was measured over 7 days by recording; a) the number of days until temperature rose by >3 °C above ambient (days to TR); and b) the DM losses in a climatic chamber, held constant at 20 ± 0.5 °C, according to Honig (1990).

Results and discussion

The concentrations of fermentable WSC at ensiling remained below the expected high level in both grasses. The CP content in the grass-legume-mixtures corresponded with the increasing ratio of the added lucerne. The number of all epiphytic micro-organisms was generally low, except for LAB on ‘Fennema’.

The fermentation quality of all silages in Exp. A was considerably improved by the additive treatments. The enterobacteria (which may cause hygienic problems), after an initial increase in numbers were reduced by more than 1 logarithmic unit within the first 3 days after ensiling. This was due to the much faster pH-decline in the treated silages (silage with additives pH 4.6 vs. control silage pH 6.8). Table 2 shows that even after storage for 90 days the pH of the treated silages was significantly lower, along with a remarkable reduction of the fermentation losses by 75 % on average and higher amounts of residual WSC.

Table 2. Effect of inoculants and organic salts on fermentation and aerobic stability (Exp. A).

Treatment	pH 90 days	Fermentation loss	Residual WSC	Aerobic stability	DM loss
		g kg^{-1} DM		days to TR	g kg^{-1} DM
Control	5.4	60	114	4.1	103
Inoculant I + Benzoate	3.8	14	149	7.0	0,0
Inoculant I + Sorbate	3.8	15	148	7.0	0,0
Inoculant II + Benzoate	3.9	16	150	7.0	0,0
Inoculant II + Sorbate	3.9	16	146	7.0	0,0
(s)	(0.6)	(18)	(14)	(1.2)	(41)

Only low numbers of fungal spoilage organisms were detected in the control silage after 90 days of storage. The treated silages appeared free from yeasts and moulds and remained stable for at least one week, the end of the regular test for aerobic stability. Consequently no DM losses were recorded during this period, while the untreated control lost 103 g kg^{-1} DM within 7 days. In general, the 4 treatments did not differ with respect to their inhibitory or stabilizing effect.

Table 3. Effect of grass : lucerne ratio on fermentation and aerobic stability (Exp. B).

Crop / Mixture	pH 90 days	Fermentation loss	Residual WSC	Aerobic stability	DM loss
		g kg^{-1} DM		days to TR	g kg^{-1} DM
100 % ABD : 0 % LUC	6.1	59	89	3.8	96
75 % ABD : 25 % LUC	5.9	22	119	3.2	66
50 % ABD : 50 % LUC	5.7	7	118	6.5	26
(s)	(0.2)	(22)	(14)	(1.4)	(28)

As a consequence of the very low epiphytic population of LAB on both crops in Exp. B and the high degree of wilting, the silage pH remained at an unsatisfactory high level. So far it remains unexplained why in mixtures with LUC the pH, fermentation losses and WSC consumption were decreased to a larger extent than in the pure ABD. The aerobic stability was improved only by the 50 : 50 mixture of ABD and LUC. DM losses during the fermentation process as well as during aerobic storage were lowered by 37 and 30 g kg^{-1} DM respectively even with the addition of just 25 % of the lucerne.

Conclusions

The quantity of residual fermentable carbohydrates, fermentation and hygienic quality and aerobic stability of silages prepared from grasses with elevated sugar contents can be increased by the addition of lactic acid bacteria, organic salts and to some extent by co-ensilage with 50 % of lucerne.

Acknowledgements

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The nutritive value and aerobic stability of big bale silage treated with bacterial inoculants

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Abstract

Studies on the influence of some bacterial silage additives on the nutritive value and aerobic stability of grass silage were conducted between 1999 and 2002. The studies involved silage made from a pre-wilted meadow sward with the addition of two bacterial inoculants: K1 (*Enterococcus faecium*, *Lactobacillus plantarum*, *Lactobacillus casei* and *Pediococcus* spp.) and K2 (*Lactobacillus plantarum* K). The silages were produced in big round bales wrapped in plastic film. The bacterial inoculants (as additives) were sprayed on during baling of the herbage. The silages were made from meadow swards cut three times a year. Dry matter, pH, organic acids and nutritive components were analysed in the silage. Stability was studied by monitoring changes of temperature in silage samples placed in boxes in aerobic conditions (temperature about 21 °C). Addition of bacterial inoculants improved the quality and aerobic stability of grass silage made in big bales. Of the bacterial inoculants studied the most effective appeared to be the inoculant K2 (*Lactobacillus plantarum* K). Bacterial inoculants with lactic acid bacteria had no influence on nutritive value of the feed.

Keywords: aerobic stability, bacterial inoculant, lactic acid bacteria, grass silage, nutritive value

Introduction

Obtaining good quality and high digestibility of nutritive components in grass silage requires the stimulation of the ensilage process. For many years chemical preservatives have been used for this purpose. Natural methods of ensilage need to be stimulated by adding biological preparations. The use of biological inoculants usually improves silage quality and increases feed intake and animal performance (Andrieu and Demarquilly, 1996). The lack of aerobic stability of silage with biological additives is their main weakness. However, recently obtained bacterial additives, thanks to the suitable selection of LAB, improve aerobic stability of silage (Driehuis *et al*., 2000; Oude Elferink *et al*., 1999). Previously starting cultures of homofermentative LAB producing lactic acid and reducing the proportion of acetic acid and alcohol were preferred. Published studies considered only the quality of silage and aerobic stability was not evaluated. The aim of this study was to investigate the influence of bacterial additives containing homofermentative LAB on the quality and nutritive value of meadow silage.

Materials and methods

This study on the influence of bacterial silage additives on chemical composition and aerobic stability of grass silage was conducted in the years 1999-2002. The experiment was carried out at the Experimental Station at Falenty near Warsaw in Poland. Meadow sward composed of 80 % grasses (*Poa pratensis, Alopecurus pratensis, Dactylis glomerata, Arrhenaterum elatius*) and 20 % weeds and herbs was used for ensilage. The meadow herbage was ensilaged with the addition of bacterial inoculants: K_1 (*Enterococcus faecium*, *Lactobacillus plantarum, Lactobacillus casei* and *Pediococcus* spp.), K_2 (*Lactobacillus plantarum* K) or without any additives (control silage). The meadow was cut three times a year. The first cut was made at full heading of *Dactylis glomerata*, the second and third cuts were taken at nine weeks intervals. Herbage was cut using a rotary mower that had a mounted conditioner. Before harvest the fresh grass was pre-wilted to a dry matter (DM) concentration of approximately 400 g kg^{-1}. Bacterial additives were put into the herbage during bale rolling in a variable bale chamber baler. The big bales (about 400 kg) were wrapped in four layers of stretch plastic film after transport to their place of storage. During the 100 day feed experiment, silage was fed to three groups of 10 heifers (200 kg). The heifers were fed *ad libitum*. The daily feed intake and refusals were recorded. Live weights were determined at the beginning, in the middle and at the end of the study. During the feeding experiment silage samples were taken for chemical analyses.

The chemical composition and quality (according to the Flieg-Zimmer scale) of feed samples was determined. Silage was analysed for: DM, crude protein, crude fibre and crude fat concentration using the NIRS technique. Organic acids were determined with the enzymatic method. Stability was analysed by monitoring changes of temperature in silage samples placed in boxes in aerobic conditions (temperature about 21 °C) for 12 days. Changes of temperature were recorded twice a day in each group of silage. Stability of silage was measured as the time necessary to increase the temperature by 1 °C over air temperature.

Results

Mean DM content in all silages was 400 g kg^{-1}. DM content is known to have a large effect on fermentation and the DM content adopted should guarantee the correct process of lactic fermentation in ensilaged material. The mean pH values in silages were similar (about pH 4.7), but there was a tendency for higher pH values in the control silage. The concentration of organic acids in silage FM was different and depended on the inoculant used. In all silage samples lactic acid dominated among other acids. Addition of bacterial inoculants containing homofermentative LAB improved silage quality. This was very evident in the case of silages made with K2. The quality of this silage was very good while the quality of the control silage was only satisfactory (Table 1).

The addition of homofermentative LAB during ensilage improved aerobic stability of silage evaluated at a temperature of 21 °C. The mean stability of the tested silages was 3.5 days (Control), 6.8 days with the addition of K1 and 7.3 days with K2 (Figure 1).

Table 1. The quality and nutritive value of grass silage made with the addition of LAB (1999-2002).

	Control		K1		K2	
	mean	SD	mean	SD	mean	SD
Dry matter (g kg^{-1})	429.8	119.6	388.2	82.3	402.6	102.6
pH	5.14	0.42	4.80	0.30	4.67	0.38
Acids in FM of silage (g kg^{-1})						
- lactic	13.2	3.4	18.6	8.7	22.5	7.3
- acetic	4.0	1.7	3.5	0.7	3.5	1.1
- butyric	1.1	1.0	0.8	1.5	0.3	0.7
Sum of acids	18.3	4.2	22.9	8.0	26.3	7.6
Points in Flieg-Zimmer scale	59	-	68	-	100	-
Quality	satisfactory	-	good	-	very good	-
Stability (in days)	3.5	0.6	6.8	1.7	7.3	3.7
Crude protein	131.9	15.8	136.0	12.1	138.4	13.8
Crude fibre	269.8	5.3	271.1	8.6	275.3	8.5
Crude fat	34.8	1.9	35.7	3.2	33.8	1.6
Intake of silage (kg d^{-1})	13.15	1.83	13.42	2.15	13.65	2.28
Intake of DM (kg d^{-1})	5.33	0.47	5.10	0.27	5.16	0.71
Daily gains (kg)	0.64	0.09	0.62	0.06	0.67	0.09

SD – standard deviation

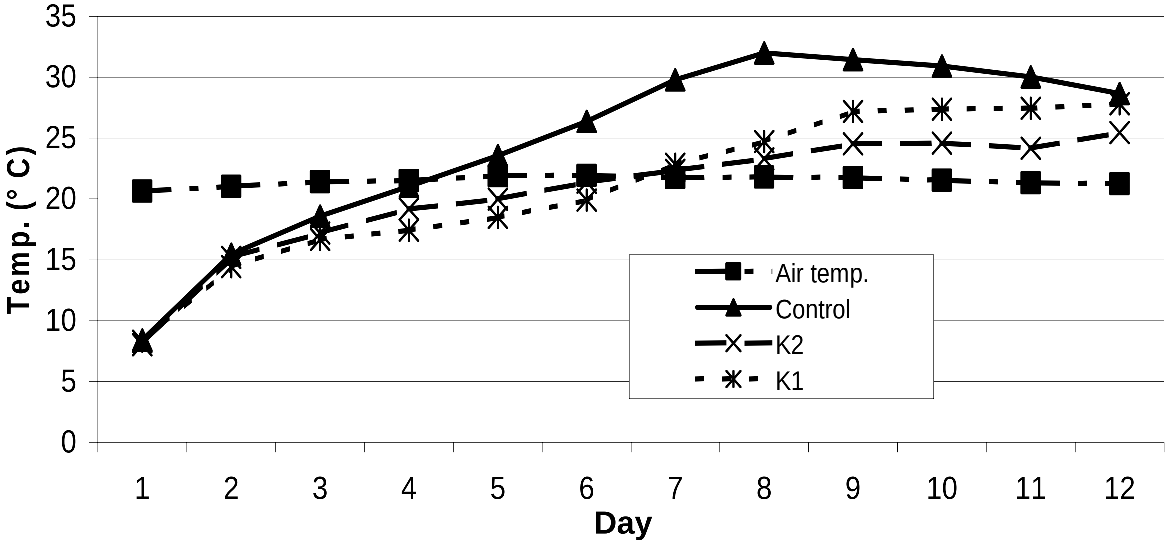

Figure 1. The aerobic stability of silage (1999-2002).

Inoculant treatment had no influence on the nutritive value of the feeds. The concentration of crude protein ranged from 131.9 g kg^{-1} (Control) to 138.4 g kg^{-1} (K2). The mean concentration of crude fibre in all silage samples was about 270 g kg^{-1}. Heifers fed the test silages consumed 5.10 to 5.33 kg of dry matter daily. Initial weight of the experimental heifers was over 170 kg. After the 100 day feeding period, the animals weighed on average about 240 kg. During the whole experimental cycle the highest average weight gains were obtained with K2 treated silage (0.67) and the control silage (0.64 kg). The lowest gains were obtained with heifers fed the K1 treated silage (0.62 kg; Table 1).

Conclusions

Addition of bacterial inoculants containing homofermentative LAB improved the quality and aerobic stability of grass silage made in big bales. Among the bacterial inoculants compared the most effective was inoculant K2 (*Lactobacillus plantarum* K). The bacterial inoculants used had no influence on the nutritive value of the feed.

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Fatty acid content, composition and lipolysis during wilting and ensiling of perennial ryegrass (*Lolium perenne* L.): preliminary findings

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Abstract

Milk from cows fed fresh grass has higher levels of n-3 fatty acids (FA) than when fed silage. This could be ascribed to a loss of precursor FA as well as to lipolysis during forage conservation. Three cultivars of ryegrass (*Lolium perenne* L.) were sampled fresh, wilted (one cultivar only) and ensiled and samples were stored frozen. After thawing, FA were extracted and triacylglycerols (TAG), free fatty acids (FFA) and polar lipids (PL) were separated by thin layer chromatography (TLC). FA methyl esters were identified by gas chromatography. In the current study, neither wilting nor ensiling produced a significant effect on the FA composition of one cultivar, whereas the proportion of C18:3n-3 in the other two cultivars decreased upon ensiling. There was a significant difference in the percentage of FFA (24.9, 21.2 and 65.2 % of total FA) and TAG (9.3, 22.9 and 25.9 % of total FA) in fresh, wilted and ensiled grass, indicating intensive lipolysis during the ensiling phase but not during wilting, and formation of TAG during wilting.

Keywords: ensiling, fatty acid, lipolysis, *Lolium perenne*

Introduction

Grasses and legumes are rich sources of the beneficial n-3 FA linolenic acid (C18:3n-3). However, in the rumen, FA are hydrolysed and poly-unsaturated FA consecutively hydrogenated. Nevertheless, summer dairy products from cows at pasture show higher levels of n-3 FA when compared to winter products, even when grass silage is the major forage component (e.g., review by Dewhurst *et al.*, 2003). It was hypothesised that this could be due to the loss of precursor FA as well as to the occurrence of lipolysis during forage conservation. To determine at which conservation stages changes in FA content, composition and structure (esterified vs. free) occur, fresh, wilted and ensiled grass were compared.

Materials and methods

In August, three perennial ryegrass (*Lolium perenne* L.) cultivars, cv. Barnhem, cv. Agri and cv. Respect were harvested for silage from a trial field in Wageningen, The Netherlands (experimental details were described in Elgersma *et al*., 2003). The cultivars Agri and Respect were of the mid-late and cv. Barnhem was of the late heading type. The regrowth period of this third cut was 40 days at a target yield of 3500 kg DM ha^{-1}. All swards were leafy without inflorescences. Within 20 min after cutting at 10 a.m., representative samples of fresh grass were taken at random locations. Similarly, a representative sample of wilted grass after drying in the field for 52 h was collected (cv. Barnhem only). Six months after ensiling, all baled silages were sampled and samples were pooled to obtain a representative sample for analysis. The samples were frozen within 15 minutes and stored at -18 ºC for about 1 to 6 months. After thawing, samples were cut into 1 cm lengths and chloroform / methanol (2/1, v/v) and the internal standard (C17:0) were added. Samples were homogenised by an ultra-turrax mixer and FA were extracted overnight. Afterwards TAG, FFA and PL were separated by

TLC and after methylation, FA methyl esters were identified by gas-liquid chromatography as described by Raes *et al*. (2001).

Results and discussion

The effects of wilting and/or ensiling on the FA content and composition of perennial ryegrass are shown in table 1.

Table 1. Effect of wilting and ensiling on fatty acid content (g kg^{-1} DM) and fatty acid composition (% of total fatty acids) of three cultivars of perennial ryegrass (n = 3).

	cv. Barnhem				cv. Agri			cv. Respect		
	fresh	wilted	ensiled	sem	fresh	ensiled	sem	fresh	ensiled	sem
Total FA (g/kg DM)	13.0^b	11.6^c	15.4^a	0.35	12.8^b	15.4^a	0.631	13.7^b	15.2^a	0.20
% of total FA										
C16:0	17.8^b	17.4^b	18.8^a	0.22	19.9	20.5	0.24	18.8^b	19.9^a	0.12
C18:1	2.89	2.76	2.51	0.32	3.27	3.47	0.06	3.58	3.37	0.06
C18:2n-6	15.5^a	14.3^b	15.3^a	0.16	16.9	17.4	0.34	16.6	17.3	0.26
C18:3n-3	54.4	54.0	53.1	0.53	50.8^a	47.1^b	0.71	53.0^a	48.1^b	0.31

[a,b,c] Means with different superscript within the same row and cultivar are significantly different ($P < 0.05$)

Effects on total FA content should be interpreted with caution as some differences might have been induced by differences in thawing losses (Fievez *et al*., unpublished results). Wilting and ensiling did not affect the FA composition to a major extent in the Barnhem cultivar, with C18:3n-3 comprising between 53.1 and 54.4 % of the total FA. However, in accordance with Elgersma *et al*. (2003), a decrease in the C18:3n-3 proportion was found for the other two cultivars after ensiling of wilted grass. Presumably, FA oxidation – specifically inducing deterioration of poly-unsaturated FA – was more extensive in these two cultivars and in the study of Elgersma *et al*. (2003) than in the Barnhem. This could be related to variation in extended wilting prior to ensiling (Dewhurst and King, 1998) or differences in heading date. Lower C18:3n-3 proportions both in the fresh and the ensiled grass of all cultivars in the current study than that of Elgersma *et al*. (2003) may be due to longer regrowth periods (40 days *v*s. 23 days respectively). The effect of wilting and ensiling on the proportional distribution of FA in lipid classes (FFA, PL and TAG) is presented in table 2.

Table 2. Effect of wilting and ensiling on distribution of fatty acids in lipid classes (free fatty acids, FFA; triacylglycerols, TAG and polar lipids, PL) (% of FFA + TAG + PL) of three cultivars of perennial ryegrass (n=3).

	cv. Barnhem				cv. Agri			cv. Respect		
	fresh	wilted	ensiled	sem	fresh	ensiled	sem	fresh	ensiled	sem
Free fatty acids	24.9^b	21.2^b	65.2^a	1.13	28.5^b	67.2^a	1.11	28.3^b	69.2^a	1.01
Triacylglycerols	9.30^b	22.9^a	25.9^a	1.24	10.5^b	24.9^a	1.31	10.1^b	21.9^a	0.73
Polar lipids	58.9^a	51.0^b	6.48^c	1.34	61.0	7.97	2.21	61.7	8.93	1.43

[a,b,c] Means with different superscript within the same row and cultivar are significantly different ($P < 0.05$)

The amount of FFA was already high (around 25 %) in fresh grass. Lipolysis of PL could have been induced by plant enzymes (Lee *et al*., 2002) during frozen storage or after thawing as observed before by Van der Veen and Olcott (1967) (FFA between 11 and 26 % of total FA). In contrast, Elgersma *et al*. (2003) found less than 2 % FFA in fresh grass samples, which were also stored frozen. However, extraction procedures (chloroform/methanol in the current study; chloroform by Van der Veen and Olcott (1967) and ethanol by Elgersma *et al*., 2003) as well as methodology to separate free and esterified FA (TLC in current study and

Van der Veen and Olcott (1967) vs. selective transesterification of esterified FA followed by direct GC analysis of both FA methyl esters as well as FFA by Elgersma *et al*., 2003) differed between the three studies. This illustrates the extreme importance of comparable and adequate sample handling, storage and extraction methodology (Christie, 1993).
Ensiling of grass had a significant effect on the proportion of FFA. Total FFA increased by 160 %. Individual FA increased, varying between 72.3 % and 213 % (data not shown). Dramatic increases in FFA proportions after ensiling have been reported before (Elgersma *et al*., 2003; Steele and Noble, 1983) and were observed for all three *Lolium perenne* cultivars in the current study. The current study indicated no increased level of FFA in wilted grass in Barnhem, which suggests lipolysis mainly took place during the actual ensiling and not during the wilting process. It is unknown whether lipolysis was plant-mediated, bacterial or both. Surprisingly, the proportion of total TAG significantly increased (180 %) in both wilted and ensiled grass compared to fresh samples. The increase of C18:3n-3 in this fraction was as high as 470 % (data not shown). Results from the Barnhem cultivar suggest TAG synthesis took place during the 52 h wilting period. Reduced moisture content during wilting could have caused stress to the plant as does short ozonification, inducing a direct conversion of monogalactosyldiacylglycerols to TAG (Sakaki *et al*., 1990).

Conclusions

In the current study, neither wilting nor ensiling produced a significant effect on the proportion of C18:3n-3 in Barnhem, whereas it was reduced after ensiling Agri and Respect cultivars. The proportion of TAG increased during wilting but not any further during ensiling, whereas the proportion of FFA did not change during wilting, but strongly increased during ensiling.

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Biotransformation of clover isoflavones during ensiling

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Abstract

Clover isoflavones are partly recovered in milk and may have some beneficial effect on human health. In this study, we measured the biotransformations of clover isoflavones during the wilting and ensiling process. Subterranean (cv. Yarloop) and red (cv. Merviot) clover, were grown in a mountain environment, collected at flowering and ensiled, after wilting and without wilting, in small vessels with formic acid. Isoflavone glycosides were hydrolyzed with an improved β-glycosidase method. Total isoflavones (TI) and free aglycones were measured by HPLC. Yarloop had a greater amount of TI than Merviot (19.4 and 10.8 g kg^{-1} DM respectively), of which half was in aglycone form. In both varieties, total formononetin content was about 58 % of TI. Wilting slightly decreased TI in Yarloop, and enhanced the hydrolysed fraction. In both species, ensiling did not change TI, but the aglycone fraction increased to 63-92 % of TI; genistein was increased, probably by demethylation of biochanin-A. In Merviot, formononetin was increased by a possible neoformation process. Ensiling totally preserved the isoflavone active forms of both clover species. This could be relevant for the conservation of the quality of forage and consequently of milk.

Keywords: isoflavones, biotransformation, clover, silage

Introduction

Isoflavones are known to have potential benefits on human health against hormone related diseases such as breast and prostate cancer, osteoporosis, and menopausal symptoms (Bingham *et al*., 1998). Thus, it is important to determine the amounts of isoflavones in our human diets.

Ruminants may consume large amounts of isoflavones if they are fed red (*Trifolium pratense* L.) or subterranean (*Trifolium subterraneum* L.) clover. In the forage, these compounds are mostly present as glycosides. After transformation in the rumen, they are partly secreted in milk as compounds with similar activity. Consequently, clover may represent a source of isoflavones in the human via milk.

The amounts of isoflavones in clover greatly depend on the species, cultivation conditions, and environmental factors (Rossiter, 1972). They also change after gathering, during storage and haymaking. Ensiling is relevant to preserve the forage but it has been reported that the composition of isoflavones change during wilting and ensiling. Hydrolysis of the glycosides, demethylation and other biological processes produce a general increase of the free aglycones such as daidzein and genistein, but also an enhanced content of hydrolysed plus free formononetin and biochanin A (Sarelli *et al*., 2003). Such phenomenon could have biological reasons or could be caused by an unsatisfactory balance of initial and final molecules, especially due to the extraction or hydrolysis method. The purpose of this study was therefore to determine the content of isoflavones in two clover species and to determine the effect of wilting and ensiling.

Materials and methods

One subterranean (cv. Yarloop) and one red (cv. Merviot) clover strain were grown in a mountain environment (Massif Central, France) and gathered at the flowering stage. The two varieties were either directly ensiled or wilted under the sun for 6 hours before ensiling. The plants were gathered in two different part of the field, chopped, had formic acid (5 ml kg^{-1} fresh material) added and were kept in 850 ml tightly closed bottles for 2 months. Before analysis, each sample was dried at 60 ^oC for 48 hours under ventilation and ground in a cutter mill. The ground material (200 mg) was twice extracted with 25 mL of 50 % ethanol, and the extracts were concentrated. Hydrolysis was carried out before extraction using the β-glycosidase method (Jones, 1979), with some modifications, to yield the hydrolysed + free fraction (HF). The free aglycones (FA) and hydrolysed isoflavones, were analysed using HPLC equipped with diode-array detector.

Table 1. Effect of wilting and ensiling on hydrolysed +free (HF, g kg^{-1} DM) fraction and free aglycones (FA, % of HF) of isoflavones in subterranean (S) and red clover.

Samples	daidzein		genistein		formononetin		biochanin A		Total	
	HF	FA	HF	FA	HF	FA	HF	FA	TI	FA
Subterranean clover										
fresh	0.36^a	*30*	4.7^a	*46*	11.4^a	*45*	3.0^a	*39*	19.4^a	*44*
wilted	0.24^a	*69*	3.6^b	*53*	8.0^b	*70*	2.1^{bc}	*46*	13.9^b	*62*
fresh ensiled	0.34^a	*50*	7.9^c	*65*	7.9^b	*65*	2.5^b	*52*	18.6^a	*63*
wilted ensiled	0.23^a	*87*	6.0^d	*99*	6.9^c	*60*	2.0^c	*76*	15.1^b	*78*
Red clover										
fresh	0.10^a	*0*	0.4^a	*53*	6.2^a	*58*	4.1^a	*49*	10.8^a	*54*
wilted	0.11^a	*0*	0.6^b	*23*	6.2^a	*51*	4.5^a	*45*	11.4^a	*47*
fresh ensiled	0.13^a	*89*	0.5^{ab}	*81*	7.0^b	*90*	4.0^a	*97*	11.6^a	*92*
wilted ensiled	0.12^a	*70*	0.6^b	*65*	6.4^{ab}	*88*	4.1^a	*92*	11.2^a	*88*

TI, total isoflavones. Different superscripts indicate significant difference ($P < 0.05$).

Results and discussion

The total amount of isoflavones (TI) in fresh subterranean clover was double that in red clover (Table 1). In both species, the major isoflavone compound was formononetin (about 58 % of TI). The total free aglycones accounted for about the half of TI.
After wilting of Yarloop, part of the isoflavonoids were degraded under aerobic and sunny conditions and HF decreased for all compounds. On other hand, the hydrolysis of the glycosides enhanced FA. Few changes occurred in Merviot except a slight increase in genistein. After ensiling, HF and TI were unchanged in both varieties, but an important hydrolysis process increased total FA in Yarloop, to 63 and 78 % of TI for fresh and wilted ensiled plants respectively. A still higher hydrolysis rate (about 90 % of TI) occurred in Merviot. Total formononetin and biochanin-A significantly decreased in Yarloop. A concomitant increase of total genistein was probably due to demethylation of biochanin-A, but daidzein was unchanged. For Merviot, the major change was an increase of formononetin content after ensiling, the variation being significant for the fresh initial forage. A neoformation of formononetin due to the wounding of the plant possibly occurred, as suggested by Sarelli *et al.* (2003). The constant level in biochanin-A, also observed after wilting, is possibly due to the balance between neoformation of the compound and decomposition by demethylation.

Conclusions

Ensiling preserved the biologically active isoflavones in the clover varieties, although they were biotransformed, mainly into aglycone forms. Wilting had only a slight negative impact on subterranean clover. The consequences of isoflavone transfer to milk have yet to be studied with fresh and silage diets.

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The technological factors affecting the quality of big bale silage

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Abstract

Big bale silage making technology has become popular among farmers. However, the quality of big bale silages is often poor. The aim of the present study was to investigate the effects of additives, herbage wilting and different crops on quality of big bale silage.
The silage crops were fresh cut and wilted red clover-grass mixture and fresh cut ryegrass. The crop was cut by a mower conditioner, baled by 'John Deere' baler and wrapped with plastic by a 'McHale' wrapping machine. The additives used were chemicals 'AIV-2000' and 'Niben', each added at an application rate of 4 l t^{-1} fresh matter. The airtight conditions in bales were determined by using special 'Ekolag AB' equipment.
Application of additives improved fermentation and silage quality. Silage quality was also improved when the crop was wilted. The airtight conditions in bales varied to a great extent. Ryegrass resulted in better silage quality compared to red clover-grass mixture.

Keywords: big bale silage, silage quality, fermentation, additive, wilting

Introduction

In view of climatic conditions, silage is the best method for preserving fresh forage with minimal losses in Estonia. When the proper ensilage techniques are used, silage will have a high nutritive value and hygienic quality. However, the results in practice indicate that the quality of silage is often poor or even unsatisfactory. These results are usually achieved when the fermentation conditions are difficult or variable, such as in big bales or when long-cut herbage is used. The main reason why the fermentation conditions in the bale are difficult is that air can easily leak into the silo. Bale silage is usually made of non-chopped or restricted cut grass. Such kinds of herbage may be difficult to ensile due to delay in fermentation or material heterogeneity. It is also difficult to achieve sufficient density of silage and to mix additive with such material. Herbage wilting can improve fermentation conditions but the risk for fungal growth may increase. Certain crops, such as legumes or legume-grass mixtures, do not easily wilt and the silage may remain heterogeneous (Lättemäe *et al*., 1998).
It has been shown that silage additives can be effective under difficult and variable fermentation conditions and may reduce these adverse effects of the material ensiled (Lättemäe, 2001). In Estonia, the liquid silage additives Siloben and Superben are available. Both are based on sodium-benzoate (NaB). The results in practice have shown that these additives improve silage quality and increase aerobic stability. However, when fermentation conditions are difficult, as in big bales, the additives are less effective. To increase the efficacy of additives, sodium nitrite ($NaNO_2$) should be used to reduce clostridial activity. The $NaNO_2$ produces gases that inhibit clostridial activity even at high pH-values. In this study NaB was used in combination with $NaNO_2$ ('Niben'). The second additive was 'AIV-2000', containing formic acid, ammonium formate and esters of benzoic acid.

Materials and methods

The field of red clover-grass mixture where the experiment was conducted consisted of about 30 % of red clover and 70 % of grasses (about 10 % of perennial ryegrass, 55 % of meadow fescue and 5 % of timothy). The ryegrass field consisted of about 95 % of perennial ryegrass.

Silage crops were harvested by a mower conditioner and baled by a 'John Deere' baler (6 June 2002). Baler was provided with a passive chopper, resulting in herbage being chopped into lengths measuring from 5 to 20 cm. Silage was made of direct cut red clover-grass mixture and of the mixture after wilting for 5 hours in the field. Ryegrass silage was made of direct cut herbage. All bales were wrapped with a 'McHale' wrapper (0.025 mm plastic film, four layers). 'Niben' and 'AIV-2000' were each added at an application rate of 4 l t^{-1} fresh matter and the treatments were conducted in four replications. A total of 36 bales were ensiled. The airtight conditions in the bales were determined by using special 'Ekolag AB' equipment. This equipment enables under- and overpressure in the bale to be measured. The timing is regarded to be as a base for airtight estimation.
The chemical composition of fresh red clover-grass mixture before ensiling was as follows: dry matter (DM) 327 g kg^{-1}, crude protein (CP) 149 g kg^{-1} DM, crude fibre (CF) 205 g kg^{-1} DM, crude ash 82 g kg^{-1} DM. The chemical composition of ryegrass: DM 308 g kg^{-1}, CP 132 g kg^{-1} DM, CF 199 g kg^{-1} DM, crude ash 74 g kg^{-1} DM. Herbage in bales was ensiled for three months, after which samples were taken for chemical and microbial analyses.

Results and discussion

The results of analyses are presented in tables 1 and 2. The silage quality was rather good. In most cases treatments did not contain butyric acid and the concentration of ammonia was low. In most treatments the aerobic stability (5.3 - > 7 days) as well as microbial composition was also good (data not shown). However, there were significant differences in chemical composition between treatments. The silage quality of red clover-grass mixture was dependent on the use of additive and herbage wilting. The lowest quality of silage was obtained when the fresh cut mixture was ensiled without additive (average DM 295 g kg^{-1}).

Table 1. The chemical composition of red clover-grass silage depending on the use of additive and herbage wilting. Red clover-grass mixture was cut by a mower conditioner 'Kuhn', baled by a 'John Deere' baler and covered with plastic by a 'McHale' wrapping machine (4 layers, white plastic film). Silage was made of fresh cut crop and wilted crop (wilted for 5 hours in the field).

Treatment	Dry matter (DM) g kg^{-1}	Crude protein g kg^{-1} DM	Crude fibre g kg^{-1} DM	pH	Amn. N, % total N	Butyric acid g kg^{-1} DM
Fresh-cut crop						
Untreated control		294	150	211	5.3	6.2
AIV-2000, 4 l t^{-1}	296	145	198	5.0	5.6	2.4
Niben, 4 l t^{-1}	296	142	196	5.1	3.9	0.2
Mean	295	145	195	5.1	5.2	1.9
$LSD_{0.05}$	48.9	14.9	15.0	0.43	0.99	2.0
Wilted crop						
Untreated control	394	144	208	5.5	3.5	0.9
AIV-2000, 4 l t^{-1}	418	144	217	5.2	3.1	0.0
Niben, 4 l t^{-1}	415	136	210	5.4	2.2	0.0
Mean	409	141	212	5.3	2.9	0.3
$LSD_{0.05}$	42.1	12.1	15.2	0.26	1.2	0.9

$LSD_{0.05}$ – Least significant difference at the probability level of 5 %, n = 3
'Niben'– Chemical additive, based on sodium benzoate
'AIV-2000'– Chemical additive, based on formic acid

This treatment contained approximately of 3.0 g kg^{-1} DM butyric acid and the ammonia concentration was the highest one. Both additives 'AIV-2000' and 'Niben' reduced clostridial fermentation and protein degradation, but 'Niben' was more effective (Table 1). Herbage wilting (average DM 409 g kg^{-1}) improved fermentation conditions and reduced proteolysis. The butyric acid concentration of untreated silage was 0.9 g kg^{-1} DM. This result was expected, because high DM concentration will inhibit fermentation and the risk of clostridial fermentation (Figure 1).

Table 2. The chemical composition of ryegrass silage depending on the use of additive.

Treatment	Dry matter (DM) g kg^{-1}	Crude protein g kg^{-1} DM	Crude fibre g kg^{-1} DM	pH	Amn. N, % total N	Butyric acid g kg^{-1} DM
Fresh-cut crop						
Untreated control	289	132	200	5.4	5.2	2.5
AIV-2000, 4 l t^{-1}	350	136	198	5.5	3.3	0.0
Niben, 4 l t^{-1}	366	133	210	5.7	2.3	0.0
Mean	335	134	202	5.5	3.6	0.8
$LSD_{0.05}$	36.9	9.6	10.4	0.29	0.95	0.96

$LSD_{0.05}$ – Least significant difference at the probability level of 5 %, n = 3
'Niben'– Chemical additive, based on sodium benzoate
'AIV-2000'– Chemical additive, based on formic acid

The ryegrass silage quality was also influenced by the use of additive (Table 2). The results were similar to those for red clover-grass silage. However, the average silage quality was higher, as expected from the better fermentation properties of ryegrass. Air-tightness varied to a great extent between separate bales. It is regarded to be good when the under-pressure in the bale declines from 200 Pa down to 150 Pa not less than for 60 seconds. Despite the fact that visible plastic damage was not found, most results were poor or only satisfactory (data not shown). The air entered into the silo probably through plastic layers or invisible damage. However, the silage quality of particular treatments was not related to air-tightness of silo.

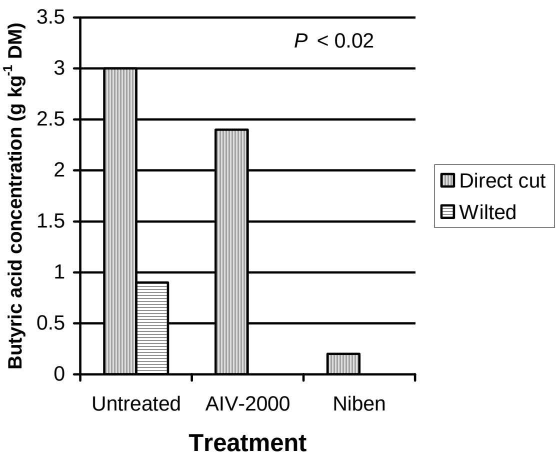

Figure 1. Butyric acid concentration in silage related to the additive treatment and herbage wilting.

Conclusions

The results showed that application of additives improved fermentation and quality of big bale silage. Quality was also improved when the herbage was wilted in the field. There was an interaction between using additive and herbage wilting. Silage quality is also better with easily fermented grasses such as ryegrass. The airtight conditions in bales varied. However, as there were no visible damage to the plastic film, the reason for the variation remained obscure. The air can leak into the silo through the plastic layer or due to invisible plastic damage. Air influx into the silo is also expected when the silage density is low.

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Simulated bird damage to the plastic film surrounding baled silages of differing dry matters

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Abstract

The experiment determined the effects of simulated bird damage to the plastic film on the conservation characteristics of three baled silages differing in dry matter (DM) concentration. Twenty bales were made from grass at each of three DM concentrations (194, 289 and 351 g kg^{-1}), and each bale was individually wrapped with a nominal six layers of black plastic stretch film. The film on alternate bales within each of these DM categories was left unaltered or was punctured with 50 small holes. Bales were stored outdoors in a single tier on their curved sides and were protected to avoid further damage. Wilting increased forage DM concentration and restricted fermentation. Simulated bird damage to the plastic film increased the extent of visible mould and waste on the top surface of the bales. Such visibly deteriorated silage had a lower DM concentration and *in vitro* DM digestibility (DMD) and higher concentrations of ash, crude protein, acid detergent insoluble N (ADIN) and acetic acid compared to silage from visibly undamaged parts of the same bales. Wilting increased silage waste beneath damaged film due to a greater depth of penetration of mould and/or aerobically deteriorated forage. This interaction had little effect in the non deteriorated parts of bales.

Keywords: baled silage, plastic, bird damage, conservation losses

Introduction

The ingress of oxygen that facilitates mould growth in wrapped baled silage can be due to (a) inferior quality plastic, (b) insufficient stretch film being applied, (c) inappropriate plastic application method or (d) damage during wrapping, handling, transport or storage caused by mechanisation difficulties, extreme weather conditions, or interference by vertebrates. Mc Namara *et al*. (2001) confirmed that damage caused by vertebrates to the plastic stretch-film surrounding baled silage was widespread. Birds, particularly rooks (*Corvus frugilegus)*, were responsible for damaging the plastic film during the interval between wrapping and removing bales to the storage site (usually within 24 hours) on 0.53 of farms. They subsequently damaged the plastic film during the long-term storage interval prior to feedout on 0.63 of farms. Such damage can result in potentially serious quantitative and qualitative losses from forage (McNamara *et al*., 2002) and it has been suggested that these losses might increase with increasing forage DM concentration. This experiment quantified the effects of simulated bird damage to the plastic stretch-film on the conservation characteristics of three baled silages differing in DM concentration.

Materials and methods

Grass in a permanent pasture sward was cut (3 m wide mower conditioner) to a 5 cm stubble height and alternating windrows were wilted for 0, 24 or 48 h. Cylinder-shaped bales with a nominal diameter and width of 1.2 m were made using a fixed chamber baler with slicing blades engaged (Claas™ rollant 46 Rotocut). Twenty bales were made at each of the three DM concentrations. They were immediately transported to the bale storage location and each bale was individually wrapped (McHale™ 991 BE) with a nominal six layers of black plastic stretch-film (Silawrap™). The plastic film surrounding alternate bales within each of these

DM categories was left unaltered or was punctured with 5 parallel rows of 10 holes (mean diameter 3 mm) across the top, curved surface of the bale, as described by McNamara *et al*. (2002). Bales were stored for 268 days in a single tier on their curved sides, outdoors in a farmyard, and all bales were protected by bird netting (Silanet™) and baited to avoid rodent damage. Bales were weighed and sampled before and after ensilage, and chemically analysed as described by McNamara *et al*. (2002). After ensilage, one composite sample was obtained from the sides and ends of each bale, from areas with no visible mould or aerobic deterioration. In addition, each bale with simulated bird damage to the plastic film had one representative sample taken from areas with visible mould and/or evidence of aerobic deterioration. All bales were assessed for the area of visibly mouldy and/or aerobically deteriorated forage on the bale surface. Bales were split using a tractor-mounted shear-grab to allow visual assessments be made through each bale. Data were subjected to two-way analysis of variance appropriate for 3 × 2 factorial arrangements of treatments.

Results and discussion

Wilting for 24 or 48 h progressively increased forage DM concentration and weight of DM ensiled in bales, but reduced bale fresh weight (Table 1). Neither bale weight nor chemical composition pre-ensiling differed between the undamaged or damaged plastic film treatments. Wilting restricted silage fermentation and reduced ADIN concentration compared to unwilted silage. The fresh silage weight increased when plastic film was damaged (Table 2), probably reflecting weight gain due to rain ingress through the film puncture holes at the bale tops.

Table 1. Bale weight and forage chemical composition at ensiling as influenced by wilting.

Wilt duration (h)	0	24	48	sem	Sig.
Bale weight (kg fresh)	948	774	713	11.6	***
Bale weight (kg DM)	184	223	249	4.2	***
Dry matter (g kg^{-1})	194	289	351	6.8	***
in vitro DMD (g kg^{-1})	698	681	697	4.3	*
Ash (g kg^{-1} DM)	83	78	78	2.5	ns
Crude protein (g kg^{-1} DM)	108	105	113	2.1	*
Buffering capacity (mEq kg^{-1} DM)	371	368	394	5.9	ns

Table 2. Bale recovery rates and evidence of losses, and chemical composition of visibly non-deteriorated silage.

Wilt duration (h; W)	0		24		48		sem	Sig.		
Damage to plastic (D)	No	Yes	No	Yes	No	Yes	WxD	W	D	WxD
Ensiled fresh weight recovery (g kg^{-1})	908	920	990	1014	991	1011	7.0	***	**	ns
Ensiled DM recovery (g kg^{-1})	904	940	927	982	904	889	32.7	ns	ns	ns
Visible mould + waste (% of visible surface)	<1	21	1	24	<1	19	3.2	ns	***	ns
Dry matter (DM; g kg^{-1})	194	197	273	276	300	326	10.2	***	ns	ns
in vitro DMD (g kg^{-1})	671	642	680	669	658	669	13.0	ns	ns	ns
Ash (g kg^{-1} DM)	93	99	91	92	95	92	4.7	ns	ns	ns
Crude protein (g kg^{-1} DM)	132	130	128	128	131	131	3.0	ns	ns	ns
ADIN (g kg^{-1} N)	110	109	83	83	80	96	9.6	*	ns	ns
Ammonia-N (g kg^{-1} N)	76	81	61	59	65	52	5.4	***	ns	ns
Lactic acid (g kg^{-1} DM)	77	66	47	44	32	25	3.8	***	*	ns
Acetic acid (g kg^{-1} DM)	25	23	12	13	8	8	1.1	***	ns	ns
Propionic acid (g kg^{-1} DM)	2.0	2.4	0.7	0.9	0.9	1.0	0.19	***	ns	ns
Butyric acid (g kg^{-1} DM)	13	15	15	14	18	14	1.7	ns	ns	ns
Ethanol (g kg^{-1} DM)	13	11	10	8	8	7	0.6	***	***	ns
pH	3.98	4.10	4.30	4.32	4.61	4.65	0.040	***	ns	ns

This appears to have also resulted in a relative overestimation of the recovery rate of ensiled DM when the plastic film was damaged. Such damage resulted in a marked increase in the extent of visible mould and/or waste on the surface of bales, an effect that was similar for bales made after 0, 24 or 48 h wilting. However, the depth to which the mould and/or rotted material penetrated tended to be greater with wilted forage. Penetration was < 2.5 cm, 2.5 to 7.5 cm and > 7.5 cm for 3, 3 and 4 of the 0 h wilt bales, respectively, with corresponding values of 0, 1 and 9 bales and of 0, 6 and 4 bales for the 24 and 48 h wilt durations, respectively. Despite these differences the visible damage was localised in the area under the punctured plastic film, and the chemical composition of samples taken from the undeteriorated part of these bales only differed from bales wrapped in undamaged plastic film in having lower lactic acid and ethanol concentrations.

Table 3. Chemical composition of visibly non-deteriorated and of visibly mouldy and/or aerobically deteriorated silage from bales surrounded by damaged plastic film.

Bale section sampled (S)	Good			Deteriorated			sem	Sig.		
Wilt duration (h; W)	0	24	48	0	24	48	SxW	S	W	SxW
Dry matter (DM, g kg^{-1})	197	276	326	161	224	272	9.9	***	***	ns
in vitro DMD (g kg^{-1})	642	669	669	465	479	578	15.8	***	***	**
Ash (g kg^{-1} DM)	99	92	92	110	119	124	5.3	***	ns	ns
Crude protein (g kg^{-1} DM)	130	128	131	175	176	167	3.2	***	ns	ns
ADIN (g kg^{-1} N)	109	83	96	221	230	232	13.1	***	ns	ns
Ammonia-N (g kg^{-1} N)	81	59	52	63	56	64	7.5	ns	ns	ns
Lactic acid (g kg^{-1} DM)	66	44	25	11	10	7	2.3	***	***	***
Acetic acid (g kg^{-1} DM)	23	13	8	208	247	292	42.3	***	ns	ns
Propionic acid (g kg^{-1}DM)	2.4	0.9	1.0	1.0	0.6	0.9	0.24	**	***	*
Butyric acid (g kg^{-1}DM)	15	14	14	<1	<1	<1	1.1	***	ns	ns
Ethanol (g kg^{-1} DM)	11	8	7	10	5	4	1.0	**	***	ns
pH	4.10	4.32	4.65	7.31	7.26	7.39	0.077	***	***	*

Samples of silage from beneath the damaged plastic film that exhibited visible mould or rotting would have undergone considerable respiration as well as rain ingress, compared to silage from visibly undamaged parts of the same bales (Table 3). Consequently the former had a considerably lower DM concentration than the latter. The large increase in acetic acid concentration in the deteriorated silage could be due to the activities of acetic or lactic acid bacteria under aerobic conditions (Pahlow, 1991). Mould and/or aerobic deterioration resulted in the concentrations of lactic, propionic and butyric acids decreasing, with a corresponding increase in pH. These losses of the more respirable fractions of organic matter resulted in an increase in ash concentration and a reduction in *in vitro* DMD. However, the major increase in crude protein concentration suggests that N was less than proportionately lost during the processes of mould growth and/or aerobic deterioration. This may have been partly associated with the effects of heating during respiration, and was reflected in an increase in the proportion of N present in ADIN.

Conclusions

Wilting increased the extent of silage waste beneath damaged plastic film due to a greater depth of penetration of mould and/or aerobically deteriorated forage. However, wilting did not reduce silage quality in the remaining parts of these bales compared to the unwilted silage.

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Round bale drying – feasibility and economic efficiency

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Abstract

Farms that are unable to use silage have to make hay, even under unfavourable weather conditions. Periods of fine weather are often too short, especially in Alpine regions, to dry the hay thoroughly in the meadow until it is ready for storage. Additional drying in storage is therefore necessary. Nowadays, round and square bales account for a steadily increasing share of the forage and straw harvest. A number of manufacturers offer various designs of drying systems for round bales: three of them were investigated. The following parameters were examined: DM content in the windrow, drying pattern of the bales, air pressure, air temperature and DM content of the bales after drying. The economic assessment involved parameters such as costs of purchase, energy consumption, duration of drying, labour input and organisational impact on hay production. The baling system and the system design as well as user experience determine the quality. The system capacity has to be adapted to the yield, while annual utilisation is the criterion for economic efficiency.

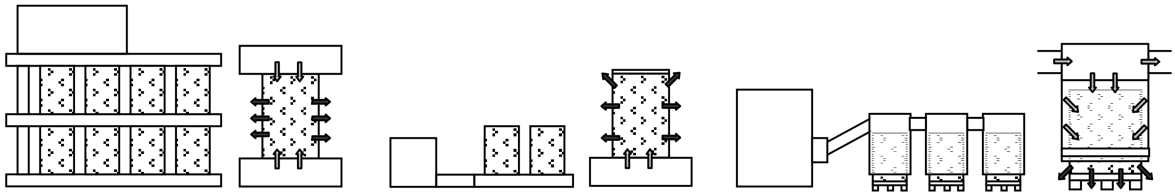
Keywords: hay, round bales, drying, economic efficiency

Introduction

Farms that produce milk for speciality cheese making (hard cheese) have to use hay, rather than silage, as fodder. In the early spring and in unfavourable weather conditions, the hay has to be dried to the storage moisture level. Aerating technology for loose hay in the stack has been in successful use for decades. Nowadays, round and square bales are steadily gaining ground. Harvest machinery manufacturers have developed powerful mechanization for silage, hay and straw from the field to the shed, in the form of high capacity balers and wagons (front loaders, fore loaders and telescopic loaders). Storage is relatively easy, as the bales can be stacked in existing buildings or under a tarpaulin outdoors. To obtain high-quality hay with the round baling method, however, either the DM content has to be high before baling or the bales must undergo subsequent drying (Baumgartner, 1996).

Materials and methods

To obtain more information about the drying properties and economic efficiency of round bale drying systems, a number of models were examined at FAT during the summer of 2003 (Figure 1). The three systems differ considerably in terms of both design and purchase cost. The round bales were produced with the aid of two types of press. The Orkel fixed chamber baler was 1.20 m in diameter and 1.20 m wide, and the bales had a soft centre and hard edge. The Deutz-Fahr variable chamber belt balers had a width of 1 m and the 1.20 m or 1.50 m diameter bales had the same density throughout. Several samples were taken from the windrow to determine the moisture content of the individual round bales. DM determination of the mixed samples was performed immediately after baling for reference, with the aid of a microwave oven. Drying for 24 hours at 105 °C was additionally carried out in the drying chamber. The temperature and relative humidity of the ambient air were recorded every five minutes during the drying process using combined measuring instruments. The system pressure inside the system was also measured with an ambient pressure gauge. The drying pattern was recorded by weighing the bales before, at various times during and after drying.



Inventagri
Top/bottom aeration with
fixed aeration box
Diesel engine / wood-fired heater

Geba-Zumstein
Bottom aeration with
fixed aeration box
Electric motor / oil-fired heater

Tecnolam
Top aeration with
PVC hoods
Electric motor / oil-fired heater

Figure 1. System design and aeration principle.

After drying, nine random samples per bale were taken with a probe inserted three times at depths of 0-20 cm, 20-40 cm and 40-60 cm. The DM content was calculated after drying in the oven. For subsequent assessment purposes, electricity consumption was recorded and oil consumption ascertained by weighing the drum. The labour time required to load and unload the bales from the system was measured and the fixed and variable costs were calculated.

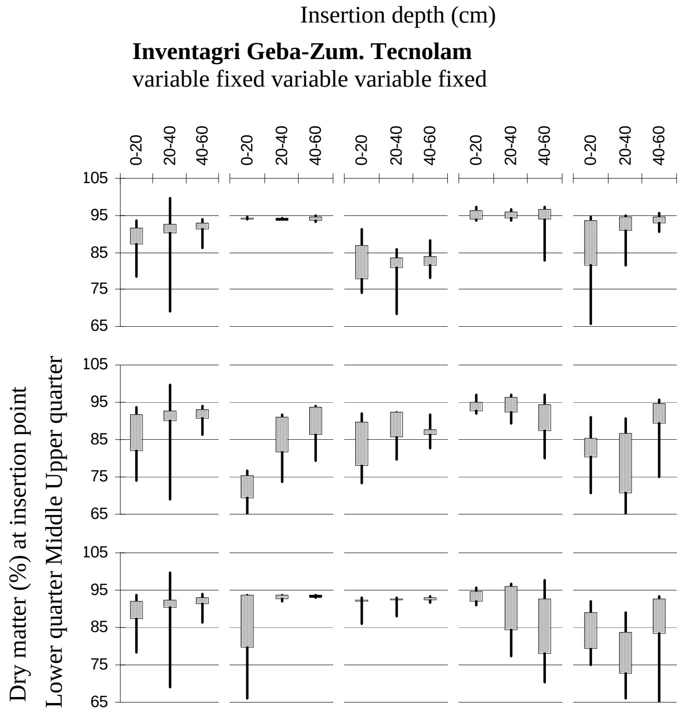


Figure 2. DM values inside the bales.

Results and discussion

Baling took place with an average DM content in the windrow of 74 %. The bales from the fixed chamber baler had an average density of 209 kg m^{-3}. The bales from the belt baler had an average bale density of 110 kg m^{-3} at 1.50 m diameter and an average density of 195 kg m^{-3} at 1.20 m diameter. The air pressure was between 5.6 and 20 mbar and drying temperatures reached 30-60 °C. After an average of 19 hours, an average bale DM content of 91 % was achieved. Bale sampling with the probe produced a varying picture (Figure 2). All the bales showed a heterogeneous drying pattern, with DM contents of over 95 % in many places and below 70 % in others (Baumgartner, 1996). The minimum value of 88 % required for stability in storage was not reached in some places. Bales with an even, low density dried more evenly than those with a hard edge and high bale density. The labour input required to operate the systems and monitor the drying process was about 1.0 MPh ha^{-1}. The saving compared to hay was about 2.4 MPh ha^{-1}, as there were fewer operations to be performed (tedding, windrowing), thus releasing a capacity of 1.4 MPh ha^{-1}. Energy consumption for the Inventagri system was 4.4 kg oil dt^{-1} DM plus wood for the wood-fired heater additionally connected via a heat exchanger. The Geba-Zumstein drying system used 9.5 kg oil dt^{-1} DM and 8.4 kWh dt^{-1} DM, while the Tecnolam system consumed 2.3 kg oil dt^{-1} DM and 14.1 kWh dt^{-1} DM.

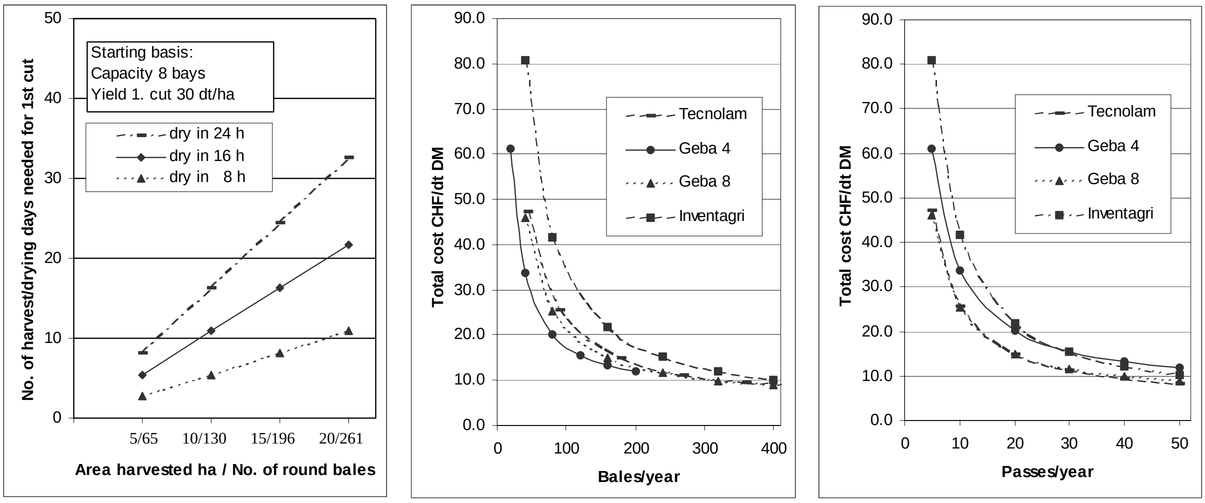


Figure 3. Harvesting days needed as a function of area harvested and total cost of process as a function of utilisation (including: depreciation, interest, repairs, insurance, accommodation, power; no labour).

The number of harvesting days needed depend directly on the drying time and system capacity. With an 8-bay system, between five and sixteen days are needed to harvest an area of 10 ha in the first cut. The total process cost drops sharply as utilisation rises. To reach a figure of around 10 CHF dt^{-1} DM, 30-40 passes need to be dried. This corresponds to 250 to 350 bales y^{-1}, according to drying capacity. For a better comparison of the systems, a Geba-Zumstein plant with eight drying bays was additionally taken into account (Figure 3).

Conclusions

All the systems will dry round bales from a DM content of minimum 65 %, preferably 70 %. The time saving on the drying period in the field is thus correspondingly less than with loose hay aerating systems, which can be loaded with 50-60 % DM and the weather risk is correspondingly greater (Nydegger, 2001).

If the bales have an even, low density of approximately 100 kg m^{-3}, the drying process can with some experience be controlled. Due to heterogeneous drying and inability to control the progress of drying, the bales should have an average DM content above 90 % at the end of drying. Turning the bales during drying promotes more even drying.

The number of drying bays is the limiting factor with respect to the maximum daily harvest volume (Mouchet, 1998). To avoid loss of quality in poor weather conditions, no more should be cut than can be dried. The drop in total process costs is minimal when utilisation exceeds 250 bales. The Geba-Zumstein and Tecnolam systems have a cost advantage over the more sophisticated Inventagri system.

Round bale drying creates a bottleneck that reduces the throughput of what should be an efficient baling process. The performance potential of the machines used cannot be utilised as fully as it can, for example, in the silage process.

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Mineral content of herbage from organically managed grasslands as influenced by yield and botanical composition

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Abstract

The mineral concentration of herbage on Norwegian organic farms was investigated by analysing herbage samples collected in 2001 and 2002 from 81 grassland sites located on 27 farms in 4 regions of Norway. For each of two cuts the results were evaluated by analysis of covariance with year, region and farm as class variables, and phenological stage of development, yield, proportion of clover and proportion of other forbs (herbaceous flowering plants other than grasses) included as covariates. The contents of P and S were on average lower and the Ca / P and N / S ratios higher than those recommended for ruminants. There was, however, a huge variation for all minerals, and the covariates, particularly the proportion of forbs, explained a large part of this variation. The concentration of Mg and Ca increased while the concentration of P and S declined with increasing clover proportion. Thus, the Ca / P and N / S ratios increased with increasing proportion of clover. The content of most minerals was positively correlated with the content of other forbs in the harvested herbage. The content of Ca and Cl decreased with increasing DM yield, and K and S decreased with increasing phenological stage in the first cut.

Keywords: macro minerals, mineral requirement, ley, clover, forbs, organic agriculture

Introduction

The mineral supply to ruminants was formerly mainly determined by soil and climatic conditions and geomedical problems in animal nutrition could be severe (Frøslie, 1984; Låg, 1989). These constraints have to a large extent been overcome by fertilisation of grassland and / or diet mineral supplementation. As organic grassland farming increases, the issue of deficiencies or imbalances of ruminant mineral supply has again been raised. This is because one of the basic principles of organic agriculture is to work as far as possible within a closed system with regard to nutrient elements, and therefore the input of fertiliser is restricted and mineral supplementation should be avoided. Consequently, the ruminant mineral supply is again more dependent on the environment. Thus, a survey was implemented in order to investigate the herbage mineral content and assess the mineral supply for ruminants in organic grassland systems in Norway. Our objective in this paper was to identify important sources of variation in macro mineral content of the sampled herbage from the survey.

Materials and methods

Herbage samples from 81 grassland sites on 27 organic farms that had maintained organic dairy or sheep production for more than 3 years were collected for each of two cuts in 2001 and 2002. The farms were located in 4 different regions of Norway, the west coastal and east mountain areas with sheep farming and the east lowland and middle Norway with dairy cattle, with seven farms in each region except for the east mountain area where there were six farms. At sampling, the yield, phenological stage of development for *Phleum pratense* L. according to Moore *et al.* (1991), and the botanical composition of the sward were recorded. The herbage samples were dried and analysed for total concentration of N (Kjeldahl), Na, Cl, K, S, Ca, Mg and P (ICP / AES). The mineral content and composition were compared with dietary mineral requirements of sheep and dairy cows in order to assess potential imbalances that can be health risks for cattle and / or sheep without mineral supplements. Variation in herbage mineral content with year, region and farm within region was evaluated separately for each cut by analysis of covariance using the GLM procedure and Type III sum of squares in SAS (SAS Institute, 1986). To adjust for differences in sward characteristics under the different years, regions or farms, DM yields, phenological stage of development, proportion of clover, and proportion of other forbs were included as covariates. The covariates contribution to the total variance was calculated from Type I sum of squares. The assumptions of normality and variance underlying the statistical analysis were tested for all response variables. A probability of $P < 0.05$ was required for each covariate to remain in the final model.

Results and discussion

The average concentrations of minerals in the examined herbage (Table 1) were generally within the range of the dietary requirements for sheep and dairy cattle (Underwood and Suttle, 1999). However, the contents of P and S were low, and for all minerals the concentration varied greatly (Table 1). Hence, a large proportion of the samples, particularly in the first cut, had a lower mineral content than recommended for sheep and cattle. First cut was taken rather late when the mean stage by count was on average 3.4 for *Phleum pratense*, which is when the inflorescence has emerged but the peduncle is not fully elongated (Moore *et al.*, 1991). Thus, the rather low mineral levels maybe partially explained by the late cut as the concentrations of most minerals tend to decline with advancing maturity (Whitehead, 2000). The average Ca / P and N / S ratios were both higher than recommended, which is less than 2 for Ca / P and between 10 and 12 for N / S (Underwood and Suttle, 1999).

Table 1. Mean and range of sward characteristic parameters and herbage mineral concentrations in a survey of organically farmed leys in Norway.

	First cut (n = 162)		Second cut (n = 106)	
Parameters	mean	range	mean	range
Phenological stage, MSC[1]	3.4	3 - 3.9	not assessed	
DM yield, g m^{-2}	388	64 - 902	223	71 - 498
Clover content, % of DM	16	0 - 76	31	0 - 92
Content of forbs, % of DM	11	0 - 72	10	0 - 51
P, g kg^{-1} DM	2.4	1.2 - 4.2	3.2	1.9 - 4.9
K, g kg^{-1} DM	17.7	7.9 - 27	21.6	9.9 - 35
Mg, g kg^{-1} DM	1.7	0.9 - 3.5	2.4	1.5 - 3.8
Ca, g kg^{-1} DM	6.9	2.3 - 16.6	10.6	4.9 - 23.3
Na, g kg^{-1} DM	2.2	1 - 7.4	2.6	1.3 - 7
Cl, g kg^{-1} DM	3.8	0.3 - 14.1	4	0.3 - 9.4
S, g kg^{-1} DM	1.4	0.6 - 3.2	2.2	0.9 - 5
N / S, dimensionless	12.9	6.1 - 28.3	12	4.4 - 22.1
Ca / P, dimensionless	2.9	0.9 - 8.4	3.4	1.4 - 8.6

[1]MSC = Mean stage by count of *Phleum pratense*, where 3.0 = boot stage, 3.7 = anthesis (Moore *et al.*, 1991)

The variation in herbage mineral content could to some extent be explained by farm, regional and yearly differences. However, the inclusion of covariates improved the power of the analysis considerably for most minerals, and, except for Cl, between 7 and 66 % of the variation was explained by the covariates (Table 2). The contents of S and K decreased as expected with advancing maturity, while the Ca content increased. The changes of K and Ca with maturity are less consistent than changes in S, according to Whitehead (2000). Phenological stage otherwise had no significant influence, which was probably due to the fact that most samples were taken within a rather narrow range of stages (Table 1). The content of

Ca and Cl decreased with increasing yield in the first cut while the K content increased with yield in the second cut. A significant positive relationship between the content of forbs and minerals is often found, as are higher contents of Mg and Ca associated with increasing clover proportion (Whitehead, 2000). However, the concentrations of P in the first cut and S in both cuts decreased with increasing clover proportion. Consequently, as N (not shown) and Ca increased, and S and P decreased, the ratios N / S and Ca / P increased with increasing clover proportion. Thus, clover contributed negatively to an optimal balance between these elements.

Table 2. Estimated regression coefficients describing the connection between herbage mineral content and phenological stage (mean stage by count, MSC, only first cut), DM yield (Yield, g m^{-2}) and the proportion (g g^{-1}) of clovers (Clovers) and other forbs (Forbs) of total DM yield.

		Estimate of regression coefficients, Type III SS				Contribution to Type I SS[1] (%)				
Mineral	Cut	MSC	yield	clovers	forbs	total	MSC	yield	clovers	forbs
P	1	ns	ns	-0.62*	1.95***	56.3	0.0	0.0	3.9	3.4
	2	-	ns	ns	2.78***	48.9	-	0.0	0.0	18.2
K	1	-4.33*	ns	ns	6.52*	70.3	31.3	0.0	0.0	3.4
	2	-	0.019**	ns	ns	71.4	-	19.2	0.0	0.0
Mg	1	ns	ns	1.50***	1.58***	79.1	0.0	0.0	4.9	35.8
	2	-	ns	1.30***	1.30***	68.2	-	0.0	3.3	22.8
Ca	1	2.74**	- 0.0036***	11.20***	7.88***	89.2	8.9	6.9	21.7	28.8
	2	-	ns	10.85***	9.83***	83.4	-	0.0	21.6	30.1
Na	1	ns	ns	ns	3.24***	87.1	0.0	0.0	0.0	25.6
	2	-	ns	ns	3.17***	82.6	-	0.0	0.0	53.9
Cl	1	ns	- 0.0037**	ns	ns	71.9	0.0	0.5	0.0	0.0
	2	-	ns	ns	ns	70.2	-	0.0	0.0	0.0
S	1	-0.48*	ns	-0.69***	1.45***	71.9	0.2	0.0	4.7	9.6
	2	-	ns	-1.60***	1.57*	68.7	-	0.0	8.3	18.8
N/S	1	3.46*	ns	18.18***	ns	77.1	1.5	0.0	33.2	0.0
	2	-	ns	13.38***	ns	68.9	-	0.0	18.8	0.0
Ca/P	1	1.27*	ns	6.06***	ns	81.9	11.3	0.0	29.6	0.0
	2	-	ns	4.50***	ns	77.0	-	0.0	27.2	0.0

*, **, *** Significant at 0.05, 0.01 and 0.001 levels of probability, respectively. ns = not significant

[1]Sum of squares by stepwise forward selection in the sequence: MSC, yield, clover, forbs, class variables (year, region, farm)

Conclusions

The content of macro minerals in the herbage from organically farmed grassland varied greatly. Phenological stage, DM yield, and, particularly, proportion of clover and other forbs contributed significantly to the variation. Increasing proportion of forbs increased the concentration of most minerals, while the increasing proportion of clover contributed positively to the content of Ca and Mg but negatively to the S content and the ratios N / S and Ca / P required in ruminant diets.

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Mineral content in winter pasture grass depending on dominant species, pre-utilisation and harvest date

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Abstract

An individual and sufficient mineral supply for beef cattle or suckler cow herds in low-input grassland systems, in particular by using winter pasture, might be difficult. Especially in late autumn and winter diseases like grass tetany (= hypomagnesemia), milk fever (= hypocalcaemia) or osteomalcia caused by mineral imbalance or deficiency may occur in ruminants. Therefore pure stands of *Festuca arundinacea* and *Lolium perenne* were analysed for their mineral concentration considering pre-utilisation (accumulation from June or July) and date of winter harvest (= December, January, February), tested over two years. Except for K, the concentrations of Na, Mg, P and partly Ca were below the requirements of ruminants for both species. Depending on the year, the date of winter harvest showed different influences. The readily soluble elements K and Na were liable to leaching throughout the winter. Divalent cations like Mg were apparently addicted to processes of translocation with advancing maturity. Pre-utilisation had a significant influence on P only. The antagonistic development of K and Ca affected the grass tetany ratio (= K / (Ca + Mg)), as an indicator for an increased tetany risk. Only in 2000/2001, when weather conditions were more mild and wet, both species exceeded the critical value of > 2.2 in December.

Keywords: year-round-grazing, winter pasture, *Festuca arundinacea*, *Lolium perenne*, mineral nutrients, grass tetany

Introduction

Festuca arundinacea is a cold-season grass used frequently to extend the grazing season into late autumn and winter in low-input systems. For the health of grazing beef cattle or suckler cows, the occurrence of diseases like grass tetany, as a result of mineral imbalances or deficiencies in winter pasture, plays an important role in year round grazing systems. While the supply of mineral elements like Ca or Mg from soil is sufficient for a maximum development of the plant, it can be insufficient to produce a concentration in herbage that is adequate to the requirements of ruminants (Whitehead, 2000). As an individual mineral supplementation in combination with concentrates as in dairy cow herds is hard to ensure for grazing cattle, adequate mineral concentrations in winter pasture are required. Information about the nutrient content of winter growth is limited and thus the aim of this study is to determine the mineral composition of winter pasture of different species in varied maturity stages. Ratios of Ca / P and K / (Ca + Mg) are presented to point out mineral imbalances and the existing risk of diseases for grazing ruminants.

Materials and methods

The experiment shown in table 1 was established under standardised conditions on an eroded stagnic Luvisol of loess (pH 6.2, 21 mg P_2O_5, 16 mg K_2O per 100 g soil DM) on the Research Station for Grassland Management and Forage Growing near Giessen, Germany, at an altitude of 160 m above sea level with annual rainfall of 753 mm and 10.2 °C average annual temperature and was part of a project on quality of winter forage (Opitz v. Boberfeld and Wolf, 2002).

Table 1. Variants, designed as a Latin rectangle with 3 replicates.

Factors	Variants
1. Species	1.1 *Festuca arundinacea*
	1.2 *Lolium perenne*
2. Pre-utilisation	2.1 June
	2.2 July
3. Winter-harvest-date	3.1 beginning of December
	3.2 mid of January
	3.3 end of February
4. Year	4.1 1999/2000
	4.2 2000/2001

Pure stands of *Festuca arundinacea* and *Lolium perenne* were observed over two years and the influence of the factors pre-utilisation and date of winter-harvest was tested. Dried samples of ground herbage were extracted by HNO_3 treatment. K, Na, Ca and Mg were determined by atomic absorption spectroscopy (Schinkel, 1984), P was determined colorimetrically (Gericke and Kurmies, 1952). All results were examined by analysis of variance with $P < 0.05$ as the level of significance and least-significance differences (= LSD) were calculated.

Results and discussion

The optimum Ca/P-ratio for ruminant nutrition, shown in figure 1(A), is considered to be between 1.5:1 and 2:1; imbalances between these elements influence the absorption in animal body tissue and incorporation into bones (Menke, 1987). The ratio is generally adequate.

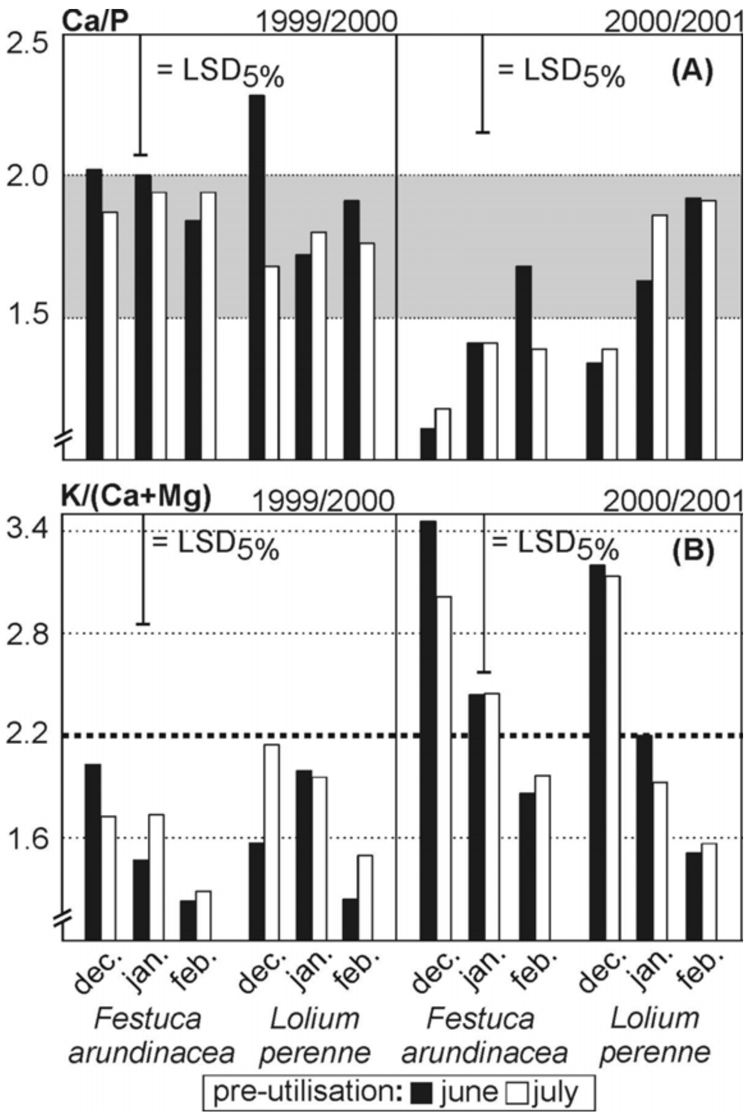

Figure 1. Ca/P- (A) and K/(Ca+Mg)-ratio (B) in-dependence of species, winter-harvest date and pre-utilisation.

Besides, decreasing concentrations of P (= 2.2 to 3.5 g kg^{-1} DM) in both winters do not achieve the required concentration of 4 g kg^{-1} DM (Kirchgessner, 1997). P shows a clear dependency on pre-utilisation, as the physiological younger growth (accumulation since July) reaches higher concentrations in December. In contrast to P the Ca-concentrations (= 2.9 to 7.0 g kg^{-1} DM) of *Festuca arundinacea* were insufficient, < 5 g kg^{-1} DM (Kirchgessner, 1997), in 2000/2001 only.

The Ca-concentrations of *Lolium perenne* are comparatively high in the severe winter 1999/2000, pre-utilised in June and harvested in December, and these of *Festuca arundinacea* during the second, mild winter are mostly low. Thus, species dependent Ca-concentrations cause remarkable Ca/P-ratios. Due to this the factor species is the most important source of variance for Ca/P-ratio in both years.

The insufficient P-concentrations throughout both winters as well as the partly imbalanced Ca/P-ratio allude to possible disorders between these metabolically closely connected elements and may lead to diseases like milk fever or osteomalacia. The influence of the winter harvest date depends on the year and is not evident for all minerals. The concentrations of the easily soluble cations K and Na, particularly in senescent plant cells, are mainly affected by leaching. In contrast to that the bivalent cations Mg and Ca are part of more complex molecules in the cell structure. Mg is largely translocated actively into roots or the base of the culm during senescence, whereas Ca, as a rather immobile element in the plant, predominantly is fixed in cell wall components. Therefore both elements only are to a minor degree susceptible to leaching. Mg-concentrations (= 1.0 to 2.2 g kg^{-1} DM) in herbage barely change during winter, what educes that the plant already has relocated Mg into roots or base of culm to avoid losses (Larcher, 2001). The herbage reaches the required level of 2 g Mg kg^{-1} DM (Kirchgessner, 1997) only in exceptional cases during the winter. In 2000/2001 with higher average rainfall and mild temperature during the winter K (= 6 to 16 g kg^{-1} DM) is highly leached, which is reflected by the development of the tetany-ratio shown in figure 1(B). Unlike Ca or Mg, K-concentrations clearly decrease from December to February. The high concentrations of K in December can provide an antagonistic effect on the absorption of Ca or Mg by ruminants and lead to a tetany-ratio which clearly exceeds the critical value of 2.2, indicating a high tetany risk. In contrast to adequate K-concentrations for beef suckler cows of at least 10 g kg^{-1} DM (Kirchgessner, 1997) throughout both winters, Na concentrations in herbage are insufficient already in December for the ruminant requirements of 1.5 g kg^{-1} DM (Opitz v. Boberfeld, 1994), confirming reports of Whitehead (2000), that a high part of K and Na is already leached before winter.

Conclusions

In winter pasture of both species the concentrations of P, Na, Mg and partly of Ca were below the required levels for ruminants, only K was sufficient during the winter. Differences between univalent and bivalent cations regarding mobility, function and complexity in plants and processes linked to senescence are important for mineral concentrations in winter. Mineral imbalances are mainly caused by an antagonistic effect of K on Ca. Due to the different weather conditions of the years it could be concluded that mild temperatures during winter increase the risk of grass tetany. Insufficient P, Na and Mg-concentrations of the tested winter pasture throughout both winters show that a long term supplementation of P, Na and Mg to grazing animals is necessary to avoid metabolic disorders and diseases in winter.

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Macroelement, microelement and heavy metal content of grass species and dicotyledons

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Abstract

Data concerning the composition of fodder from pasture (grass, meadow-hay) can be frequently found in literature. Data relating to the element content of grass or non-grass species composing natural grasslands are either scarce. To analyse the element content of plants, samples were collected over 3 years (1998-2000) from different types of natural grasslands. In non-fertilised grasslands, the dominant species was *Festuca pseudovina*. The dominant species in fertilised grasslands were *Poa pratensis*, with *Bromus inermis* or *Elymus repens* being the dominant species in some sites. Results showed that leguminous plants had the highest content of four of the five macroelements. The highest level of K was found in dicotyledonous plants. Na and Ca content of plants were higher in non-fertilised grasslands, while the level of all other macroelements was higher in plants from fertilised grasslands. Since Se contents showed high dispersion, only a trend was observed, namely that grass species do not have a significantly lower content of Se than other grassland plants. In non-fertilised grasslands, grass species contained the most Cr and Pb, while leguminous plants contained the most Cd. In fodder from fertilised grasslands, the highest quantity of Cd and Cr was found in grass species, and the most lead was found in other dicotyledons.

Keywords: grass species, dicotyledons, macroelement content, heavy metal content

Introduction

Data concerning the composition of fodder from pasture (grass, meadow-hay) can be frequently found in literature. Analysis has been undertaken comparing regions (Fekete and Keresztény, 1979), and comparing species (e.g., Genevini and Sciraffia, 1981; Kota *et al.*, 1996). The effect of fertilisation (e.g., Schmidt, 1990) and the changing of the composition of the grasslands utilised at different times have also been examined, (Friedler and Höhne, 1984; Horb *et al.*, 1980). The above studies generally refer to sown grass species, or in certain cases to sown dicotyledons. Data relating to the element content of grass or non-grass species composing natural grasslands are either scarce or inadequately summarised.

Materials and methods

To analyse the element content of plants, samples were collected over 3 years (1998-2000) from different types of natural grasslands. The botanical composition of the sampling sites was determined by Balázs's quadrat method (Balázs, 1949). In 1999 and 2000 plants in all green samples were divided into groups of grass species, leguminous species and other dicotyledons. The K, Na, Ca, Mg, P, Se and Cd, Cr, Pb content of each group was measured by a spectrometer.

The plant stand of the sampling sites can be divided into two categories: fertilised and non-fertilised. Non-fertilised grasslands did not receive any fertilisers, and as these sites were undergrazed, manure from sheepgrazing was of insignificant quantity. In these grasslands, the dominant species was *Festuca pseudovina*. The dominant species in the fertilised grasslands were *Poa pratensis*, with *Bromus inermis* or *Elymus repens* being the dominant species in some sites.

Results

Table 1 shows the average macroelement content of grass species, leguminous species and other dicotyledons. The data presented here represents the May measurements.

Based on the computed average of the data, the expected conclusion that grass species contain less macroelements than other grassland plants has been confirmed. Leguminous plants contained the highest quantity of four of the five macroelements examined, while K accumulated mostly in other dicotyledonous species. The difference between the macroelement content of grasses and other grassland species was manifold, but between leguminous and other grassland species it was insignificant. The Na and Ca content of the fodder from non-fertilised grasslands exceed that of the fertilised grasslands. The elements K, Mg, and P were found in greater quantities in fodder from fertilised grasslands than in fodder from non-fertilised grasslands.

Table 1. Average macro-, microelement and heavy metal content of fodder in fertilised and non-fertilised grassland (1999-2000).

Element	units	grasses	leguminous	other dicotyledons
Non-fertilised grasslands				
K	mg kg^{-1}	12,440.0	18,223.3	23,440
Na	mg kg^{-1}	1,989.2	4,992.7	3,687
Ca	mg kg^{-1}	4,452.5	14,560	13,162.5
Mg	mg kg^{-1}	1,131.7	2,873.3	2,582.5
P	mg kg^{-1}	2,102.5	2,763.3	2,592.5
Se	µg kg^{-1}	578.5	738.7	546.5
Cd	mg kg^{-1}	0.82	1.18	0.80
Cr	mg kg^{-1}	2.86	1.94	1.37
Pb	mg kg^{-1}	3.72	3.03	1.77
Fertilised grasslands				
K	mg kg^{-1}	18,915	24,353.3	27,335
Na	mg kg^{-1}	613.2	2,698.3	1,591.2
Ca	mg kg^{-1}	3,470	12,995	10,900
Mg	mg kg^{-1}	1,240	4,125	3,602.5
P	mg kg^{-1}	3,244.2	3,476.7	3,550
Se	µg kg^{-1}	703.5	648.7	846.2
Cd	mg kg^{-1}	1.25	0.89	1.12
Cr	mg kg^{-1}	3.16	1.83	2.05
Pb	mg kg^{-1}	2.82	3.5	4.03

The sampled grass fodders had satisfactory content of macroelements to meet the nutritional requirements of sheep.

The Se (microelement) content of the fodder showed a variation of more than 30 % for habitats and years, therefore only a tendency between fertilised and non-fertilised grasslands was observed. The leguminous plants in the non-fertilised grasslands contained more Se than in the fertilised grasslands, and there was no significant difference in Se content between grasses and other dicotyledons. In the fertilised grasslands the other dicotyledons contained more Se than the leguminous plants and the grass species. The desirable quantity of Se in mass fodders is 0.05-2 mg kg^{-1}. The grassland fodders proved to be non-deficient in Se, and they do not reach the toxic level of 5 mg kg^{-1} standard.

The analysed grasslands showed high variation in heavy metal element content between plant groups. In non-fertilised grasslands most Cd was found in leguminous plants, while in the fertilised grasslands most Cd was found in grass species. In general, fertilised grasslands contained more Cd. The toxic standard of 0.5 mg kg^{-1} in fodder was exceeded in each plant group, in each type of grassland. Grass species contained the most Cr in both grassland types. The lowest Cr content was found in leguminous plants in fertilised grasslands. Clover species in fodder from non-fertilised grasslands accumulated more Cr than the other dicotyledons. The Cr content was higher in the fodder of fertilised grasslands in total and it exceeded the average plant quantity of 1 mg kg^{-1}. In non-fertilised grasslands, grasses absorbed the greatest quantity of lead, while in fertilised grasslands the other dicotyledons did. Except for grass species, plants in fertilised grasslands contained more lead than plants in non-fertilised grasslands. Lead content of 10 mg kg^{-1} or more in grass fodder is considered toxic, but this level was not approached by any of the grassland plant groups.

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The influence of habitat conditions on the content of magnesium in cocksfoot, timothy and perennial ryegrass

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Abstract

The content of magnesium (Mg) in the DM of cocksfoot (*Dactylis glomerata* L.), timothy (*Phleum pratense* L.) and perennial ryegrass (*Lolium perenne* L.) from pure stands and from binary mixtures was evaluated in two habitats differing in the type of soil at ground water level (i.e., 'dry' and 'wet'). The proportion of each species sown in the binary mixtures was 50 %. The evaluation was carried out in the sowing year and in the following year at the 1st, 2nd and 3rd cuts. In the dry habitat, where the content of Mg and potassium (K) in the soil was higher, the Mg content of the cocksfoot, timothy and perennial ryegrass from the pure stand and the binary mixtures was lower than in the wet habitat, where the content of the above elements was lower. In the pure stands, in both habitats in all cuts, cocksfoot contained the highest level of Mg in DM and the timothy the lowest. In the mixtures, in both habitats, competition for Mg between cocksfoot and timothy was lower and started later than was the case between perennial ryegrass and timothy, or between perennial ryegrass and cocksfoot. Competition for Mg between these species was greater in the wet habitat than in the dry habitat.

Keywords: magnesium, cocksfoot, perennial ryegrass, timothy

Introduction

In Poland, over 60 % of hay produced is deficient in magnesium (Mg) (Kozłowski and Kukułka, 1994). Both the biological properties of the species and the habitat conditions determine the content of this element in plants. Soil Mg contents in Poland are low, especially in the Voivodeship of Lublin, where soil with a high Mg content constitutes only 20 % of arable land (Lipiński and Bednarek, 1998). Cocksfoot, timothy and perennial ryegrass are grasses which can be found in most meadows and pastures in Poland. In pure stands, the above species differ in their Mg content (Golob and Čop, 1990). However, in mixtures where they compete for nutrients, the Mg content of these species can be different to those in pure stands. The intensity of competition for nutrients may change with species' development and growth and with their responses to changing habitat conditions (Harkot, 1999). The present studies investigated whether the content of Mg in cocksfoot, timothy, and perennial ryegrass depended on neighbouring species in the mixtures, and whether competition for this element between them depended on habitat conditions.

Materials and methods

The studies were carried out in 'dry' (water table deeper than 200 cm, annual precipitation up to 550 mm, brown leached soil with 1.6 % humus, P – 5.9, K – 15.2, Mg – 8.8 mg in 100 g of soil and pH in KCL of 5.1) and 'wet' (water table 70-100 cm, annual precipitation of up to 650 mm, delluvial soil with 4.6% humus, P – 3.6, K – 5.0, Mg – 8.0 mg in 100 g of soil and pH in KCL of 6.8) habitats. A randomized block design with four replications was used. Cocksfoot (*Dactylis glomerata* L.), timothy (*Phleum pratense* L.) and perennial ryegrass (*Lolium perenne* L.) were grown in pure stands and in binary mixtures (with 50 % of each species). The same mineral fertilisation was applied to all grass stands (either monoculture or mixture) in each year as follows: 240 kg N, 120 kg P, 180 kg K ha^{-1}. Three cuts were carried out during each vegetation period. During the 1st cut, all the plants of the same species studied were at the same stage of maturity in the pure stand and in the mixture (cocksfoot in the heading stage, timothy and perennial ryegrass in the shooting stage). The second cut was harvested 6 weeks after the first cut and the third was taken 8 weeks after the second cut. The Mg content (assessed by the atomic absorption spectroscopy method) was evaluated in each cut in the sowing year and in the following vegetation year in the DM of all three grasses in monoculture and mixture.

Results and discussion

The Mg content (g kg^{-1} DM) of the grasses varied widely depending on the habitat, the year of the study, the cuts and the companion grass species in the mixtures. Thus, values for cocksfoot ranged from 1.0 to 4.0, for timothy from 0.7 to 3.6, and for perennial ryegrass from 1.6 to 4.1. Irrespective of the grass stand, the Mg content in the DM of cocksfoot, timothy and perennial ryegrass was significantly higher in the wet habitat than it was in the dry habitat (Table 1).

Table 1. The content of Mg (g kg^{-1} DM) in *Dactylis glomerata* (*Dg*), *Phleum pratense* (*Php*) and *Lolium perenne* (*Lp*) form pure stands and binary mixtures; A – dry habitat, B – wet habitat.

Grass stand	Year of sowing						Second year						Mean	
	Cuts													
	I		II		III		I		II		III			
	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Dg in pure stand	2.0	3.0	2.5	3.4	2.2	3.2	2.2	1.9	1.8	2.3	2.0	3.2	2.1	2.8
Php in pure stand	1.5	2.8	1.5	2.5	1.7	2.9	1.2	2.3	1.4	1.7	1.2	2.4	1.4	2.4
Lp in pure stand	1.8	4.5	3.3	3.6	2.3	2.9	1.6	2.0	1.4	3.1	1.2	3.9	1.9	3.3
Dg with *Php*	2.5	4.0	3.1	3.8	2.3	3.2	1.0	2.4	1.8	3.4	2.0	3.4	2.1	3.4
Dg with *Lp*	2.2	3.6	2.6	3.6	2.4	3.6	1.1	1.6	2.0	2.6	2.2	3.1	2.1	3.0
Php with *Dg*	1.6	2.8	1.6	2.4	0.7	3.6	1.4	2.2	1.4	2.4	1.0	2.2	1.3	2.6
Php with *Lp*	2.0	2.2	1.6	2.4	2.0	2.4	1.6	1.8	1.4	2.0	1.6	2.5	1.7	2.2
Lp with *Dg*	2.5	3.4	3.0	3.9	2.9	2.7	1.6	2.9	1.8	2.3	2.0	3.1	2.3	3.0
Lp with *Php*	2.3	4.1	3.1	3.3	2.7	3.0	1.7	1.8	1.4	2.0	2.0	3.2	2.2	2.9
Mean	2.0	3.4	2.5	3.2	2.1	3.1	1.5	2.1	1.6	2.4	1.6	3.0	1.9	2.9
$LSD_{p<0.01}$														
Grass stand	0.20	0.50	0.24	0.34	0.33	0.26	0.25	0.25	0.36	0.18	0.48	0.25	0.30	0.40
Habitats		0.07		0.06		0.06		0.05		0.05		0.07		0.12
Grass stand × habitats		0.40		0.30		0.30		0.26		0.30		0.40		0.60

The soils of the above habitats differed in their potassium (K) content, which strongly influenced the plants' Mg uptake antagonistically (Zalewska, 1994). In the wet habitat, where the K concentration in the soil was relatively low, plants were found to have a higher Mg content than in the dry habitat, which had a higher soil K concentration. In the latter habitat, particularly in the second year of the study, the Mg content in the DM of timothy and perennial ryegrass was lower than optimal (2.0 g kg^{-1} DM) as far as fodder quality was concerned (Kozłowski and Kukułka, 1994). The results confirmed an increasing Mg concentration in the grasses in consecutive cuts, as has already been shown by Golob and Čop (1990).

In mixture with timothy, cocksfoot contained more Mg than in pure stands in both habitats in the sowing year and in the wet habitat in the following year (significant in the 1st and 2nd cut). In the second year and in the dry habitat, the 1st cut demonstrated the negative influence of timothy on Mg concentrations in cocksfoot. In the sowing year, the proximity of perennial ryegrass had a positive influence on Mg contents in cocksfoot, especially in the wet habitat. In the following year, in the 1st cut in both habitats, cocksfoot grown in mixtures with perennial ryegrass contained significantly less Mg than that grown in pure stands.

Timothy grown in mixture with cocksfoot in both habitats contained an amount of Mg similar to that in the pure stands, except for in the 3rd cuts in the sowing year and the 2nd cut in the wet habitat in the following year. Perennial ryegrass negatively affected the Mg content of timothy only in the wet habitat in the sowing year in the 2nd and 3rd cut and in the following year in the 2nd cut. In the remaining cuts in the wet habitat and in all cuts in the dry habitat, timothy grown mixed with perennial ryegrass contained the same – or more – Mg than in pure stand.

Perennial ryegrass grown in mixture with cocksfoot in the dry habitat contained the same, or higher, concentration of Mg as that in pure stand (except for the 2nd cut in the sowing year), whereas in the wet habitat, the concentration was reduced (except for the 2nd cut in the year of sowing and the 1st cut in the following year). Timothy negatively affected the Mg content of perennial ryegrass only in the wet habitat.

Conclusions

Cocksfoot, timothy and perennial ryegrass differ in their Mg content in DM. However, habitat conditions and the composition of the mixture influence the accumulation of this element by plants. The choice of species to be included in a mixture,and the growth habitat both have a large effect on forage quality. This study found that in the dry habitat, which was richer in Mg and K, the content of Mg in cocksfoot, timothy and perennial ryegrass both in pure stands and in binary mixtures was lower than in the wet habitat, which was poorer with respect to these elements. This proves that there is a strong dependence between the Mg content in plants and soil K level, rather than simply a dependence on the soil Mg level. In both habitats, competition for Mg between cocksfoot and timothy was less intense and started later than was the case between perennial ryegrass and timothy, or between perennial ryegrass and cocksfoot. Competition for Mg between these species was stronger in the wet habitat than was the case in the dry habitat.

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Selenium concentrations in herbage from various swards in low-input grassland systems

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Abstract

In low-input grassland systems a demand-oriented supplementation of micro- and macro-elements for ruminants is hardly practicable. Concerning selenium, herbage and conserves from extensively managed grassland are frequently the only source, but in many regions of central Europe the actual concentrations are inadequate to meet animal requirements. The objective of this 2 year study was to determine the range of selenium concentrations in herbage and soils of extensively managed grassland. To investigate potential correlations between selenium uptake and biotic and abiotic factors, 66 locations with distinguishable environmental conditions and varying botanical composition were selected. The selenium concentration in soil was closely related to the content of organic matter. However, neither a correlation between selenium concentration in soil and selenium concentration in plant was found. There was also no relationship between organic matter in soil and selenium concentration in plant. The selenium uptake was not influenced by soil pH either. Most of the small number of plant samples with selenium concentrations above 50 µg kg^{-1} DM were taken in sites with changeable soil water conditions. Apparently, oxidising conditions in soil during spring and early summer cause the transformation to selenate, which is an easily available selenium form for plants.

Keywords: selenium, botanical composition, abiotic factors

Introduction

Selenium is an essential element for animal and man. It is a constituent part of glutathion-peroxidases, deiodinases and other important proteins and in that way responsible for defence mechanisms against oxidative stress and hormone control (Himeni and Imura, 2000). Selenium deficiency in ruminant nutrition is associated with muscular dystrophies and muscle calcification, reduced fertility, growth depression, retained placenta after parturition and sudden death of lambs and calves in stress situations (Gissel-Nielsen *et al.*, 1984). Frequent incidences of clinical and subclinical symptoms of selenium deficiency are diagnosed in growing cattle with dietary concentrations below 50 µg Se kg^{-1} DM. The minimum concentration in feeding rations, to avoid selenium deficiency symptoms in beef cattle, is considered to be 100 µg Se kg^{-1} DM, but in the long term, concentrations in rations for growing cattle should not exceed 2000 µg Se kg^{-1} DM to avoid toxic effects (Anonymous, 1996). Selenium deficiency is no problem in dairy cow nutrition since mineral mixtures contain selenium in adequate amounts. However, a consistent supplementation to all individuals of a herd in extensive grazing systems is hard to realize (McDowell, 1996). In low-input systems, the most common selenium source is the available selenium in fresh forage, silage and hay from extensively managed grassland.

Materials and methods

The selenium concentration in soil (0-10 cm depth) and herbage (primary growth) of 66 pastures and meadows with distinguishable environmental conditions and varying botanical composition in low mountain ranges in different areas of central Germany were analysed. The plant samples were taken mid May in two subsequent years. Se was determined by hydride technique AAS (Anonymous, 1997) after microwave-assisted extraction of samples in high-pressure vessels. Total carbon concentrations were determined according to Dumas (CNS inflammation, Anonymous 1998). The plant communities were classified following the Braun-Blanquet method (Braun-Blanquet, 1964).

Results and discussion

Figure 1 shows selenium concentrations in primary growth of two years in samples from 66 extensively managed pastures and meadows, classified into five different plant communities. Only 2 of 132 values were above 100 µg Se kg^{-1} DM, with most values well below 50 µg Se kg^{-1} DM. Herbage from *Lolio-cynosuretum* communities have the lowest Se concentration and herbage from *Bromion racemosi*-swards (temporary wet meadows) have the highest Se concentration. Most of the peak values of *Arrhenatherion elatioris, Festuco-Cynosuretum, Lolio-cynosuretum* and *Polygono-Trisetion* were also influenced by temporary wet soils and therefore characterized by a high constancy of typical wet meadow species. Apparently, for a short time, oxidizing conditions following a decline of ground water or stagnant water levels cause increasing amounts of selenate (Se^{6+}) to be formed. This is the best available selenium species for plants (Gissel-Nielsen *et al.*, 1984). Other factors described in the literature with potential influence on the selenium concentration of plants, such as selenium concentrations in soil, soil organic matter content, soil pH (Gissel-Nielsen *et al.*, 1984) and sulphur content (Murphy and Quirke, 1997) are insignificant because of the entirely low selenium level.

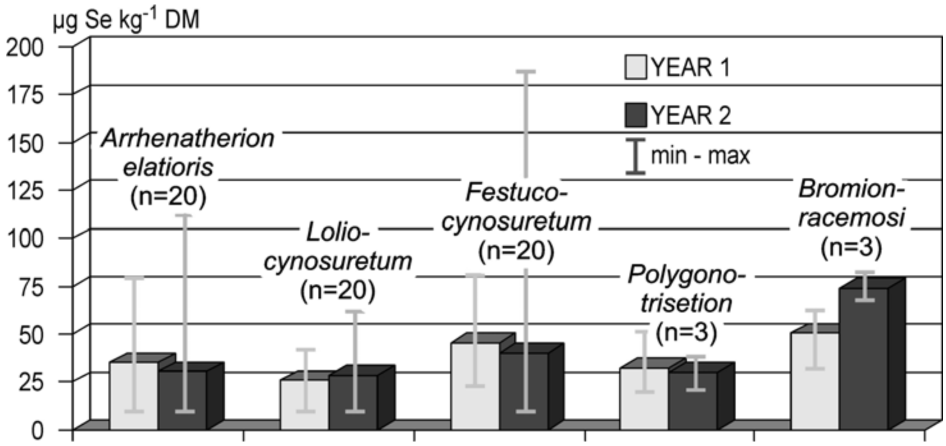

Figure 1. Selenium concentration in herbage from different plant communities.

Figure 2A shows the selenium concentrations in soil in relation to plant selenium in the first investigation year. The results of the second year are similar. Although soil selenium varies in a wide range, no correlation exists. High amounts of selenium in soil are not reflected in plant selenium concentrations. High selenium concentrations in soil correspond with high carbon concentrations (Figure 2B). Apparently, this is due to the fixation of selenium on organic soil compounds. The formation of stable organic selenium complexes prevents selenium leaching from soils but also selenium uptake by plants. However, favourable conditions for selenium availability for plants, such as: small amounts of organic matter, clay and metallic oxides in soil and a relatively high pH (Gissel-Nielsen *et al.*, 1984) also raise the risk of leaching. Fixation on soil constituents on the one hand (high amounts of non-available selenium in soil) and unproductive losses on the other hand (little amounts of total selenium in soil) are responsible for the missing correlation between selenium concentration in herbage and carbon concentration in soil (Figure 2C) or soil pH (Figure 2D). In addition, decreasing selenium emissions derived from fossil fuel combustion, which is an important source in selenium cycling (Heygarth *et al*., 1994), might aggravate the critical selenium supply of animals in future.

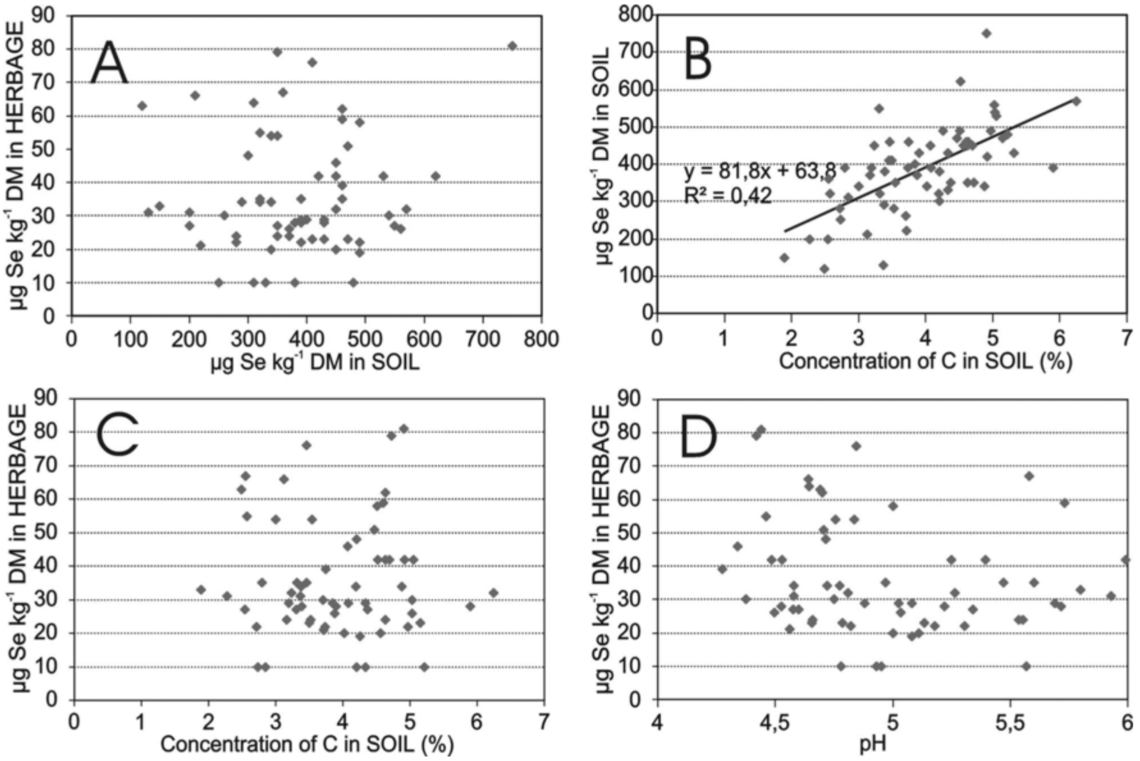

Figure 2. Relationship of soil Se to herbage Se (A), relationship between soil carbon to soil Se (B), relationship of carbon to herbage Se (C) and of soil pH to herbage Se (D).

Conclusions

Selenium concentrations of herbage from extensively managed grassland (not temporary wet meadows) are critically low. In low-input grassland systems the probability of deficiency symptoms and therefore decreased productivity is high. The need for specific, efficient and cheap methods for selenium supplementation in extensive grazing systems is evident.

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Nutritive effect of copper, zinc and manganese excess in the meadow vegetation on the mineral status of grazing sheep in the Middle Rhodope mountain regions

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Abstract

This paper assesses the availability of copper, zinc and manganese in permanent grassland in the Middle Rhodope mountain area and the effect of minerals offered during the grazing period on the status of lambs. The trace element exposure was estimated by concentrations in 70 plant samples. The lamb status was characterised by analysing 42 tissue samples. All determinations were performed by AAS. The evaluation of the natural pasture resources with regard to the mineral supply indicated an irregular distribution of Cu, Zn and Mn depending on the vegetation stage, the botanical composition and the geological type of site.
At the beginning of grazing period the Cu content of pasture grass exceeded the nutrient needs from 45 % to 61 % in the mountain and alpine pastures and declined to deficient values in August (5.95 and 6.65 mg kg^{-1} DM, respectively). Vegetation developing on the syenite and gneiss formations provided sufficient zinc to meet requirements. High concentrations of manganese were due to the increased soil acidity.
Elevated copper transfer due to the prevailing gneiss structures was associated with an increased deposition in liver and kidneys by 130 % and 43 % to levels causing subclinical excess in lambs.

Keywords: permanent grassland, trace elements, lamb status

Introduction

The traditional extensive animal breeding in the mountain regions is facing a number of ecological problems concerning the heterogeneous spatial distribution of the basic essential trace elements in the natural pasture area. Due to the interrelated action of such factors as geological origin of sites, botanical diversity and stage of maturity, some imbalances along the food chain of ruminants can occur (Angelow *et al.*, 2001; Kafedjiev *et al*., 2001). The different extent of selenium deficiency typical for the mountain regions contributes to the secondary bioaccumulation of certain metals (Petrova *et al*., 2000).
The objective of this study was to evaluate the availability of Cu, Zn and Mn in permanent grassland in a highland ecosystem and influence on the animal organism.

Materials and methods

Subject of study were pastures in the area of Middle Rhodope. Mountain pastures at the altitude of 1200 m are located on brown forest soils of pH = 4, formed on andesite and gneiss. The botanical composition prevails with representatives of *Agrostis capillaris* L. and *Festuca fallax* Thuil. Alpine pastures over 1400 m are characterised by strongly acid soils (pH = 3.8) on syenite geological formations. Grass vegetation (Odjakova, 1999) is dominated by *Nardus stricta* L. (84 %).
The trace element availability was estimated through concentrations in 70 plant samples collected from 5 standard plots (2×2 m^2). The lamb status was assessed via analysis of 42 tissue samples. All determinations were performed by AAS.

Results and discussion

The data in table 1 demonstrate the dependence of the trace element availability on the stage of plant maturity.

Table 1. Seasonal dynamics of the Cu, Zn and Mn content in the pasture vegetation (mg kg^{-1}).

Cu	May		June		July		August	
Pastures	x	Sx	x	Sx	x	Sx	x	Sx
Mountain 1200 m	12.9	1.9	8.8	0.6	6.2	0.7	5.9	0.5
alpine over 1400 m			11.6	0.2	7.9	0.6	6.6	0.2
Zn	**May**		**June**		**July**		**August**	
Pastures	x	Sx	x	Sx	x	Sx	x	Sx
Mountain 1200 m	46.4	4.4	44.6	2.0	34.9	3.6	31.2	4.6
alpine over 1400 m			61.8	4.5	59.6	7.4	46.9	4.0
Mn	**May**		**June**		**July**		**August**	
Pastures	x	Sx	x	Sx	x	Sx	x	Sx
Mountain 1200 m	239.7	32.1	323.5	22.9	264.9	11.4	176.6	49.4
alpine over 1400 m			163.4	9.4	236.8	25.3	209.5	52.3

The established effect was most pronounced for the Cu concentrations. At the beginning of grazing period the Cu content of the pasture grass exceeded the nutrient needs of sheep from 45 % to 61 % in the mountain and alpine pastures and declined to deficient values in August (5.95 and 6.65 mg kg^{-1} DM, respectively).
The Zn concentrations demonstrated an insignificant decrease with the advance of maturity of the vegetation. With the exception of marginal concentrations in the mountain pasture vegetation, recorded in July and August (34.9 and 31.2 mg kg^{-1} DM), requirements for small ruminants were adequately supplied.
The levels of Mn exhibited extremely high accumulation in herbage during the whole grazing period (3- to 5-fold over nutritional needs, amounted to 60 mg kg^{-1} DM).
The various geological formations and soil pH of the pastures of both levels of study account for the significant differences established in the accumulation capacity of grass phytocenoses.
The syenite geological formations, characteristic of the area of Middle Rhodope Mountain at an altitude of over 1400 m, provide for a higher transfer of Zn along the 'soil-plant' nutrition chain compared to the gneiss formation. In contrast, vegetation developed on gneiss structures (mountain pastures at 1200 m) had larger amount of Cu.
The high concentrations of Mn is due to the process of acidification of forest soils that leads to mobilisation of the manganese uptake by plants (Hurley and Keen, 1987).
The results for the lamb tissues accumulation reflect the imbalanced trace element availability in the natural pasture vegetation (Table 2).

Table 2. Concentrations of Cu, Zn and Mn in tissues of the Karakachan lambs (mg kg^{-1} DM).

	Cu		Zn		Mn	
Indicator tissue	x	Sx	x	Sx	x	Sx
Liver	461.9	40.6	111.9	4.1	13.2	0.9
Kidney	21.5	0.4	105.7	3.7	6.1	0.8
Muscle						
Musculus longissimus dorsi	4.8	0.8	96.4	4.8	0.6	0.1
Musculus semimembranosus	6.4	0.9	84.7	7.5	0.9	0.1
Spleen	12.9	2.5	114.0	7.5	4.0	1.0
Heart	21.7	1.7	97.9	6.5	2.6	0.6
Wool	16.6	1.2	193.0	10.0	6.2	0.3

The copper concentration in liver and kidney exceeds by 130 % and 43 %, respectively, the reference values for normal status: 220 mg kg^{-1} DM and 15 mg kg^{-1} DM (Harris, 1997).
Such deposition in liver has commonly been related to degenerative processes in animal tissues because of the high lamb sensitivity to the copper accumulation and to an adverse effect on the Zn, Se and Fe metabolism (Arnhold *et al.*, 1993). The Zn concentration in the liver was below the optimal value of 200 mg kg^{-1} DM (McDowell, 1993) and may be associated with the inadequate concentrations in pasture as well as the antagonistic impact of elevated Cu. The elevated Mn concentration in liver by 65 % higher than the referent content of 8 mg kg^{-1} DM (Anke *et al*., 1996) may cause disturbances in the Fe absorption.

Conclusions

The evaluation of the natural pasture resources in the Rhodope mountain area with regard to the mineral supply indicated an irregular distribution of Cu, Zn and Mn depending on the vegetation stage, the botanical composition and the geological type of site. The elevated Cu transfer to the meadow vegetation due to the prevailing gneiss formations creates a risk of potential toxic bioaccumulation in lambs manifested by increased deposition in liver and kidney.

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Incidence of mycotoxins in grassland

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Abstract

Mycotoxins in grassland swards may have animal health impacts in low-input grassland systems in late autumn or winter. Pure stands of *Festuca arundinacea* and *Lolium perenne* were observed under standardized conditions in experiment 1. Experiment 2 was focused on the forage quality of mixed swards of two different plant communities in ten different locations at altitudes from 320 to 475 m above sea level in Central Germany. In both experiments, samples of three successive years were analysed to compare the effects of different weather patterns on fungal infections and mycotoxins. Samples were taken in mid December. The extent of fungal infection – estimated by the concentration of ergosterol – was higher for *Lolium perenne* than for *Festuca arundinacea.* The *Lolio-Cynosuretum* communities were more liable to fungal infections than *Festuco-Cynosuretum* plant communities. In some cases the mycotoxins ochratoxin A and zearalenone were detected. Zearalenone was detectable in a few stands of *Lolium perenne* (max. 0.02 mg kg^{-1} DM) or in *Lolio-Cynosuretum* plant communities (max. 0.17 mg kg^{-1} DM), respectively. The occurrence of ochratoxin A was more frequent and less specific with respect to botanical composition.

Keywords: fungal infection, ochratoxin A, winter pasture, zearalenone

Introduction

In Central European grasslands mycotoxins are usually not detectable in herbage of spring and summer growth, but in the course of the growth period it is more likely that toxins such as zearalenone and ochratoxin A occur (Opitz v. Boberfeld *et al*., 2000). Regarding animal health, this could pose a problem for low-input grassland systems, where the extension of the grazing period or year-round outdoor grazing could improve productivity by reducing costs for conserves and stables (Opitz v. Boberfeld and Sterzenbach, 1999). Quality aspects, e.g., energy concentration and crude protein of winter pasture herbage apparently fulfil the requirements for suckler cows at least until December, assuming appropriate management (Opitz v. Boberfeld and Wolf, 2002; Opitz v. Boberfeld and Wöhler, 2002). This paper focuses on the problem of forage spoilage by fungal contamination of different grass swards used in winter pasture systems.

Materials and methods

Two experiments were established to investigate the possible effects of the botanical composition and weather conditions on the extent of mycotoxin concentrations in various grass swards in autumn and winter. Pure stands of *Festuca arundinacea* and *Lolium perenne* were observed under standardized conditions in experiment 1. Experiment 2 was focused on mixed swards considering the plant communities *Lolio-Cynosuretum* and *Festuco-Cynosuretum* in ten different locations in altitudes from 320 to 475 m above sea level. In both experiments, samples of three successive years were analysed to compare the effects of different courses of weather. The samples were taken mid of December. There was no harvest between mid June and the sampling date to obtain sufficient winter yield. The concentrations of zearalenone and ochratoxin A were determined by HPLC using immuno-affinity column with a fluorescence detector (Anonymous 1993). The ergosterol concentration in herbage was measured by HPLC with a UV detector after saponification in petrol-ether (Schwadorf and Müller, 1989; Anonymous, 1993). Ergosterol is a substance that mainly occurs in fungi and is therefore used to estimate the extent of fungal infection.

Results and discussion

In comparison of the pure stands of the two grass species the extent of fungi infection (see figure 1) – estimated by the concentration of ergosterol – was higher for *Lolium perenne* than for *Festuca arundinacea*. Apparently, structural differences influence the extent of fungal infections. The more erect growth type of *Festuca arundinacea* in combination with its solid fibre component with silicate inclusions reduces the penetration in tissue by fungi, whereas flattened *Lolium perenne* leaves in ground level lay themselves more open to attack and afford a suitable micro-climate for fungi. Analogously, the *Lolio-Cynosuretum* communities, usually with high proportions of *Lolium perenne*, are more liable to fungi infections than *Festuco-Cynosuretum* plant communities (data not shown). However, high amounts of ergosterol are no indication for high mycotoxin concentrations in herbage (Figure 1). Zearalenone is only detectable in pure stands of *Lolium perenne* or in *Lolio-Cynosuretum* plant communities (Figure 2). The occurrence of this toxin in individual swards is not consistent over the years. Swards with relatively high zearalenone concentrations might have no-detectable levels twelve month later. The occurrence of ochratoxin A is more frequent and less specific concerning the botanical composition. Regarding the pure stands (Figure 1) this mycotoxin was found in both, *Lolium perenne* and *Festuca arundinacea* in different years. The incidence of this toxin in mixed swards (Figure 2) is apparently related to the weather conditions in autumn and winter. After the relatively moist and mild weather before December 2000, ochratoxin A was found in the majority of the samples whereas it was only detectable in a few samples in 2001 with a more dry summer and a cool November and December. There was no evidence that particular locations have a higher or a lower risk for high ochratoxin A concentrations than others. This was emphasized by the sward with maximum concentration (= 0,096 mg ochratoxin A kg^{-1} DM) in 1999 and null detection in 2001.

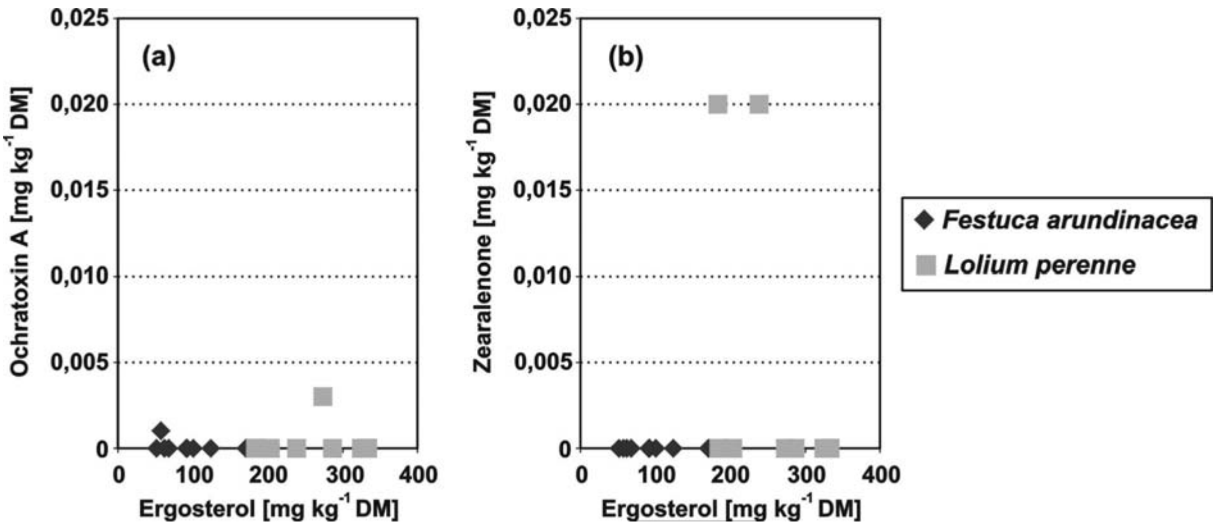

Figure 1. Comparison of ergosterol concentrations with concentrations of ochratoxin A (a) and zearalenone (b).

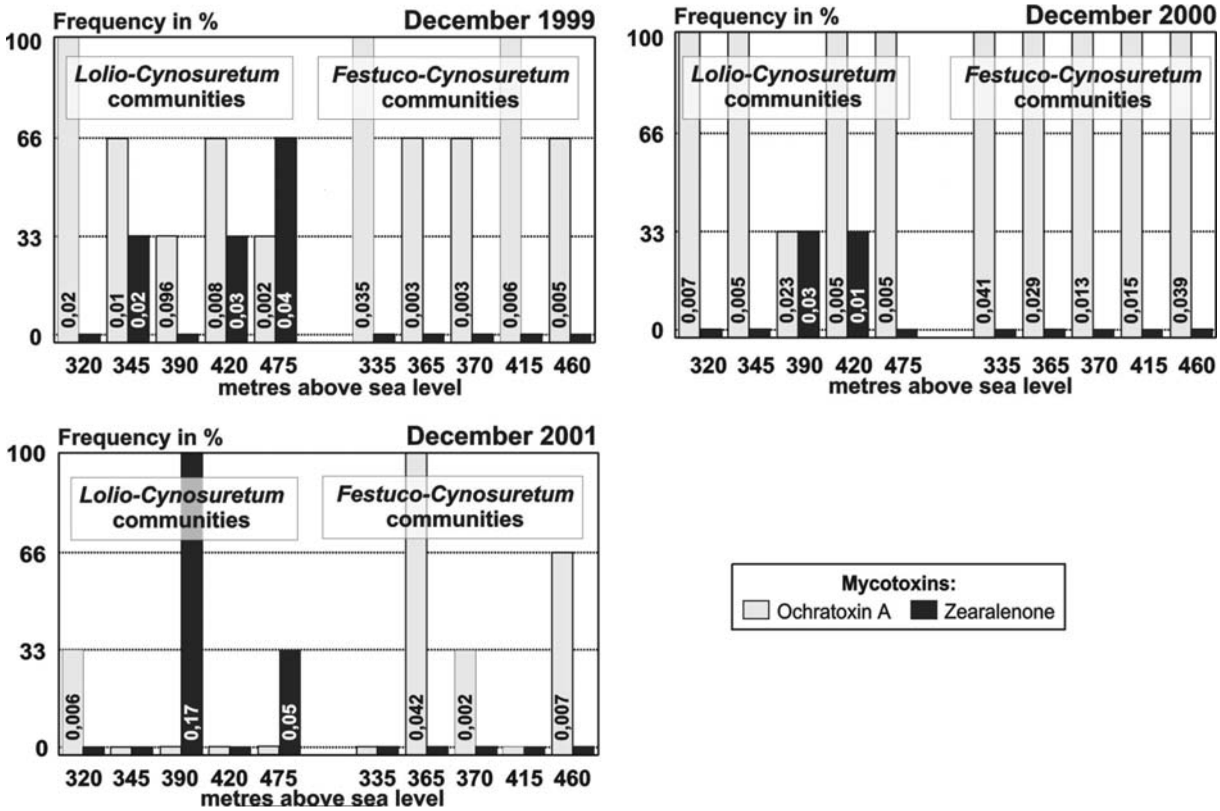

Figure 2. Incidence and maximum concentrations [mg kg^{-1} DM] of ochratoxin A and zearalenone in two pasture plant communities in different locations.

Conclusions

Mycotoxins have the potential to decrease forage value from winter pastures. The prediction of health hazards for particular swards or locations is extremely difficult because of external effects (e.g., weather patterns). Analysed samples were from homogenised plant material from the entire area, so it is possible that patches contained higher amounts of mycotoxins.

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Accumulation of ochratoxin A in a sward of winter pasture situated in the Wielkopolska region

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Abstract

During 2000-2002, an experiment was carried out on a low input pasture to investigate the influence of the timing of pre-utilisation in summer (last use at the beginning of June, July or August) and the date of harvest in winter (at the beginning of November, middle of December, and end of January), on the concentration of ochratoxin A in the sward. The net plot area of each replicate was 20 m^2. Forage from each plot (27 samples per year) was analysed for the concentration of ochratoxin A using the OchraTest column Vicam and the HPLC method. The highest concentration of ochratoxin A in the examined sward was 1.82 ng g^{-1} DM. On the basis of mean values for the two years of study, the highest number of samples in which ochratoxin A exceeded 0.3 ng g^{-1} DM occurred when the sward was harvested in January (61.1 %), indicating that the shorter the period of unfavourable weather conditions, the lower the percentage of ochratoxin A positive samples – 44.4 % in November and 55.6 % in December.

Keywords: forage quality, ochratoxin A, winter pasture

Introduction

In recent years, the importance of winter pastures in beef production in Europe has been growing steadily. In Poland, especially in its western part, there are already farms which utilise pastures during late autumn and winter. The major problem, however, is the quality of forage ingested by animals, as it tends to deteriorate over the growth season and there is danger of accumulation of various mycotoxins, the most important of which is ochratoxin A (Goliński, 1987).

The objective of this work was to evaluate the accumulation of ochratoxin A in a sward used for winter pasture situated in the Wielkopolska region.

Materials and methods

During 2000-2002, in Brody (52°26' N, 16°18' E) near Poznań Experimental Station of August Cieszkowski Agricultural University, studies were carried out to evaluate the accumulation of ochratoxin A in the sward of winter pasture. The experiment was set up in a randomised Latin square design with three replicates in a low-input pasture system in a paddock with a *Lolio-Cynosuretum* community dominated by *Poa pratensis*. The botanical composition of the sward in spring was: *Poa pratensis* – 31.8 %, *Agropyron repens* – 18.3 %, *Lolium perenne* – 14.5 %, *Poa trivialis* – 9.8 %, *Festuca pratensis* – 5.5 %, *Trifolium repens* – 2.4 %, *Taraxacum officinale* – 3.7 % and other species – 14.0 %. The factors in experiments for two consecutive years were: timing of pre-utilisation in summer (last use at the beginning of June, beginning of July, beginning of August) and date of harvest in winter (at the beginning of November, middle of December, and end of January). The net plot area of each replicate was 20 m^2. Each year, in the second half of August, in order to simulate the return of nutrients from the faeces of grazing animals, the pasture was fertilised with ammonium nitrate at 50 kg N ha^{-1}. The soil was a poorly mineralised muck with a pH_{KCl} of 6.5, total nitrogen of 0.61 % and 55.0, 14.0 and 6.6 mg of P_2O_5, K_2O and Mg per 100 g of soil, respectively (results of 2000 year analyses). The weather conditions during the winter pasture regrowth in our experiment are presented in table 1. The pasture surface was covered with snow from 24th December 2000 to 6th January 2001 and 20th December 2001 to 21st January 2002. To collect samples for chemical analyses an area of 10 m^2 of sward was cut on each plot. For estimation of dry matter content, samples were dried for 48 h at 106 °C in a forced draught oven. The herbage samples were clipped 5 cm above ground, dried at 60 °C and ground through a 1-mm screen. Herbage from each plot (27 samples) was analysed for concentration of ochratoxin A.

Table 1. Weather conditions influenced the winter pasture regrowth during the experiment.

Item	2000/2001					2001/2002				
	Sep	Oct	Nov	Dec	Jan	Sep	Oct	Nov	Dec	Jan
Mean air temperature (ºC)	12.5	11.5	6.0	2.5	0.3	11.9	12.3	3.4	-1.4	0.7
Minimum air temperature (ºC)	8.8	8.2	-0.8	-7.4	-6.6	9.3	9.2	0.7	-3.5	-2.2
Maximum air temperature (ºC)	17.7	15.5	13.0	13.6	9.6	15.5	16.2	6.1	1.1	3.6
Soil temperature at 5 cm (ºC)	15.0	11.5	6.2	2.8	-0.1	13.8	12.2	3.5	0.1	0.5
Rainfall totals (mm)	57.9	7.9	62.3	51.3	27.2	139.8	28.0	18.4	41.5	43.4
No. of days with snow cover	-	-	-	8	6	-	-	-	13	21

Herbage samples (10 g) for analyses of ochratoxin A concentration were soaked and extracted overnight with 30 ml of acetonitrile:water (60:40, v/v). After filtration through a Filtrak 389 paper (Germany), 10 ml of the extracts were collected and subsequently added to 40 ml of distilled water and filtered through a Whatman No. 5 paper. The filtrate (15 ml equivalent of 1 g dry matter of the sample) was applied on top of the OchraTest column, Vicam (USA), at a rate of 1-2 drops s^{-1}, the column was subsequently dried (reflux of air) and washed at the same flow rate with 10 ml of 0.01 % washing solution (25 g NaCl + 5 g $NaHCO_3$ + 0.1 ml Tween-20 (surfactant) + 1 L H_20) followed by 10 ml of distilled water. Ochratoxin A was washed out from the column using 1.5 ml of methanol at a rate of 1 drop s^{-1}. After solvent evaporation under a gentle stream of nitrogen at 40 °C, the residue was reconstituted in 0.5 ml of methanol and a 100 µl sample was analysed by HPLC method using Waters 501 apparatus with a C_{18} Nova Pak Waters column (3.9 × 300 mm) and Waters 420 Fluorescence Detector (λ_{Ex} 365 and λ_{Em} 420 nm). The detection limit was 0.3 ng g^{-1} for mobile phase water:acetonitrile:acetic acid (99:99:2, v/v/v) with a flow rate 0.6 ml min^{-1}.

Results and discussion

Contamination levels of swards of winter pasture with ochratoxin A, for the different harvesting dates of the last regrowth, differed during the two years of the investigations, being significantly higher in 2001. On the basis of mean values for the two years of study, higher concentrations of ochratoxin A – respectively: 0.55 and 0.50 ng g^{-1} DM – were found in herbage harvested in December and January when compared to herbage collected in November (0.36 ng g^{-1} DM). This was probably associated with higher precipitation and air humidity in the 2001 autumn-winter period as well as with longer period when pastures were under snow (Table 1). The highest concentration of ochratoxin A was 1.00 ng g^{-1} DM in the first year of the study, with 1.82 ng g^{-1} DM in the second year (Table 2). Trace quantities of this mycotoxin, either close to the limit of detection or its total absence, were recorded most often in samples harvested in August; this was observed mainly in 2000/2001.

Considering fodder quality obtained from winter pastures, it is interesting to analyse the percentage distribution of positive sward samples contaminated with ochratoxin A, and these results are presented in figure 1. On the basis of mean values for the two years of studies, the highest number of samples in which ochratoxin A exceeded the level of 0.3 ng g^{-1} DM (detection limit) occurred when the sward was harvested in January (61.1 %), indicating that the shorter the period of unfavourable weather conditions the lower the percentage of ochratoxin A positive samples – 44.4 % in November and 55.6 % in December.

Table 2. Maximal concentration of ochratoxin A in a winter pasture sward (ng g^{-1} DM).

Date of harvest	Pre-utilisation	Investigation years	
		2000/2001	2001/2002
November	June	0.31	1.82
	July	0.00	1.05
	August	0.00	1.22
December	June	0.65	0.95
	July	0.40	1.26
	August	0.00	1.11
January	June	0.42	1.29
	July	1.00	1.21
	August	0.31	1.14

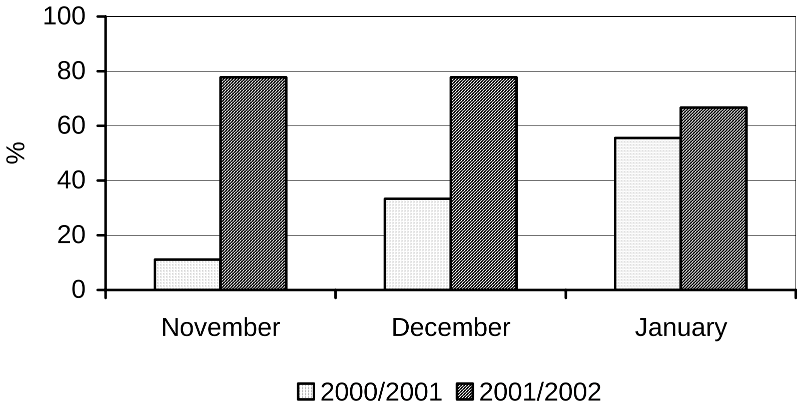

Figure 1. The percentage distribution of positive sward samples contaminated with ochratoxin A at different harvest dates of winter pasture.

The results of our investigations indicate that concentration of ochratoxin A in samples of herbage from winter pasture in Wielkopolska region is significantly lower than reported by Opitz von Boberfeld *et al*. (2000). The relevant concentration of ochratoxin A in the pasture situated in central Germany was 5.0 ng g^{-1} DM. In our studies, the herbage of winter pastures was found to contain levels of ochratoxin A that were three times lower than this.

Conclusions

The results confirm a considerable concentration of ochratoxin A in the herbage of winter pastures in Wielkopolska region. More than half of the analysed samples contained more than 0.3 ng g^{-1} DM of ochratoxin A. The highest concentration of ochratoxin A in the examined sward was 1.82 ng g^{-1} DM.

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Variation of the alkaloids ergovaline and peramine in wild populations of endophyte infected *Festuca rubra*

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Abstract

Festuca rubra is a perennial grass which is naturally infected by the endophytic fungus *Epichloë festucae*. Infected grass plants produce several alkaloids toxic to herbivores. In natural grasslands from western Spain, where cattle are maintained under extensive management, 70 % of the *Festuca rubra* plants were found to be infected by *Epichloë festucae*. We determined the concentration of the alkaloids ergovaline (toxic to livestock) and peramine (an insect feeding deterrent) in endophyte infected plants from two wild populations of *Festuca rubra*. Both alkaloids were detected in plants of both populations. The percentage of plants containing ergovaline ranged from 17-50 % and that containing peramine from 33-80 % at each population studied. A low percentage of the plants (10-17 %) were found to produce both alkaloids. In one of the populations 70 % of the analysed plants produced peramine but not ergovaline.

Keywords: alkaloids, *Epichloë festucae*, grasses, fungal endophytes

Introduction

Festuca rubra is a common perennial grass in semiarid natural grasslands of western Spain. In these ecosystems, known as dehesas, cattle are maintained under extensive management. A survey recorded in the dehesa (province of Salamanca) showed that 70 % of the *Festuca rubra* plants are infected by the endophytic fungus *Epichloë festucae* (Zabalgogeazcoa *et al*., 1999). Infected grass plants produce alkaloids toxic to herbivores. To date it has been reported that *Festuca rubra* plants infected by *Epichloë festucae* produce two alkaloids (Siegel *et al*., 1996): ergovaline, and peramine. Ergovaline is toxic to livestock and peramine is an insect feeding deterrent.
The objective of this work was to determine the concentration of ergovaline and peramine in endophyte infected plants from two wild populations of *Festuca rubra* in the dehesa ecosystems.

Materials and methods

Thirty to forty plants of *Festuca rubra* were collected in two locations (Servández and Palancar), in the dehesa grasslands (province of Salamanca). A space of at least 20 m was left between selected plants. One tiller of each plant was transplanted and maintained in the soil in an experimental farm. To determine the presence of endophytes, pieces of stem were surface sterilized and placed on potato dextrose agar plates.
To determine the ergovaline and peramine concentrations, plants were harvested at the heading stage, at the end of May. Herbage samples were freeze dried.
Ergovaline concentration was determined in ground samples following the chromatographic method of Hill *et al*. (1993) with the modifications suggested by Yue *et al*. (2000). Ergotamine tartrate was used as the internal standard; the ergovaline standard was provided by Dr Forrest Smith (School of Pharmacy, Auburn University).
Peramine was quantified by the chromatographic method of Barker *et al*. (1993). The peramine standard was a gift from Dr G.A. Lane (AgResearch, New Zealand).

Results and discussion

Eighty percent of the *Festuca rubra* plants from the Palancar population and 78 % from the Servández population were infected by *Epichloë festucae.*

The alkaloid ergovaline was detected in 50 % of the infected plants from Palancar and in 17 % of plants from Servández (Table 1). The range and mean of the ergovaline concentration were similar in the plants of both populations. Eighty percent of the *F. rubra* infected plants from Servández and 33 % of infected plants from Palancar produced permine. The peramine concentration of plants was similar in both population. Neither of the two alkaloids were detected in the non-infected plants.

The percentage of plants that produced ergovaline and not peramine was greater in the Palancar population than in the Servández population (Table 2). By contrast, a greater percentage of plants from Servández (70 %) produced peramine and did not contain ergovaline, as compared to Palancar (17 %). This could be useful in developing an association resistant to insects that does not cause health problems in livestock. Neither of the two alkaloids were detected in several endophyte infected plants from both populations (Table 2).

Ergovaline is the main causative agent of fescue toxicosis in livestock, a syndrome mainly characterized by a reduced weight gain. Most research workers regard 0.40 $\mu g\ g^{-1}$ (ppm) ergovaline in diet as the critical toxic level for cattle. Our results showed that ergovaline concentration in *Festuca rubra* plants was below the toxic level, and therefore the endophyte infection in *Festuca rubra* populations from the dehesa grasslands is probably not detrimental to grazing livestock.

Table 1. Number of infected *Festuca rubra* plants producing ergovaline and peramine alkaloids and range of concentrations.

Population	Number of infected plants	Ergovaline			Peramine		
		Plants with ergovaline	Range (ppm)	Mean (ppm)	Plants with peramine	Range (ppm)	Mean (ppm)
Palancar	24	12 (50 %)	0.06-0.25	0.13	8 (33 %)	2.8-6.6	3.8
Servández	30	5 (17 %)	0.07-0.23	0.14	24 (80 %)	2.0-8.2	3.7

Table 2. Percentage of infected plants producing ergovaline and permine alkaloids in *Festuca rubra* populations.

Population	Ergovaline and peramine	Ergovaline (no peramine)	Peramine (no ergovaline)	No alkaloids
Palancar	17	29	17	37
Servández	10	3	70	17

Acknowledgements

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Mycotoxin occurrence in farm maize silages in northern Italy

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Abstract

Whole-plant maize silage stored in horizontal silos represents more than 50 % of the diets of dairy cows and it is considered dangerous as ruminant feed when it contains more than 4 ppb of aflatoxin B_1 (AB_1), 60 ppm of fumonisin B_1 (FB_1), and 300 ppb of zearalenone (ZEA). A survey of 20 dairy farms was conducted over two years in order to determine the level of mycotoxin contamination in maize forage at ensiling and in the corresponding silages, in relation to the level of aerobic deterioration of the silos. The silages showed higher average AB_1 values than the forages at ensiling and 22 % of the silage samples had values higher than 4 ppb. The ZEA values were higher than 300 ppb in 20 % of the samples. In the top area of one highly deteriorated silo, the ZEA values were up to 40 times higher than those of the central area of the silo and of forage at ensiling. FB_1 contamination was considerably lower than the recommended maximum levels both in the forages at ensiling and in silages. The results of the survey suggest that it is essential to prevent air infiltration in the silo, in order to avoid further fungal development and toxin synthesis during conservation.

Keywords: maize, silage, mycotoxins, aerobic deterioration

Introduction

Whole-plant maize silage, stored in horizontal silos, is the major diet source of lactating dairy cows in the Po Plain (Italy). The conditions associated with well preserved silage, i.e., low pH and anaerobiosis, are also unfavorable for the growth of most moulds. However, if air gains access, silage is at risk from storage moulds especially in the side areas, through leakages in the plastic films or at openings for feeding-out. Spoilage of silages by filamentous fungi involves nutrient and energy losses and the risk of contamination by mycotoxins (Wilkinson, 1999). Mycotoxin contamination of maize grain has frequently been described (Hussein and Brasel, 2001), while limited information is available on mycotoxins in maize silage (Oldenburg, 1991). The identification of the conditions for mycotoxin production in relation to silage conservation techniques could help the development of strategies for the restriction of toxin and mould contamination, and allow effective management of the problem. This study presents the results of a survey for mycotoxin contamination on farm maize forages and silages. The relationship with the level of aerobic deterioration is discussed.

Materials and methods

The survey was carried out over two years in the western Po Plain (Italy) on 20 dairy farms that produce milk for a Grana cheese factory. A total of 96 samples of maize forage was taken at ensiling, and the resulting 50 clamp silos (25 for winter feeding and 25 for summer feeding) and the 23 piles (16 for winter feeding and 7 for summer feeding) were sampled both in the central (C) and in the top (T) areas. The core samples taken from the feed-out face of each silo were analysed for fermentation characteristics, pH, DM content, and mycotoxin contamination. The core depth and weight were measured to determine the silage density. All the samples (n = 186) were analysed for AB_1, FB_1 and ZEA contamination. The mycotoxins were solvent-extracted and quantified by ELISA assay. A protocol was set up for the extraction of the mycotoxins from the silage samples. The silos were characterised for the level of aerobic deterioration by measuring the temperatures using an 80-cm probe thermometer inside the stored silage during feed-out at 20, 40 and 60 cm depths from the working face. Measurements were taken in summer and winter at 12 locations across the working face and at six elevations (10, 30, 60, 100 and 150 cm below the top surface and 20 cm above the base). The ambient temperature was recorded at the same time. The area of the working face with visible moulds was also determined during the feed-out. The silo sizes, the amount of silage consumed each day and the feeding rates were also recorded. Silage temperatures above the temperature measured in the central zone of the silo (150 cm below the top surface) were used as an index of heating associated with aerobic deterioration, since rises in temperature are clearly linked to yeast activity and DM losses. A silo was considered aerobically deteriorated when temperatures of at least 10 °C above those recorded in the central zone of the silo involved 10 % of the area of the working face and visible moulds were present in at least the top layers near the side walls.

Results and discussion

The main silo characteristics are presented in table 1. Two groups of farms were identified on the basis of the status of the maize silages during feed-out: A) aerobic deterioration both in winter and in summer, and B) no aerobic deterioration either in winter or in summer. Over winter and summer the top temperatures at the working face exceeded 30 °C in the group A farms, while in the group B farms were lower than those recorded in the central zone in winter and slightly higher in summer.

Table 1. Main characteristics of maize silos [A] involved in the survey.

Group	Daily consumption ($kg FM cow^{-1}$)	Density ($kg FM m^{-3}$)		Winter				Summer			
				Temperature		pH	Feed-out	Temperature		pH	Feed-out
		top	centre	top	centre	top	(m)	top	centre	top	(m)
A	21	221	621	35	19	4.9	0.11	36	24	5.1	0.14
B	25	321	576	11	16	3.7	0.24	28	23	3.9	0.31

[A] Main fermentation characteristics of central zone of maize silages (n = 76) were: DM content 345 ± 27 g kg^{-1}; pH 3.61 ± 0.14; lactic acid 41 ± 12 g kg^{-1} DM; acetic a. 15 ± 9 g kg^{-1} DM; NH_3-N 62 ± 13 g kg^{-1} TN; no butyric acid.
[B] The temperature (°C) was calculated as an average of the 20-cm depth measurements.

The mycotoxin contamination is reported in table 2. As far as the ZEA is concerned, a high variability in contamination was observed in the silages, according to the different zones of the silo, with the highest values corresponding to the top areas. In 20 % of cases a contamination was found that was higher than 300 ppb, which represents the maximum recommended value in feed. Figure 1 shows the working face of a silo that was opened in summer, with highly aerobically deteriorated top-side areas. In these zones the ZEA values were up to 40 times higher than those of forage at ensiling, while in the central and undeteriorated areas the ZEA concentration was similar to that of the corresponding forage at ensiling. The AB_1 showed higher average values in the silages in comparison to the forages at ensiling. A total of 22 % of the silage samples showed values that were higher than 4 ppb, which could determine a risk of contamination of milk by aflatoxin M_1 in high producing dairy cows, with a daily intake of 25 kg silage FM cow^{-1} d^{-1}, (Veldman *et al*., 1992). The FB_1 levels that were found both in the silages and in the forage at harvesting were considerably lower than the recommended maximum levels for ruminants (60 ppm), established by the American Food and Drug Administration, and no differences in the level of contamination were observed between the forage at harvesting and silages, even in the top areas of the silo.

Table 2. Occurrence of aflatoxin B1, fumonisin B1 and zearalenone in maize forage and silage. For each mycotoxin, the values are expressed as a percentage of the total number of samples (n = 186).

Zearalenone		ND[A]	30-300 ppb	>300 ppb
	Forage	48	50	2
	Silage zone C[B]	40	55	5
	Silage zone T[C]	40	47	13
Aflatoxin B_1		ND	0.6-4.0 ppb	>4.0 ppb
	Forage	21	79	0
	Silage zone C	8	78	14
	Silage zone T	5	87	8
Fumonisin B_1		ND	0.9-10 ppm	>10 ppm
	Forage	18	75	7
	Silage zone C	12	84	4
	Silage zone T	3	88	8

[A] ND = not detected; [B] C = central; [C] T= top

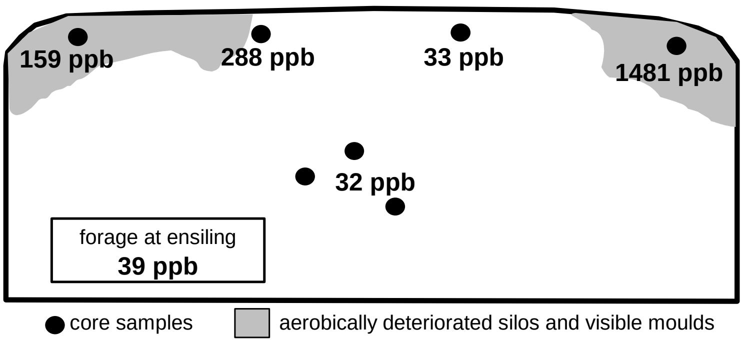

Figure 1. Example of a summer silo with top-side aerobically deteriorated zones and zearalenone contamination.

Conclusions

From the data it appears that the maize silage is at risk from zearalenone and, to a lesser extent, from aflatoxin B_1 contamination. Due to the high amounts of maize silage used in the diet of high-producing dairy cows, the daily intake of these mycotoxins can be close to or higher than the recommended limits. Since it appears that zearalenone accumulation occurred during conservation of aerobically deteriorated silos, it is very important to avoid any further fungal development during conservation, by adopting all the strategies that are necessary to reduce air penetration in the silo.

Acknowledgement

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NIRS calibration transfer in determining nutritive value of herbage silage

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Abstract

The possibility of transfer of NIR calibrations between different instruments is very important particularly when the determination of *in vivo* parameters is required. The aim of the present work was to compare NIR analytical results of organic matter (OM), crude protein (CP), acid and neutral detergent fibres (ADF and NDF) and *in vivo* organic matter digestibility (OMD) contents in herbage silages from two standardized instruments. Differences were acceptable for OM, ADF and NDF determinations taking into account the error of the reference method. CP and OMD values presented a high bias when the 2nd derivative of spectra was used in calibration. Bias value was reduced by using the 1st derivative but it was still high. Further trials showed that this behaviour could be due to room enviroment conditions.

Keywords: calibration transfer, NIRS, standardisation, clone

Introduction

Development of NIRS calibrations is time consuming, expensive and difficult, particularly when *in vivo* determinations are involved. Many laboratories are not able to carry out reference analysis and physical differences between instruments produce different spectra for the same sample. Several approaches have been made to standardize instruments so that they produce identical spectra, the clone algorithm (Shenk *et al*., 1985) being the most commonly used. CIAM has been developing calibrations to determine organic matter (OM), crude protein (CP), acid and neutral detergent fibres (ADF and NDF) and *in vivo* organic matter digestibility (OMD) contents in herbage silages (Castro *et al*., 2002) on a Foss NIRSystem 6500 Spectrophotometer (Foss GmbH, Germany) and they were transfered to LIGAL to analyse silages from dairy farms on a Foss NIRSystem 5000 Spectrophotometer. This work aimed to compare analitycal results from both instruments and to improve their performance.

Materials and methods

Standardized spectra (Shenk *et al*., 1985) of 980 routine samples of herbage silages (LIGAL) were selected for calibration and validation. Spectra were recorded on the master instrument (CIAM) and NIR analysis results were compared by using the WinISI software 1.5 (InfraSoft International, PA16870, USA). Soil contaminated samples (OM less than 80 %) were removed from calculations. A further trial was carried out to compare CP and OMD obtained on both instruments at three different dates, checking for possible changes in sample composition with time. A set of 15 samples were recorded in duplicate on both spectrophotometers and CP was determined in the same subsample. Reference and NIRS data were compared by regression with WinISI Software (MONITOR calibrations).

Results and discussion

NIRS results of routine analysis (Table 1) show a good agreement between master and host values of OM, ADF and NDF, taking into account the wide variability of samples and the repeatability of reference methods. CP and OMD values from Master were lower than those from Host (bias= -0.79 and -1.51, standard error of determination SED= 1.05 and 2.35, respectively), perhaps due to a time delay from Host to Master spectra recording. Protein contents of 15 samples determined by reference method are summarized in table 2. CP values were lower (bias = -0.76, slope = 0.85) on date 1 than those of dates 2 and 3. These samples were also analysed by NIRS on the same dates both by Master and Host Spectrophotometers. Tables 3 and 4 summarize NIRS values of CP and OMD, respectively.

Table 1. NIRS analysis results of herbage silage by Master and Host instruments.

[1]Component	[2]OM		[2]CP		[3]CP		[2]ADF		[2]NDF		[2]OMD		[3]OMD	
Instrument	Master	Host	Master	Host	Master	Host	Master	Host	Master	Host	Master	Host	Master	Host
N	853		853		853		853		853		853		853	
Minimum	80.20	80.01	3.83	3.78	4.82	4.41	22.64	21.63	34.39	32.16	42.53	42.71	34.98	34.37
Maximum	97.05	97.40	24.75	25.56	24.65	25.54	52.51	52.00	75.50	74.26	79.82	84.61	81.13	82.74
Mean	88.32	88.42	12.49	13.29	12.48	12.96	36.39	36.35	53.79	52.97	62.60	64.12	63.09	64.05
SD	3.16	3.66	3.13	3.35	3.15	3.37	4.98	5.16	7.36	7.24	6.53	7.49	6.77	7.24
R^2	0.94		0.96		0.97		0.974		0.971		0.953		0.967	
SED	0.99		1.05		0.76		0.840		1.479		2.346		1.707	
Bias	-0.09		-0.79		-0.48		0.043		0.778		-1.512		-0.968	
Slope	0.88		0.92		0.92		0.953		1.001		0.853		0.918	

[1]OM, CP, ADF and NDF g (100 g DM)$^{-1}$; OMD g (100 g OM)$^{-1}$

[2, 3]NIRS calibrations obtained from the 2nd and 1st derivative of spectra, respectively

Table 2. Variability of crude protein (CP) determination by reference method.

	Crude Protein (g/100 g DM)				Regression results				
	Minimum	Maximum	Mean	Sd		R^2	SEL	bias	slope
Determination 1 (D1)	8.30	13.03	10.88	1.35	D1 vs. D2	0.98	0.84	-0.79	0.85
Determination 2 (D2)	8.59	14.09	11.67	1.56	D1 vs. D3	0.97	0.82	-0.76	0.86
Determination 3 (D3)	8.60	14.15	11.65	1.53	D2 vs. D3	0.99	0.17	0.02	1.01

SEL= standard error of laboratory determinations

Table 3. Variability of crude protein (CP) whithin and between NIRS instruments.

	2nd derivative of spectra				1st derivative of spectra			
	Minimum	Maximum	Mean	SD	Minimum	Maximum	Mean	SD
Master 1(M1)	8.22	14.04	11.58	1.79	7.89	13.83	11.45	1.88
Master 2 (M2)	8.31	13.52	11.40	1.75	7.89	13.62	11.31	1.89
Master 3 (M3)	8.42	13.46	11.41	1.64	8.20	13.50	11.40	1.77
Host 1 (H1)	8.77	14.74	12.21	1.80	8.27	14.28	11.86	1.88
Host 2 (H2)	9.36	14.18	12.07	1.47	8.56	13.82	11.64	1.68
Host 3 (H3)	9.23	14.29	12.25	1.63	8.47	13.94	11.85	1.80
	Regression results							
	R^2	SED	Bias	slope	R^2	SED	Bias	slope
M1 vs. M2	0.97	0.36	0.19	1.01	0.99	0.22	0.14	0.99
M1 vs. M3	0.98	0.33	0.17	1.08	0.99	0.23	0.04	1.06
M2 vs. M3	1.00	0.16	-0.02	1.06	1.00	0.19	-0.10	1.07
H1 vs. H2	0.96	0.48	0.14	1.19	0.98	0.39	0.23	1.11
H1 vs. H3	0.96	0.39	-0.05	1.08	0.98	0.28	0.01	1.04
H2 vs. H3	0.99	0.30	-0.18	0.90	0.99	0.30	-0.22	0.93
M1 vs. H1	0.99	0.64	-0.62	0.99	1.00	0.43	-0.42	0.99
M2 vs. H2	0.99	0.75	-0.67	1.18	0.99	0.41	-0.33	1.12
M3 vs. H3	0.99	0.85	-0.84	1.01	1.00	0.46	-0.45	0.98

SED = standard error of NIR determinations CP, g (100 DM g)$^{-1}$

Mean reference CP values were lower than NIRS results obtained from Master and higher than those from Host instrument but close to both of them. Bias and slope values within instruments were similar apart from the 2nd reading on the Host (slope ranged from 0.90 to 1.19), probably due to changes in room temperature. Bias values between instruments ranged from -0.84 to -0.62 when the 2nd derivative of spectra was used to develop calibration but it was reduced (-0.45 to -0.33) when using the 1st derivative.

Bias and slope values of OMD determination by NIRS within and between instruments ranged from 0.131 to 0.892 and 0.993 to 1.05, respectively, when the 2nd derivative of spectra was used in calibration. The use of the 1st derivative improved bias and slope values within instruments but it increases bias values between instruments. Nevertheless, overall differences between OMD mean values (range 58.74-60.49) were acceptable.

Table 4. Variability of *in vivo* digestibility (OMD) whithin and between NIRS instruments.

	2nd derivative of spectra				1st derivative of spectra			
	Minimum	Maximum	Mean	SD	Minimum	Maximum	Mean	SD
Master 1(M1)	52.61	66.22	60.49	4.42	51.40	66.90	60.14	4.72
Master 2 (M2)	52.75	65.15	59.93	4.20	51.02	66.08	59.80	4.66
Master 3 (M3)	52.38	65.26	59.78	3.96	50.96	66.00	59.59	4.43
Host 1 (H1)	51.78	65.34	59.66	4.44	49.92	65.98	59.20	4.77
Host 2 (H2)	51.80	64.40	59.04	4.19	49.75	65.14	58.74	4.71
Host 3 (H3)	51.84	64.79	58.91	3.93	50.41	65.60	58.92	4.48
	Regression results							
	R^2	SED	Bias	slope	R^2	SED	Bias	slope
M1 vs. M2	0.99	0.77	0.56	1.05	0.99	0.55	0.33	1.01
M1 vs. M3	0.97	1.09	0.71	1.10	0.98	0.89	0.54	1.06
M2 vs. M3	0.98	0.56	0.15	1.05	0.99	0.52	0.20	1.05
H1 vs. H2	0.98	0.94	0.62	1.05	0.98	0.80	0.46	1.00
H1 vs. H3	0.97	1.17	0.75	1.11	0.98	0.70	0.21	1.06
H2 vs. H3	0.99	0.53	0.13	1.06	0.99	0.48	-0.18	1.05
M1 vs. H1	1.00	0.87	0.83	0.99	1.00	0.99	0.93	0.99
M2 vs. H2	1.00	0.92	0.89	1.00	1.00	1.10	1.06	0.99
M3 vs. H3	0.99	0.95	0.87	1.00	1.00	0.73	0.68	0.99

SED = standard error of NIR determinations OMD, g (100 g OM)$^{-1}$

Conclusions

A good agreement was found between Master and Host values for OM, ADF and NDF.

Taking into account variability of results within instruments, the agreement of Master and Host CP and OMD values was acceptable, but it was improved by using 1st derivative of spectra in calibration to analyse CP. Slope values when the 2nd host results of CP (H_2) are involved may be due to changes in room temperature.

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Near infrared spectroscopy analysis of nitrogen and phosphorus in the leaves of woody plant species

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Abstract

In this study, we used near infrared reflectance spectroscopy (NIRS) to estimate the N and P contents of leaf samples of eighteen woody plant species. Samples of these species were obtained in western Spain and were typical of mountain, riparian, and relatively dry areas. A remarkable variation in the contents of both elements was found in the samples: N ranged from 6.6 to 45.0 g kg^{-1}, and P from 0.24 to 2.97 g kg^{-1}. Multiple linear regression (MLR) and partial least squares regression (PLSR) were used for developing NIRS calibrations. The calibration statistics were better when using PLSR. Using this procedure, coefficients of multiple determination (R^2) of 0.99 and 0.94 were obtained for N and P, respectively; the standard errors of cross validation (SECV) were 0.79 g kg^{-1} and 0.15 g kg^{-1}, and root mean square errors of prediction (RMSEP) were 0.76 g kg^{-1} and 0.11 g kg^{-1}.

Keywords: chemical composition, woody plant species, NIRS

Introduction

The nutrient content of leaves affects several aspects of plant physiology such as photosynthetic rates, growth capacity or nutrient use efficiency (Aerts and Chapin, 2000). Therefore, analysis of nutrient concentration in samples of leaf tissues is an important part of most ecophysiological studies. Sometimes, this type of study requires analyses of several primary constituents and secondary metabolites on a large number of samples of different plant species, with only small amounts of sample available. Near infrared reflectance spectroscopy (NIRS), a non-destructive technique, is a very useful tool in such circumstances (Foley *et al.*, 1998). NIRS has been used successfully to determine chemical constituents of pastures and other foods, with accuracy and precision for more than 20 years (García Ciudad *et al.*, 1993), but applications in nutritional ecology are rare. The objective of this study was to develop calibration equations for the estimation of nitrogen and phosphorus concentrations in leaf samples of several woody plant species. These parameters are essential to quantify N and P use efficiency.

Materials and methods

Eighteen woody species were included in this study, distributed in six areas in the central western region of the Iberian Peninsula. According to their distribution in the selected areas, three groups of species were identified: riparian (*Frangula alnus, Fraxinus angustifolia* and *Sambucus nigra*), mountain (*Pinus sylvestris, Acer monspessulanum* and *Betula pubescens*) and species typical of relatively dry areas (C*rataegus monogyna, Pyrus bourgaeana, Quercus faginea, Q. pyrenaica, Q. rotundifolia, Q. coccifera, Q. suber, Pinus halepensis, P. pinaster, P. pinea, Taxus baccata* and *Ilex aquifolium*). At each site, four or five mature specimens were selected randomly on each sampling date. From these individuals, a composite sample of branches with leaves from different crown positions in each canopy was taken at weekly intervals through the growing season in 2001. The leaves were separated into annual age classes and a total of 183 samples were obtained. The samples were oven-dried at 60 ºC and ground using a 1 mm mesh sieve. N and P concentrations in all leaf samples were determined by Kjeldahl and molybdo-vanadate methods, respectively.

NIR spectra of all samples were recorded from 1100 to 2500 nm as log 1/R. Multiple linear regression (MLR) and partial least squares regression (PLSR) were used for developing NIR calibrations. In each case, three mathematical procedures were considered: log 1/R, first derivative and second derivative. To estimate the accuracy of calibrations, the values obtained by reference methods were compared to those predicted by means of NIRS.

Results and discussion

The means, range, and standard deviations of N and P concentrations from the calibration and validation sample sets are shown in table 1. The statistics of the calibration and validation are shown in table 2. A large amount of variability was observed in the concentration of both elements, but particularly in P, for which the highest concentration measured was 12 times that of the lowest. This variation is likely to be caused not only by differences among species, but also by the different ages of the leaves within a given species. The concentrations of the samples in each validation set are included in the intervals of variation of the calibration sets. This condition is a requirement for the development of good calibration equations.

Table 1. Statistical data for nitrogen and phosphorus concentrations (expressed as g kg^{-1} dry matter) determined by chemical analysis.

Component	Set	n	Range	Mean	SD
Nitrogen	calibration	112	6.60- 45.00	16.13	6.28
	validation	71	7.40-23.20	13.20	3.28
Phosphorus	calibration	112	0.24-2.97	1.04	0.48
	validation	71	0.43-1.98	0.82	0.25

Table 2. Calibration and validation statistics for partial least squares regression (PLSR) and multiple linear regression (MLR) methods.

MLR				PLSR			
	Log 1/R	1D	2D		Log 1/R	1D	2D
Nitrogen							
calibration set							
No. terms	5	5	5	No. factors	7	7	8
R^{2} (1)	0.98	0.98	0.99	R^{2} (1)	0.96	0.99	0.99
SEC(2)	0.77	0.81	0.66	SEC(2)	1.08	0.67	0.59
				SECV(3)	1.18	0.79	0.93
validation set							
r^{2} (4)	0.93	0.93	0.94	r^{2} (4)	0.94	0.92	0.94
SEP(5)	0.94	0.80	0.79	RMSEP(6)	0.78	0.90	0.76
Phosphorus							
calibration set							
No. terms	6	6	6	No. factors	10	9	7
R^{2} (1)	0.92	0.91	0.91	R^{2} (1)	0.92	0.94	0.93
SEC(2)	0.13	0.14	0.13	SEC(2)	0.13	0.11	0.12
				SECV(3)	0.15	0.15	0.18
validation set							
r^{2} (4)	0.65	0.71	0.65	r^{2} (4)	0.68	0.74	0.69
SEP(5)	0.14	0.12	0.13	RMSEP(6)	0.12	0.11	0.12

(1) Coefficient of multiple determination; (2) Standard error of calibration; (3) Standard error of cross validation; (4) Coefficient of determination; (5) Standard error of prediction; (6) Root mean square error of prediction.

Although differences were small, better calibrations were obtained with the partial least squares regression (PLSR) than with the multiple linear regression (MLR) (Table 2). Bolster *et al*. (1996) also obtained better results with PLSR when estimating the content of N and other constituents of tree foliage samples. For both methods, the second derivative predicts the content of N better, while the first derivative provides a better prediction of P content.
It is well known that NIRS can provide very good predictions of N content in different types of plant and animal samples. As expected, estimations of N were more accurate than those of P (Table 2, Figure 1). Using PLSR and second derivative for the estimation of N content, a value of 0.76 g kg^{-1} was obtained for the root mean square error of prediction (RMSEP). Using the first derivative, a RMSEP value of 0.11 g kg^{-1} was obtained for the estimation of P content. Bolster *et al*. (1996), obtained similar results for N content estimation. However, Flinn *et al*. (1996) obtained a greater SEP for the estimation of P than in this study.
The results of this investigation show that NIRS can be a very useful tool for studies of plant ecophysiology, when nutrient use efficiency is measured in leaf samples of different species.

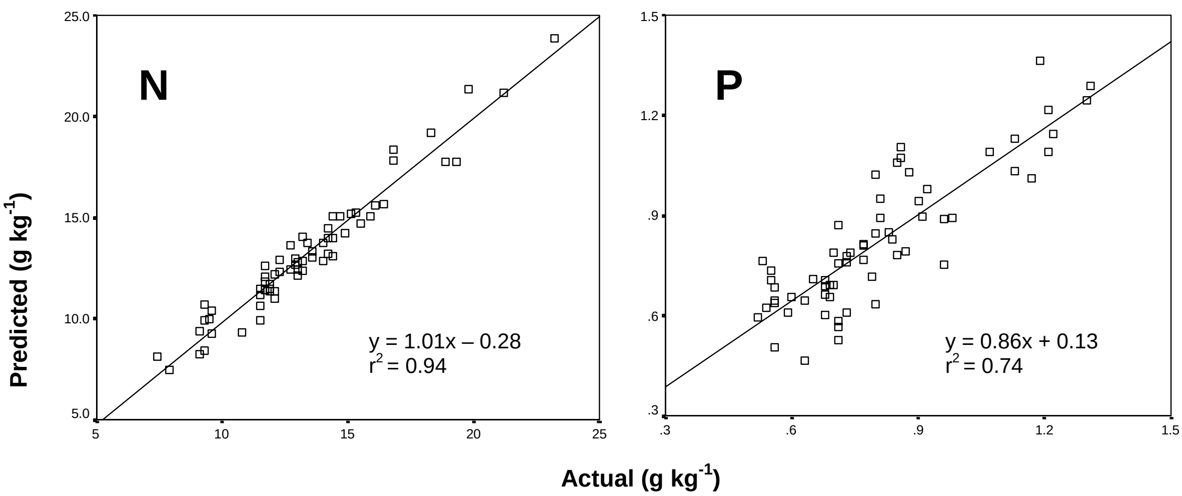

Figure 1. Relationship between NIRS predicted and actual values for N (second derivative) and P (first derivative) content using partial least squares regression (PLSR).

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Using of NIRS to estimate the leaf:stem ratio in different botanical species of seminatural grasslands

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Abstract

Leaf:stem ratio of forages is an important factor affecting quality and forage intake by ruminants. However, its manual determination is a tedious, time consuming and costly process. The objective of this study was to evaluate the suitability of near infrared reflectance spectroscopy (NIRS) for predicting the proportion of blades in different botanical species of seminatural grasslands. The study was carried out in two seminatural grasslands, during the first cycle of growth of the 2003 growing season and involved 90 samples belonging to ten grasses in different phenological stages. Twenty-five plants of each species were manually separated into 2 fractions: blades and the rest of the plant. The morphological fractions were oven-dried and then reconstituted to obtain the original whole plant. This was ground and scanned by a monochromator Foss NIRSystems 6500. A modified partial least square calibration model was developed for the proportion of leaves. The cross-validation coefficient of determination was 0.91 and the standard error 4.7 %. It is concluded that NIRS can be used to estimate the morphological composition of native grasses in a rapid and accurate way.

Keywords: leaf fraction, NIRS, botanical species, seminatural grasslands

Introduction

The nutritive value of forage is highly dependent on the stage of maturity. The digestibility of forage at different phenological stages varies because of differences in ontogeny and feeding value (Wilson, 1994). In order to explain the variation of the nutritive value of seminatural grasslands it is necessary to consider the variation of leaf:stem ratio of its botanical components. However, manual determination of these fractions is a tedious, time consuming and costly process. Leaf:stem ratio has been predicted successfully by NIRS in ryegrass swards (Leconte *et al.*, 1999), but research has not been conducted using NIRS to predict the morphological fractions of native species. The aim of this study was to evaluate the suitability of NIRS for predicting the dry proportion of leaves in grasses of seminatural grasslands.

Materials and methods

Samples of 2 plots were collected from the diet offered to lambs used to determine the organic matter digestibility. Samples were taken during the first cycle of growth of the 2003 growing season at the INRA Station of St Genes Champanelle France at three different dates (between June and July).

Samples of approximately 300 g of fresh weight were separated into species, and 25 plants of each botanical species belonging to the grass family were chosen at random and manually separated into leaf and stem fractions. The stem fraction included sheaths, stems, and inflorescences. Each fraction was dried separately in a forced air oven at 60 ºC and they were weighted to determine the leaf:stem ratio. Afterwards, whole samples were reconstituted and they were ground on a Retch mill (1mm sieve). Finally, they were stored in plastic bags at room temperature prior to NIRS analysis.

Ground forage samples were scanned twice between 1100 and 2500 nm (in 2 nm steps) using a monochromator Foss NIRSystems 6500 and a quartz window ring cup holding approximately 1 g of sample. All spectra and reference data were recorded with the ISI software.

A calibration model was developed for the proportion (dry matter basis) of leaves, using the Modified Partial Least Square (MPLS) technique. The standard normal variate and detrend (SNVD) scatter correction procedure was applied to the spectral data. The spectra were transformed through a mathematical first order derivative. The statistics used for equation development and evaluation were, the standard error of calibration (SEC) and cross-validation (SECV), the determination coefficient in calibration (R^2c) and in cross-validation (R^2cv), the ratio of the range in the reference data to the SECV (RER) and the ratio of the standard deviation to the SECV (RPD) (Williams and Sobering, 1996).

Results and discussion

The statistical parameters of the MPLS calibrations are described in table 1.The variability of the blade percentage covered by the calibration set, is shown by the broad range, similar to the variability found by Leconte *et al*. (1999) in ryegrass swards. The equation obtained explains more than 90 % of the variation existing in blades' percentage. Furthermore, the calibration and cross validation errors are similar than the errors reported by others authors (Leconte *et al*., 1999; Smart *et al*., 1998). Also, RER and RPD values indicate that the equation should be capable of predicting the required values, with a level of accuracy greater than the recommended minimum values (Williams and Sobering, 1996). It is concluded that NIRS can be used to estimate the morphological composition of grasses of seminatural grasslands in a rapid and accurate way.

Table 1. NIR calibration and cross-validation statistics for leaves fraction of grasses.

	N	Mean	Range	SEC	R^2c	SECV	R^2cv	RPD	RER
Leaves	90	25.8	6.0-79.0	3.9	94.0	4.7	91.1	3.4	15.5

N: Number of samples; SEC: Standard error of calibration; R^2c: Coefficient of determination in calibration; SECV; Standard error of cross-validation; R^2cv: Coefficient of determination in cross-validation; RPD: Ratio of the standard deviation to the SECV; RER: Ratio range to the SECV.

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Faecal Near Infrared Reflectance Spectroscopy for ruminant feed intake prediction

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Abstract

The aim of this research was to determine if NIRS calibrations can be developed for prediction of intake characteristics of ruminants. Farmers have little information on the intake of producing animals, especially grazing animals. The intake characteristics studied were total dry matter intake and botanical composition of intake (grass and clover portions). Under grazing conditions, the latter may differ substantially from sward composition. The database consisted of faecal sample sets from three feeding trials: dairy cow, suckler cattle and sheep samples. Animals were kept in a stable and offered recorded allowances of a predominantly grass clover ration. The database was expanded through repeated spectroscopy under different sample conditions.

From a mixed suckler and dairy cows database, a calibration of total dry matter intake was developed with satisfactory reliability (N = 139, $R^2 = 0.98$, standard error of cross validation (SECV) = 6.78 g DM ($kg^{-0.75}$)). The calibrations on botanical composition (dairy cow and sheep database) also had relatively good accuracy (SECV = 3.99 % and 4.59 % respectively for legume and grasses proportions). Results with the small but compound databases show that high quality NIRS calibrations on feed intake of ruminants are attainable.

Keywords: ruminant faeces, NIRS, feed intake prediction, botanical composition

Introduction

Grazing animals diet characterisation provides for important management information for efficient forage based livestock production. However, the estimation of dry matter intake at pasture remains difficult, even if, the development of the n-alkanes methodology realised real progress (Dove and Mayes, 2003). This method can't be applied routinely as it needs the use of synthetic alkanes. Moreover, the difficulty to obtain a representative sample of ingested herbage, when mixed sward are offered to animals, remains its major disadvantage. During the last 20 years, the potential of Near Infrared Reflectance Spectroscopy (NIRS) to predict chemical composition and digestibility of feeds has been demonstrated. Likewise, the potential of NIRS analyses of faeces to predict diet characteristics has been shown (Coates, 2000).

The aim of this paper is to determine if faecal NIRS calibrations can be developed to predict and to characterise intake of grazing ruminants. The robustness of NIRS calibrations integrating faeces of different animal species has also been tested.

Materials and methods

Databases used in this study are derived from feeding trials conducted on sheep and suckling cows fed with fresh forage only (Farming Systems Section, Libramont (B)) and on dairy cows fed with diet containing maize silage, fresh forage and concentrate (Animal Sciences Group, Wageningen UR Lelystad (NL)). Parameters used were: (1) total dry matter intake (DMI in g kg^{-1} metabolic weight ($kg^{-0.75}$)) (Belgian Blue White suckling cows and Red Holstein lactating dairy cows) and (2) percentages of legume and grasses in ingested diet (Texel × Bleu du Maine sheep and Red Holstein lactating dairy cows).

To generate the database, suckling cows (n = 3) housed in individual boxes received fresh grass cut every morning for fifteen days. The grass, a mixed forage of white clover, timothy and rye grass, was offered *ad libitum* twice daily.

For the sheep experiment, castrated adult sheep (n = 9) were fed individually with three forage plant species (two grasses and a legume) offered in separate feeding troughs. These plant species, that could be selected freely, were offered *ad libitum* but in different proportions. During ten days, each forage species was cut daily, stored at 4 °C and offered in 2 meals the following day. Sward purity (percentage of weeds), for each forage species, was determined daily. In this way, botanical composition of sheep intake was obtained inon a dry matter basis. During trial periods, suckling cows and sheep faeces were sampled 3 times per day.

For the dairy cow trial, six lactating dairy cows were offered a grass clover mixture *ad-libitum*, three kilogram of concentrate and three levels of maize silage supplementation in a latin square design. Treatments were zero, 2.5 and 5.0 kg DM maize silage per cow per day. Cows produced approximately 20 kilogram milk per day on average. In three periods of four days each, the intake of concentrates, maize silage and grass clover mixture was measured. During one measuring period, the grass clover was cutdaily in one paddock in order to have a constant quality between days. The clover percentage in the cut herbage dry matter from period one, two and three was 19, 24 and 57 % respectively. Faeces were sampled twice daily (0600 h and 1700 h). The eight samples taken during one period from one cow were mixed up proportionally, resulting in a total of 18 faecal samples along with the same number of records on feed intake data.

NIRS acquisitions and calibrations

Dried and ground faecal samples were submitted to NIRS analysis (NIRS system monochromator 5000). All individual spectra were recorded in the range of 1100 to 2500 nm by 2 nm steps and correlated with DMI or with percentage of legume and grasses. Dairy cow faecal samples were measured in triplicate to increase the number of spectral references. Characteristics of reference databases are summarised in table 1. Calibrations were developed according to the partial least square procedure with cross validation of the ISI software. Evaluation of calibration performances was done through the observation of the corresponding coefficient of determination (R^2), standard error of calibration (SEC) and standard error of cross validation (SECV). To evaluate the robustness of these calibrations, the ratio between the standard deviation (SD) of the reference population and the SECV was calculated. SD/SECV values of 2.5-3.0 are considered adequate for a qualitative samples screening but values of at least 3.0-5.0 are required for quality assurance (Williams and Soberig, 1992).

Table 1. Characteristics of reference databases.

Parameters	Animal	Mean	Minimum	Maximum
DMI g $kg^{-0.75}$	Dairy cow	136.3	105.9	156.6
	Suckling cow	80.3	57.6	105.6
Grass %	Dairy cow	48.9	23.9	69.3
	Sheep	65.7	45.7	76.5
Legume %	Dairy cow	24.3	12.5	47.1
	Sheep	34.3	23.4	54.3

Results

Calibration results are shown in table 2. From these results, it was not possible to predict DMI only from dairy cow NIRS calibrations. Though the R^2 of this calibrations is satisfactory, the calibration is associated with a high standard error of estimation and a SD/SECV ratio lower than 3. This lack of precision is probably due to the low number of available dairy cow samples (n = 18) and to the relatively small variability of the DMI reference values (coefficient of variation = 10 %). The practice of NIRS measurements of faecal samples in triplicate does not increase this variability. Combining the dairy cow and suckling cow databases increased the NIRS variability and improved the calibration parameters (R^2 = 0.98; SEC = 4.88 g DM $kg^{-0.75}$; SD/SECV = 4.56). With a standard error of estimation of 6.78 g DM $kg^{-0.75}$, the averaged bias recorded could be of about 900 g day^{-1} for a cow of 650 kg (about 5 % of the total ingested diet).
Botanical composition of grazed grass could be predicted by NIRS with a relatively high accuracy. In contrast to the DMI, calibration performance was better for the dairy cow database. Indeed, the addition of sheep database did not improve calibration parameters.

Table 2. Statistics of NIRS calibrations for predicting diet attributes.

	Faeces	N	Mean	SD	SEC	R^2	SECV	SD/SECV
DMI g $kg^{-0.75}$	Dairy cow	54	136.29	14.40	5.66	0.85	9.28	1.55
	Suckling cow	84	80.37	13.60	2.57	0.96	3.15	4.31
	Global	**139**	**100.94**	**30.92**	**4.88**	**0.98**	**6.78**	**4.56**
Grass %	Dairy cow	53	48.62	13.69	3.45	0.94	4.24	3.23
	Sheep	127	44.98	9.28	3.26	0.88	4.40	2.10
	Global	**177**	**46.12**	**10.94**	**3.45**	**0.90**	**4.59**	**2.38**
Legume %	Dairy cow	54	24.32	12.86	2.87	0.95	3.24	3.96
	Sheep	122	22.00	5.67	2.01	0.87	2.91	1.95
	Global	**177**	**22.73**	**8.60**	**2.99**	**0.88**	**3.99**	**2.15**

N = number of observations with outliers (standardised distance (H) > 3) excluded.

Discussion and conclusion

Results based on the small but varied databases, show that NIRS calibrations with good performances could be developed to characterise ruminant feed intake. It can be concluded that, once we will have enough reference observations for dairy cows and sufficient variability in databases, we will be able to develop a NIRS calibration that will integrate animals species variability. We demonstrate that faecal NIRS can predict animal intake, in term of plant species composition. Statistical performance of faecal calibrations are equivalent to the one of NIRS calibrations developed to predict species composition from sward samples. The compound calibrations on grass and legume portion did not meet the quality assurance (SD/SECV > 3), probably due to the big difference in composition between sheep and dairy cow faeces. Faecal NIRS seems an interesting method to estimate diet quality but the major concern is the development of accurate reference database covering the range of variation that could be met for the different herbaceous species in the field. In conclusion it's use to predict diet characteristics of grazing animal must be linked to the development of reference data as diverse as possible.

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Impact of the mathematical treatment of spectra on the robustness of NIRS calibration

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Abstract

The aim of the present study is to examine the impact of spectra mathematical treatment on the calibration, prediction and repeatability accuracy of equations on the Lithuanian-grown perennial grasses. The database of NIR spectra was composed of 1021 samples of perennial grasses grown in various areas from 1998 to 2001. Dried and ground samples were scanned by the NIRS-6500 using Spinning Module. The reference values of crude protein (CP) by Kjeldahl, crude fibre (CF) by Henneberg-Stohmann, modified acid detergent fibre (MADF), neutral detergent fibre (NDF) and water soluble carbohydrates (WSC) by anthron method were of medium to large variation. A mathematical transformation included derivatives 0, 1, 2 and 3, gaps and the first smoothing occurred across 2, 4 and 6, and 2 and 4 data points, respectively. Mathematical treatment had a different impact on the accuracy of the equations of quality parameters, and the standard errors of data repeatability were as follows: CP 0.30-1.23; CF 0.44-1.10; MADF 0.42-0.81; NDF 0.56-1.28; WSC 0.37-1.31. Standard errors of the prediction results of differently prepared sample sets were relatively large and depended on the mathematical treatment used for the development of the equations.

Keywords: NIRS, mathematical treatment, accuracy, quality of grasses

Introduction

The characteristics of near infrared radiation reflected from a sample are used to predict certain sample characteristics and each application of this type must be obtained by calibration. It introduces a number of complications such as the choice of wavelength and mathematical treatment of the reflectance data (Butkutė, 2000; Park *et al.,* 1997). The first step in calibration is subjecting the calibration file to various mathematical treatments of the data (Hruschka, 1987 in Dryden, 2003). Choice of derivative may depend on the analyte and other peculiarities. Derivatized log (1/R) of optical data is commonly used to address problems associated with overlapping peaks and large baseline variations (Hruschka, 1987 in Dryden, 2003). The mathematical treatment also allows for selection of the gap over which the derivative will be calculated, and degree of smoothing for the calibration. Gap size is important in calibration sensitivity to system noise (Williams, 1987 in Dryden, 2003). Smoothing is used to reduce instrument and/or sample noise (Hruschka, 1987; Williams, 1987 in Dryden, 2003). The best mathematical treatment can be found through trial and error (Park *et al.,* 1997). In the present study the impact of spectra mathematical treatments on the calibration and prediction accuracy are examined as well as on the repeatability data in developing equations for the prediction of quality of Lithuania-grown perennial grasses.

Materials and methods

The NIR spectra of perennial grass samples grown in various areas of Lithuania and different species and varieties from plant breeding plots were collected from 1998 to 2001. Fresh samples chopped into particles of 3-5 cm, were fixed at 105 °C for 15 min, dried at 65 ± 5 °C and ground by Cyclotec mill with 1 mm sieve, scanned by the NIRS-6500 using Spinning Module. For repeatability testing each of 20 samples was divided into three parts: the first was made up as described above, the others differed in drying or grinding regime. NIR spectra were accompanied by the data of constituents: crude protein (CP), crude fibre (CF), modified acid detergent fibre (MADF) (Faithfull, 2002), neutral detergent fibre (NDF) and water soluble carbohydrates (WSC) by anthron method. Mathematical treatment of spectral data of wavelength interval 1100-2500 nm was performed using the ISI-NIRS 2 Version 3.10 software (Infrasoft International, Port Matilda. PA, USA). Six different mathematical treatment models for each quality constituent were derived, each of them described by four digits. The first means derivative, the second is the gap over which the derivative is calculated, the third is the smooth, i.e., the number of data points in a running average and the fourth is the second smooth. Interfering effect was minimised by SNVD. Equations were calculated using a MPLS algorithm, and cross-validation was used to avoid overfitting.

Results and discussion

Equations were developed using the raw log (1/R), first, second and third order derivatised data. Gap was changed from 2 to 6 and smooth from 2 to 4. The recommended number for second smooth is usually 1. So we used the combinations of figures presented in table 1. The calibration sample set included grasses of different species and different maturity which determined medium to large variation of data of the grass quality parameters. Mathematical treatments resulted in RSQ from 0.941 to 0.970 for CP, CF and WSC and from 0.969 to 0.981 for MADF and NDF. This means a strong relationship between the NIRS and reference data. Derivatives 0 and 3 were of the least success in the most cases of calibration and cross-validation. The best statistics in cross-validation was when mathematical treatment 2,6,4,1 or 1,4,4,1 was used. For CP raw spectra (0,4,4,1) had a slight priority.

Table 1. The influence of mathematical transformation on the standard errors SEC and SECV and coefficients of correlation RSQ and 1-VR in calibration and cross-validation.

	CP		CF		MADF		NDF		WSC	
Pre-	In calibration[1)]									
treatment	SEC	RSQ	SEC	RSQ	SEC	RSQ	SEC	RSQ	SEC	RSQ
0,4,4,1	0.877	0.958	1.466	0.941	0.973	0.969	1.650	0.972	1.563	0.949
1,4,4,1	0.852	0.960	1.231	0.958	0.886	0.974	1.469	0.978	1.340	0.963
2,4,4,1	0.797	0.964	1.054	0.970	0.805	0.979	1.373	0.981	1.231	0.969
3,4,4,1	0.830	0.962	1.374	0.948	0.774	0.981	1.381	0.980	1.319	0.964
1,2,2,1	0.841	0.962	1.367	0.948	0.870	0.975	1.584	0.974	1.303	0.965
2,6,4,1	0.804	0.964	1.058	0.969	0.792	0.980	1.371	0.980	1.302	0.965
	In cross-validation[1)]									
	SECV	1-VR	SECV	1-VR	SECV	1-VR	SECV	1-VR	SECV	1-VR
0,4,4,1	0.899	0.956	1.553	0.934	1.083	0.962	1.815	0.967	1.642	0.944
1,4,4,1	0.905	0.955	1.388	0.947	1.020	0.965	1.632	0.973	1.542	0.951
2,4,4,1	0.926	0.951	1.323	0.952	1.085	0.962	1.744	0.969	1.579	0.949
3,4,4,1	0.934	0.952	1.652	0.924	1.162	0.957	1.726	0.970	1.642	0.944
1,2,2,1	0.903	0.956	1.477	0.940	1.061	0.963	1.735	0.969	1.556	0.950
2,6,4,1	0.890	0.956	1.271	0.955	1.029	0.965	1.635	0.972	1.510	0.953

[1]Reference data in the calibration set: CP n 1021, mean 14.14 %, range 4.44-29.30, CV31.2 %; CF n 426, mean 28.06 %, range 14.60-44.50, CV21.6 %; MADF n 291, mean 25.36, range 13.46-36.59, CV22.3 %; NDF n 326, mean 45.46, range 19.2-66.04, CV21.8 %; WSC n 327, mean 13.17 %, range 2.17-41.20, CV53.1 %

Two important sources of error must be considered at this point to validate the robustness of calibrations. The first of them is accuracy, i.e., the agreement between the reference value and the predicted value from the NIR spectrum, and the second one is precision which should be assessed by the repeatability of NIR predicted data. Mathematical spectra transformation affected equation accuracy parameters, i.e., standard error and coefficient of correlation, of NIR predicted and reference data in prediction, and between predicted data of two scans in repeatability (Table 2). By summation results of prediction and repeatability of sample set prepared as described in Materials and methods, the best equations for the prediction of CF, MADF, NDF are those developed using treatment 2,6,4,1 and for the CP and WSC, 1,4,4,1.

Table 2. The influence of mathematical transformation on the statistics of accuracy of the equation in prediction and repeatability.

Quality parameter	Range of the statistics					
	Standard error	Coefficient of correlation	The best pre-treatments	Standard error	Coefficient of correlation	The best pre-treatments
	In prediction[1)]			In repeatability[1,2)]		
CP	0.820-0.899	0.980-0.983	2,4,4,1; 1,4,4,1	0.305-1.232	0.824-0.989	1,4,4,1; 2,6,4,1
CF	1.192-1.790	0.912-0.963	2,6,4,1; 2,4,4,1	0.442-1.097	0.895-0.982	1,4,4,1; 2,6,4,1
MADF	1.081-1.316	0.959-0.972	2,6,4,1; 1,2,2,1	0.423-0.812	0.920-0.981	0,4,4,1; 2,6,4,1
NDF	1.582-2.300	0.951-0.977	2,4,4,1; 2,6,4,1	0.565-1.277	0.964-0.990	2,6,4,1; 1,4,4,1
WSC	1.521-2.486	0.910-0.967	2,4,4,1; 1,4,4,1	0.374-1.314	0.955-0.997	0,4,4,1; 1,4,4,1
	In repeatability of differently dried samples[3)]			In repeatability of differently ground samples [4)]		
CP	1.232-2.431	0.824-0.858	1,4,4,1; 1,2,2,1	0.754-1.352	0.913-0.976	1,4,4,1; 2,4,4,1
CF	1.116-2.565	0.815-0.913	2,6,4,1; 2,4,4,1	1.149-1.467	0.839-0.947	2,6,4,1; 1,4,4,1
MADF	0.965-1.912	0.908-0.952	1,4,4,1; 1,2,2,1	0.820-1.726	0.891-0.960	1,4,4,1; 1,2,2,1
NDF	4.416-5.144	0.820-0.869	0,4,4,1; 2,6,4,1	2.534-3.435	0.919-0.954	1,4,4,1; 2,6,4,1
WSC	2.956-5.115	0.845-0.901	1,2,2,1; 0,4,4,1	1.137-2.238	0.955-0.989	0,4,4,1; 2,4,4,1

[1] Reference data of independent sample set: CP n 75, range 4.96-29.22; CF n 24, range 19.6-39.6; MADF n 55, range 13.51-35.12; NDF n 25, range 23.72-64.33; WSC n 37, range 3.16-35.04; [2,3,4]the independent samples set n 20; [2]second scan after few weeks break; [3]comparison between dried as described in Materials and methods and dried at 105^0C; [4]comparison between ground as described in Materials and methods and ground without sieve

The effect of possible, relevant variation of temperature, peculiarities of sample preparation etc., on the spectral data is well known. In total the repeatability of differently prepared (dried and ground) sample sets is noticeably worse than the repeatability of two scans of the same set with a few weeks' break (Table 2). In many cases large standard errors in the latter stage of testing were affected by *bias*. The best coefficients of correlation in this case were found by the equations for the prediction of CP, CF, NDF and partly for MADF, developed with the same mathematical treatment as the best equations for the test of prediction and repeatability of two scans of the same set. So mathematical treatment of the calibrated optical data is an important factor for the development of accurate and robust equations and together with other calibration factors subdue the effect of particle size or other sample preparation inaccuracies.

Conclusions

Mathematical treatment of the calibrated spectra affected the accuracy and precision of equations in all levels of their robustness test. In the calibration within 1100-2500 nm wavelength range the priority is given to 2,6,4,1 and 1,4,4,1 or even to 2,4,4,1 for most of the tested quality components in all levels of accuracy testing of equations. The results of the present study show an importance to take into account the statistics of data in repeatability.

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Comparison of *in situ* crude protein degradation of grass silage in sheep wethers and dairy cattle

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Abstract

Rumen degradation characteristics of crude protein in 29 grass silages were studied independently in three dairy cows and three wethers fitted with rumen cannulae. The grass silage was conserved in big bales after 24 hours of wilting and was either ensiled directly (DIR) or with supplementation of an additive (ADD): commercial formic acid (3.5 L t^{-1}) or Live System (2 L t^{-1}). Wethers and cows were given, at maintenance level, a diet with a roughage: concentrate ratio of 60:40 offered in 2 meals daily. The roughage used in the trials was grass silage of similar characteristics to the forages to be incubated in both wethers and cows. The *in situ* rumen incubations were performed with standard operational procedures, which were comparable for both species. The difference in chemical composition between direct and treated sets of grass silage was not large, and the differences of degradation parameters were not significantly different. The soluble crude protein fraction ‘a’ was higher ($P < 0.01$) and the slowly degradable fraction ‘b’ lower ($P < 0.001$) in wethers than cows in both kinds of silage. The total disappearance ‘a + b’ of crude protein in rumen of DIR silage was higher in cows, whereas that of ADD silage was higher in wethers. However, the effective degradability, with an assumed degradation rate of 0.06 h^{-1}, was similar in both species and without differences between different additives used.

Keywords: crude protein, *in situ* degradability, sheep, cattle

Introduction

In the new systems for estimating protein supply to ruminants, it is required to know the proportion of protein degradable in the rumen. These systems have been designed to allow estimation of protein value of feedstuffs for dairy cows. Normally these values are used for sheep too on the assumption that rumen kinetics are comparable between both species. However, wethers and cows normally receive different diets. The diet is the most important source of variation in results of the *in situ* procedure to determinate the rumen disappearance (Huntington and Givens, 1995), giving a degradation rate higher in wethers than cows (Ševek and Everts, 1999). The present study compares the rumen degradation of crude protein of grass silage in dairy cows and wethers fed the same diet at maintenance level for both species. The effects of the characteristics of silage is studied too.

Materials and methods

From 1993 to 1996 grass was ensiled, after 24 hours of wilting, in big bales. The grass was directly ensiled (DIR, n = 17) or ensiled with addition (ADD, n = 12) of formic acid (3.5 L t^{-1}) or of *Lactobacillus plantarum* and *Enterococcus faecium* (2.0 L t^{-1}) Thus a total of 29 independent samples were used for the determination of *in situ* degradability. All the samples were obtained in the experimental SERIDA farm. The paddocks, which were grazed and ensiled, were of natural grass or seeded with *Lolium perenne* and *Trifolium repens* or *Lolium multiflorum* alternating with maize.

Three dry Holstein-Friesian cows (live weight 750 kg) and three wethers of Manchega race (live weight 65 kg) were fitted with a rumen cannula, and kept indoor at the SERIDA and ETSIA experimental farms for the *in situ* assay, respectively. All animals were fed at maintenance level by a diet of silage and concentrate in a proportion 60:40 (dry matter basis) in two daily meals. The forage was a grass silage similar to the forages studied. *In situ* crude protein (CP) ruminal degradation of feed was determined by the nylon bag technique with standard operational procedures (Oldham, 1987). Nylon bags (11 × 7 cm for wethers and 10 × 20 cm for cows) with pore size of 50 µm were filled with 25 mg of freeze-dried grass silage per cm^2 of surface. The bags were suspended into the rumen by duplicate in two consecutive sets for 3, 6, 12, 24, 48 and 72 hours. After removing the bags, they were rinsed in a washing machine for 12 min and dried at 60 ºC for 48 hours (De la Roza *et al.*, 2001). In addition a set of three bags were included in the washing process to determine the disappearance at zero time. Bag residues after rumen incubation were analysed for Kjeldahl-N.

The relationship between CP disappearance from nylon bags and incubation time was described by non-linear equation proposed by Ørskov and McDonald (1979). Effective degradability of CP was calculated assuming the rumen outflow rate of 0.06 h^{-1}. Data were analysed by ANOVA, the principal factors being species and additive (fixed effects), using the GLM procedure (SAS, 1990).

Results and discussion

In chemical analyses, the averages of the sets of DIR and ADD did not significantly differ except for pH, neutral detergent fibre (NDF) content and estimated metabolizable energy (ME) (Table 1). Though the numerical difference in dry matter content between both kind of silage was high, the variability between samples in this parameter prevented statistical significant differences. The average organic matter (OM) and crude protein (CP) contents were 898.1 g kg^{-1} DM ± 2.61 and 165.1 g kg^{-1} DM ± 6.51 respectively with no significant differences for DIR and ADD. Acid detergent fibre (ADF) content was similar in both kinds of silage with an average of 326.5 g kg^{-1} DM ± 3.57. The NDF content of DIR samples was 568.8 g kg^{-1} DM whereas ADD samples had lower NDF contents (510.8 g kg^{-1} DM, $P < 0.05$). Therefore the estimation of the ME, which is related to NDF content, in DIR silage was lower than ADD silage (9.2 vs. 10.2 MJ kg^{-1} DM ± 0.14, $P < 0.01$).

Table 1. Chemical analysis of silage without (DIR) or with (ADD) additive (g kg^{-1} DM).

	DIR	ADD	s.e.	Effect
pH	4.30	3.82	0.090	*
DM	234.6	165.7	23.74	NS
OM	896.2	900.7	2.61	NS
CP	157.7	175.6	6.51	NS
NDF	568.8	510.8	10.63	*
ADF	329.7	321.9	3.57	NS
ME (MJ kg^{-1}DM)	9.2	10.2	0.14	**

Statistical significance: * $P < 0.05$, ** $P < 0.01$

Table 2 contains the average estimated parameters of degradability of CP of the grass silages and the results of the statistical analysis comparing the effects of species (Sp) and additive (Ad) and its interaction. The use of additives in silage-making did not significant influence the degradability parameters of the crude protein, though the fractional degradation rate (c) tended to be higher in ADD than DIR (0.065 vs. 0.058; $P < 0.1$). In both cases, a high value of soluble fraction (a) of nitrogen was observed (51.11 % ± 1.835). Nevertheless, the potential (89.06 % ± 1.856) and effective (69.59 % ± 0.989) degradability results were similar in both treatments. Though the soluble crude protein fraction was higher in wethers than cows (54.24 vs. 48.00 % ± 1.030; $P < 0.01$), the potential degradability of both silage was higher in cows than wethers (89.85 vs. 86.77 % ± 0.684; $P < 0.05$), because the fraction b was lower in wethers (32.53 vs. 41.98 % ± 0.850; $P < 0.001$). However, since the fractional rate of degradation did not result in statistically significant differences between species, the effective degradability, assuming an outflow rate of 0.03 h^{-1} for wethers and 0.06 h^{-1} for cows, was similar in both species and without differences between kinds of silage.

Table 2. Comparison of estimated parameters of degradability (%) between dairy cows and wethers.

	DIR		ADD			Effect		
	Wethers	Cows	Wethers	Cows	s.e.	Sp	Ad	SpxAd
a	54.28	48.85	54.19	47.14	1.030	**	NS	NS
b	29.97	44.47	35.09	39.49	0.850	***	NS	**
c	0.054	0.061	0.064	0.074	0.003	NS	T	NS
ED	68.19	70.11	72.15	67.87	1.049	NS	NS	NS

Statistical significance: T $P < 0.10$, ** $P < 0.01$, *** $P < 0.001$

Conclusions

Based on the results of present study, it can be concluded that, for degradability parameters, the main source of variation is the animal species used in trials. However, despite different results for ‘a’ and ‘b’ degradability values in cows and wethers, the effective degradability value obtained using a comparable outflow rate was similar for both species.

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Estimation of the ruminal degradability of crude protein of grass silages by means of proteases

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Abstract

In the new systems of protein evaluation it is important to know the proportion of degraded protein in the rumen. Different *in vitro* methods have been designed to estimate this, but not all of them have been validated with *in situ* results. 66 grass silages (19 non-treated – DIR –, 19 with biologic additive – BIO – and 28 with chemical additive – CHE –, were used to compared the *in situ* degradation with *in vitro* degradability with *Streptomyces griseus* protease. The *in situ* incubations were performed with standard operational procedures on three Holstein cows, empty and dry, consuming a diet to maintenance level with a forage:concentrate ratio of 60:40, offered in two meals daily. The forage used was grass silage and dehydrated alfalfa. The BIO silage was higher in OM content ($P < 0.01$), lower in pH ($P < 0.01$), crude protein CP ($P < 0.001$) and NDF ($P < 0.05$) proportions, and higher in estimated ME content ($P < 0.001$) than the other silages tested. Nevertheless, the degradation parameters of BIO silage did not differ from the CHE silage, whereas DIR silage showed the highest degradability value ($P < 0.001$). There were no statistically significant differences in the *in vitro* degradability between the different kinds of silages. The prediction of the potential degradability showed better regression coefficients with the nitrogen disappearance after one hour incubation with protease (PD1, $R^2 = 0.49$) than after 24 hours (PD24, $R^2 = 0.40$). With quadratic equations, the precision improved only with 1 hour of incubation ($R^2 = 0.50$). If the disappearance after 24 h of incubation is included in the equation, the accuracy improves slightly ($R^2 = 0.53$).

Keywords: rumen degradability, proteases, silages, dairy cow

Introduction

In the new feed evaluation systems for ruminants, the knowledge of protein degradability in the rumen is considered to be the most important factor (NRC, 2001). Generally, the ruminal degradability is estimated by the *in situ* degradation method in fistulated animals according to the methodology proposed by Ørskov and McDonald (1979). However, the availability of *in vivo* and *in situ* degradability values are limited because those methods require work with fistulated animals and are rather complicated, labour intensive and expensive. That is to say, the dynamics and logistics of the methodology result in considerable work, due to the amount of samples, number of bags that can be placed in an animal and different time intervals to perform kinetics studies (Nocek and English, 1986; De la Roza *et al*., 1998a).
Different laboratory methods had been tried in order to evaluate the degradability characteristics under standard laboratory conditions (Aufrére and Cartailler, 1988; Susmel *et al*., 1993; De la Roza *et al*., 1998b). The most promising results were obtained using proteolityc enzymes, but validation with *in situ* data is still not extensive enough.
The purpose of this work was to establish an easy laboratory methodology using proteases in order to find a relationship between *in situ* grass silage protein degradability values with those obtained on *in vitro* studies.

Materials and methods

A total of 66 grass silages, 19 without additive (non-treated – DIR), 19 with biologic additive (BIO) and 28 with chemical additive (CHE), were used to compared the *in situ* degradation parameters with *in vitro* values using *Streptomyces griseus* protease. The *in situ* incubations were performed with standard operational procedures according to Oldham (1987), on three non-pregnant and dry Holstein cows fitted with rumen fistula and consuming a diet at maintenance level, with a forage:concentrate ratio of 60:40. The feeds were offered in two meals daily. Forages were grass silage and dehydrated alfalfa. The degradability data obtained with the *in situ* method were fitted to the Ørskov and McDonald (1979) model. Effective degradability was calculated with an assumed outflow rate (k) of 0.06 h^{-1}.

As an enzymatic technique the one proposed by Aufrére and Cartailler (1988) and modified by De la Roza *et al*. (1998a) was applied, using 250 mg of feed samples, ground through a 0.75 mm screen. Then, grass silages were incubated at 40 ºC for two consecutive time periods (1 and 24 h, denoted by PD1 and PD24 respectively) with addition of 1.5 mg of *Streptomyces griseus* protease (Sigma P-5147) in buffer solution. At the end of each incubation period and after centrifugation, tube contents were filtered through Whatman No. 54 filter papers. The filtered solutions and the original feeds were analysed for nitrogen content (Kjeldahl). Nitrogen degraded was calculated as the proportion between nitrogen content in filtered solutions and total nitrogen content in the initial sample.

The relationship between *in situ* degradability parameters and enzymatic solubilities was determined by means of covariance analysis considering DP1 and DP24 as covariables, additives as fixed-effects and the corresponding interactions (SAS, 1990).

Results and discussion

Chemical and fermentative analyses were different depending on additive employed. The BIO silage was higher in organic matter content ($P < 0.01$), lower in pH ($P < 0.01$), crude protein ($P < 0.001$) and neutral detergent fibre ($P < 0.05$) proportions, and higher in estimated metabolizable energy content ($P < 0.001$) than the other silages (DIR or CHE).

As can be seen in table 1, the degradation parameters (A, B and C) and effective degradability (ED) of BIO silage did not differ from the CHE silage, except for potential degradability (PD). The lower PD was for BIO silage ($P < 0.001$), whereas DIR silage had a higher degradability value. On the other hand, enzymatic solubility (PD1 and PD24) were similar for the different additives.

Table 1. Degradability coefficients (A, B, C) and potential degradability (PD) calculated with the *in situ* method and nitrogen degraded by enzymatic solubility (PD1 and PD24).

Parameter	Non treated (DIR)	Chemical additive (CHE)	Biological additive (BIO)	s.e.m.
A (%)	50.88	49.67	46.57	8.020
B (%)	43.07b	40.46ab	37.41a	6.138
C (% h^{-1})	0.0584	0.0611	0.0600	0.028
PD (A+B) (%)	93.93^{c}	90.13^{b}	83.97^{a}	5.460
ED (%)	70.86^{b}	68.45^{ab}	64.63^{a}	7.82
PD1 (%)	50.53	47.73	47.46	6.908
PD24 (%)	61.28	62.03	60.82	5.046

A: soluble fraction; B: potentially degradable fraction; C: constant rate of degradation
a, b, c: Refers to significant differences at $P < 0.01$. s.e.m. = standard error of mean

According to the covariable model fitted (PD = Intercept + slope * x; x = PD1 or PD24) and in view of not significant interactions obtained between the fixed effect and the covariables, the highest regression coefficient for potential degradability prediction was for nitrogen degraded by enzymatic solubility after one hour of incubation (PD1; R^2 = 0.49), whereas after 24 hours of protease incubation the regression coefficient was smaller (PD24; R^2 = 0.40); see table 2. Fitting quadratic equations only improved the accuracy when one hour of incubation was considered (PD1; R^2 = 0.50). When the nitrogen degraded after 24 h of incubation was included in the quadratic equation, the precision improved slightly (PD24; R^2 = 0.53).

Table 2. Regression equations between *in situ* potential degradability (PD) and nitrogen degraded by enzymatic solubility at 1 (PD1) and 24 h (PD24).

Additive	N	PD1				PD24			
		Intercept	slope	R^2	RSD	Intercept	slope	R^2	RSD
DIR	19	74.72	0.380	0.49	0.598	73.34	0.336	0.40	0.649
CHE	28	71.81				69.11			
BIO	19	65.93				63.53			

RSD: residual standard deviation. DIR = No treated; CHE = Chemical additive; BIO = Biological additive

It is evident that an enzymatic procedure cannot fully simulate the effect of microbial fermentation in the rumen. Nevertheless, some authors have reported higher correlation coefficients using enzymatic methods than those obtain in this report (Aufrére and Cartailler, 1988; Susmel *et al*., 1993; De la Roza *et al*., 1998a). It is possible that preservation of the forages altered the enzyme accessibility in a more variable way.

Conclusions

Results of this work indicate that enzymatic solubility with *Streptomyces griseus* facilitates prediction of potential degradability of nitrogen in grass silages provided one hour of incubation is applied.

Acknowledgements

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Determination of fibre and fibre fraction contents with conventional and filter bag techniques

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Abstract

In nineteen samples of red clover (*Trifolium pratense L.)*, harvested four times during 1997 and 1999 in different morphological stages, the crude fibre (CF) content was determined according to the method of Neumann in Bassler (1976) and neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) contents were determined according to the methods of Goering and Van Soest (1970). The same samples were also analysed using Ankom's F57 filter bags (ANKOM Corp, USA) to determine crude fibre (CF_{FB}), neutral detergent fibre (NDF_{FB}), acid detergent fibre (ADF_{FB}) and acid detergent lignin (ADL_{FB}) contents. The differences between NDF and NDF_{FB}, between ADF and ADF_{FB} and between ADL and ADL_{FB} contents were statistically significant (P < 0.05). Rinsing the samples with acetone prior to the treatment with reagents ($acCF_{FB}$, $acNDF_{FB}$, $acADF_{FB}$ and $acADL_{FB}$) reduced differences to CF, NDF, ADF and ADL contents to a non significant level (P > 0.05). Mixing the samples of red clover with grasses (Italian ryegrass) revealed that the acetone rinsing should always be applied when the amount of red clover in the mixture exceeds 20 %.

Keywords: *Trifolium pratense*, red clover, legumes, fibre, determination, methods

Introduction

Forages are routinely analysed for their neutral and acid detergent fibre (NDF and ADF, respectively) and acid detergent lignin (ADL) content for use in ruminant ration formulation. Conventional techniques for fibre determination require careful individual handling and filtering of samples, requiring a skilled technician. The conventional technique is also time consuming because only a limited number of samples can be analysed simultaneously. The filter bag technique eliminates many of the handling and filtering problems and improves the efficiency of the assay through batch processing (Komarek *et al.*, 1994). The aim of this paper was to compare two techniques of fibre determination: the conventional and filter bag technique. These techniques were already compared recently. However, the analyses with filter bags were always performed with the Ankom's 'Fiber Analyser' apparatus, which was not used in the present study.

Materials and methods

In nineteen samples of red clover (*Trifolium pratense*) harvested in different morphological stages in 1997 and 1999 the crude fibre (CF) and neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) were determined. The same analyses were also performed with the use of filter bags (F57; Ankom Corp., Fairport, USA) and labelled as CF_{FB}, NDF_{FB}, ADF_{FB} and ADL_{FB}. The samples were also rinsed with acetone before CF_{FB}, NDF_{FB}, ADF_{FB} and ADL_{FB} determination and labelled as $acCF_{FB}$, $acNDF_{FB}$, $acADF_{FB}$ and $acADL_{FB}$. In all filter bag analyses the Ankom's 'Fiber Analyser' apparatus was not used. The differences between methods were determined and statistically evaluated (SAS/STAT, 1994). Regression equations were calculated and are presented within figures.

Results and discussion

The CF, NDF, ADF and ADL contents were used as reference values when compared with CF_{FB}, NDF_{FB}, ADF_{FB}, ADL_{FB} or $acCF_{FB}$, $acNDF_{FB}$, $acADF_{FB}$ and $acADL_{FB}$ contents. The CF, NDF, ADF and ADL contents varied between 163 and 293 g kg^{-1} dry matter (DM), 308 and 493 g kg^{-1} DM, 209 and 382 g kg^{-1} DM, 20 and 74 g kg^{-1} DM, respectively. The CF, NDF, ADF and ADL contents were on average lower than those obtained with filter bags, with differences ranging from 17 g with CF to 66 g with ADF. These differences were statistically significant ($P < 0.05$), except the difference between CF and CF_{FB} contents (Figure 1).

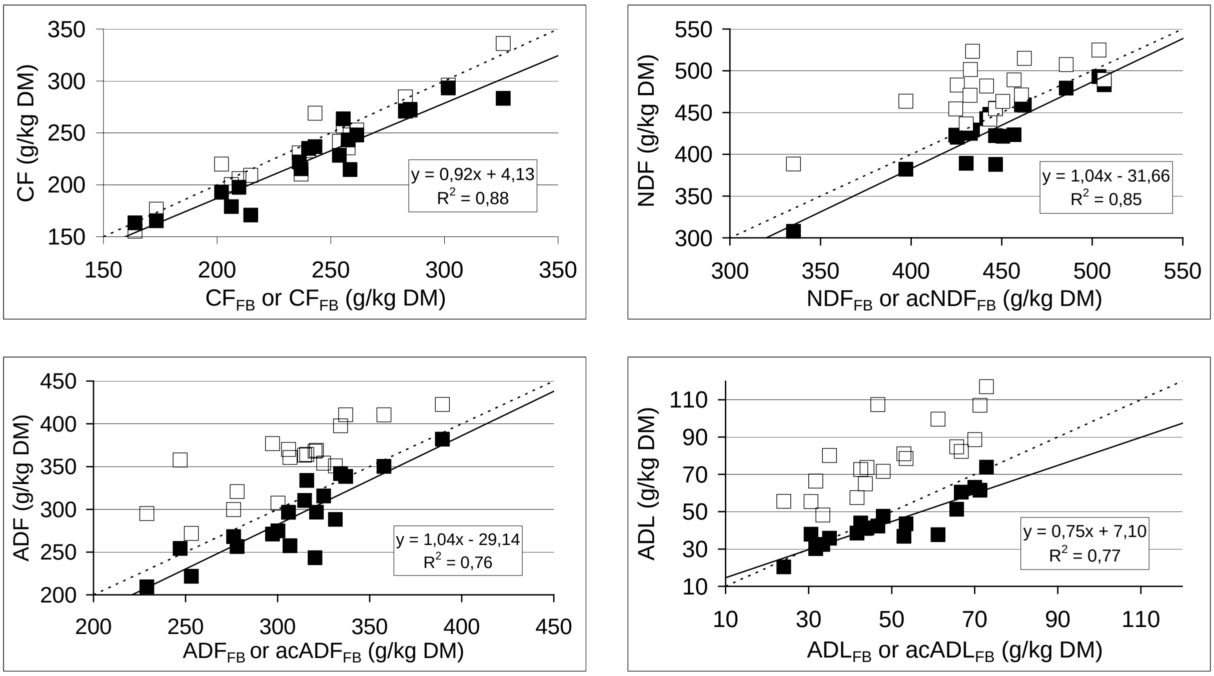

Figure 1. Relations between the CF, NDF, ADF and ADL contents and the CF_{FB}, NDF_{FB}, ADF_{FB}, ADL_{FB} or $acCF_{FB}$, $acNDF_{FB}$, $acADF_{FB}$ and $acADL_{FB}$ contents of red clover samples, which were either rinsed (■) or not (□) with acetone. The independent variable in the regression equations are fibre contents of acetone rinsed samples.

Spanghero *et al.* (1997) compared the NDF and NDF_{FB} contents of various feedstuffs and found large differences between them especially in compound feeds and total mixed rations, even when they used thermostable α-amylase in the rinsing water. Similar differences were also obtained between ADF and ADF_{FB} and ADL and ADL_{FB} (Jung, 1991; Komarek *et al.*, 1994; Spanghero *et al.*, 1997). These differences may be a consequence of the effects of various factors. There is a possibility that the reagents could not reach evenly all the substrate, thus leaving some substrate undissolved within the bags. Another reason involves large nonsoluble sample particles which could limit the passage of reagents to the substrate and the passage of dissolved substrate to and through the bag pores. On the contrary, Komarek *et al.* (1994) did not report any differences between NDF and NDF_{FB} content of maize grain and wheat bran using thermostable α-amylase in the rinsing water.
Rinsing the samples with acetone prior to treatment with reagents ($acNDF_{FB}$, $acADF_{FB}$ and $acADL_{FB}$) lowered differences to NDF, ADF and ADL contents to a non significant level ($P > 0.05$; Figure 1). It seems that acetone removed those substances which limited the passage of reagents to the substrate or dissolved substrate to and through the bag pores. However, determination of ADL content with ADL_{FB} content was not very accurate even when the samples were rinsed with acetone prior to determination of ADF (Figure 1). These

large differences were a consequence of small quantities of material left after the ADF determination and even smaller quantities of material after 72 % H_2SO_4 digestion which are difficult to weight accurately. Kelley (2001, personal communication) suggested that error could appear due to incomplete removal of acid before drying and its reaction with humidity or due to the accumulation of material in the bag pores.

Conclusions

When samples containing legume forages are analysed on NDF, ADF and ADL content with Ankom's Filter bag technique the samples should be rinsed with acetone prior to the treatment. Samples of red clover were also mixed with Italian ryegrass in various proportions (data not shown) and the results indicated that acetone should be applied when the amount of red clover (legumes) in the mixture exceeds 20 %. However, because of limited number of grass-legume mixtures used, the effect of acetone rinsing on the content of fibre determined with filter bags has to be confirmed.

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Assessment of provitamins A from silage by high performance liquid chromatography

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Abstract

The need for reliable data on the carotenoid content of feeds has become increasingly important following an enhanced interest in the possible link between carotenoid intake, especially of those with provitamin A activity, and health. Silage is among the best sources of carotenoids in the winter season. Unfortunately, its carotenoid composition has been little studied and this work is one of the few examples of a modern approach to the subject.
Carotenoids in a silage obtained from *Cucurbita pepo* L. and wheat thatch were completely extracted using methanol and acetone. After saponification, HPLC separation was conducted on a Nucleosil 120-5 C_{18} column, using as mobile phases: A – acetonitrile:water (9:1) and B – ethyl acetate. The flow rate was 1 ml min^{-1} and the solvent gradient was as follows: from 0 to 10 min. – 10 to 90 % B, then from 10 to 15 min. – 90 to 10 % B. Calibration was by the internal standard method, using echinenone as internal standard.
The major carotenoids were: (all-E)-β, β-carotene, lutein, α-carotene, β-carotene-5, 6-epoxide, 15Z-β, β-carotene; in addition, traces of violaxanthin, auroxanthin, anteraxanthin, zeaxanthin, α-cryptoxanthin and β-cryptoxanthin were identified. The provitamin A value of the analysed silage was 6,030 μg R.E. kg^{-1} dry weight.

Keywords: carotenoids, HPLC, chromatography, silage, analysis

Introduction

Carotenoids are widely distributed natural pigments, responsible for the yellow, orange, and red colours of fruits, flowers, roots, fish, invertebrates and birds. They occur in the chloroplasts of higher plants, but they are also found in algae, bacteria, moulds, yeasts and in some animal tissues. From more than 700 known carotenoids, about 50 are precursors of vitamin A. Carotenoids have also been linked with enhancement of the immune system and decreased risk of degenerative diseases such as cancer, cardiovascular disease, macular degeneration and cataract formation. These biological effects are independent of the provitamin A activity and have been attributed to the antioxidant properties of carotenoids.
The need for reliable data on the carotenoid content of feeds has become increasingly important following an enhanced interest in the possible link between carotenoid intake and health. Silage is among the best sources of carotenoids in the winter season, but its carotenoid composition has been little studied and this work is an example of a modern approach to this subject, with HPLC being the most appropriate analytical technique available to date for carotenoids' analysis (Scheidt and Liaaen-Jensen, 1995).

Materials and methods

Silage was prepared using a mixture of *Cucurbita pepo* L. fruits and dried wheat thatch. The fruits' mesocarp was converted into a paste using a blender and a laboratory mill to obtain powdered wheat thatch. These two ingredients were combined into 3 kg paste with 70 % water content, which was kept at room temperature for three weeks in a laboratory-scale fermenter. Samples of 10 g silage were extracted in a blender, using 100 ml methanol; an appropriate amount of echinenone solution (internal standard) was added to each sample. The resulting mixture was filtered under suction on a sintered-glass funnel and the solid material was re-extracted twice with 100 ml acetone. The extract was washed with distilled water, concentrated under reduced pressure in a Buchi rotary evaporator (at 40 °C) and dissolved in 25 ml diethyl ether; saponification was carried out using 25 ml of a 30 % KOH solution in methanol at room temperature for 16 hours. The unsaponifiable fraction was then extracted with petroleum ether and washed repeatedly in distilled water until free of alkali. The aqueous layers were re-extracted with 50 ml of diethyl ether, the organic layers were combined, washed several times with distilled water and evaporated to dryness under reduced pressure and finally dissolved in 5 ml ethyl acetate; a 20 μl aliquot was injected into the HPLC system. HPLC separations were made on a system consisting of a Kontron Instruments pumping system 322, a Rheodyne 7152 injection valve with a 20 μl loop and a Waters 990 photodiode array detector connected to a computer running WATERS 990 software for data analysis. Separations were carried out using one of the reversed-phase systems published in the literature (Young *et al.*, 1989) on a Nucleosil 120-5C_{18} column (250 × 4.6 mm, 5 μm particle size), the solvent gradient being optimised for a minimum overall separation time (Muntean and Rotar, 2001; Muntean *et al.*, 2003). Carotenoids were separated at room temperature, under gradient conditions: from 0-16 min. 10 % A, 90 % B, from 16 to 25 min. 90 % A, 10 % B. A was a mixture of acetonitrile:water (9:1) and B ethyl acetate, both A and B containing 0.5 % EPA. Separations were monitored at 450 nm. Visible absorption spectra were recorded on-line using the photodiode array detector of the HPLC system, being then compared with those of the reference carotenoids from the spectrum library (obtained using reference carotenoids). Identification of carotenoids was made on the basis of visible spectral characteristics, retention times, HPLC co-chromatography with standards, relative elution order compared to authentic standards and literature data (Britton, 1995; Davies, 1976). Quantification was performed by the internal standard method, with echinenone as internal standard. The provitamin A concentration was expressed in retinol equivalents (RE), according to the requirements of FAO/WHO (FAO/ WHO, 1988).

Results and discussion

As shown in the HPLC chromatogram in figure 1, the major carotenoids in the silage obtained from *Cucurbita pepo* L. and wheat thatch are: (all-E)-β, β-carotene, lutein, α-carotene, β-carotene-5, 6-epoxide and 15Z-β, β-carotene. In addition, traces of violaxanthin, auroxanthin, anteraxanthin, zeaxanthin, α-cryptoxanthin and β-cryptoxanthin were also identified.

From the above-mentioned carotenoids, only (all-E)-β, β-carotene, 15Z-β, β-carotene, α-carotene, β-carotene-5,6-epoxide, α-cryptoxanthin and β-cryptoxanthin are provitamins A, of which the concentrations are listed in table 1.

Table 1. Concentration of provitamin A carotenoids from *Cucurbita pepo L.* and wheat thatch silage.

Peak index	Carotenoids	Concentration [μg g^{-1} dry weight]
6	α - cryptoxanthin	traces
7	β - cryptoxanthin	traces
8	β - carotene - 5, 6 - epoxide	1.79
9	α - carotene	2.85
10	(all E) - β, β - carotene	32.85
11	15Z - β, β - carotene	2.05
Provitamin A activity		6.03 μg R.E. g^{-1} dry weight

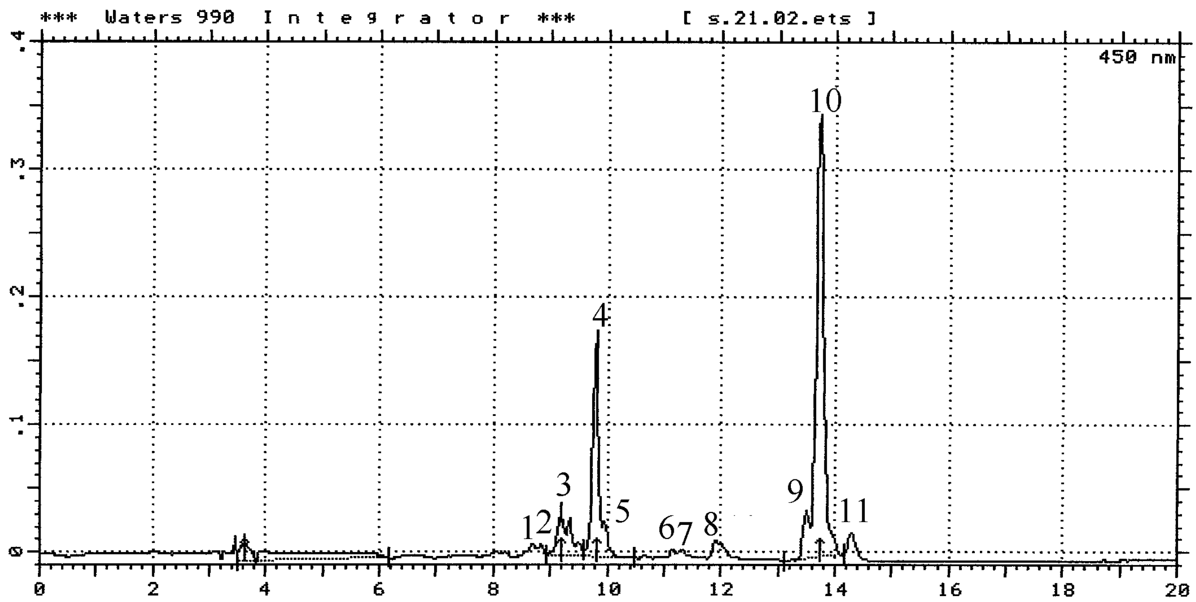

Figure 1. HPLC chromatogram of the total saponified extract obtained from *Cucurbita pepo* L. and wheat thatch silage; peak identities: 1, violaxanthin; 2, auroxanthin; 3, anteraxanthin; 4, lutein; 5, zeaxanthin; 6, α-cryptoxanthin; 7, β-cryptoxanthin; 8, β-carotene-5, 6-epoxide; 9, α-carotene; 10, (all-E)-β, β-carotene; 11, 15Z-β, β-carotene.

Conclusions

The proposed HPLC method proved its usefulness for the provitamin A analysis in silage, being remarkable for its low separation time. The preparation procedure and optimisation of the solvent gradient can be utilised also for the analyses of other feed products.
Based on the results obtained, we can conclude that the silage obtained from *Cucurbita pepo* L. fruits and wheat thatch is a valuable source of provitamin A carotenoids.

Acknowledgements

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Notes on the use of beeswax as a source of alkanes for the alkane technique

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Abstract

The alkane technique allows estimates of daily intake, diet composition, and digestibility. However, a number of feeds, namely grains and solvent extracted oil seed meals, do not contain a high enough alkane concentration. Thus those dietary components need to be labelled if they are to be included in any estimates of diet composition. There are several ways of labelling, either applying a synthetic alkane or a natural wax, such as beeswax. Besides being cheaper, the use of beeswax makes the estimate of diet composition more robust to variations in individual alkane concentrations. Also, beeswax is easier to apply to a supplement than synthetic alkanes. A range of beeswax samples were analysed to give an overview of the variability between batches. Implications for laboratory alkane analysis are indicated.

Keywords: beeswax, alkanes, marker, intake, diet composition

Introduction

Alkanes have found a widespread use as markers for the determination of intake, diet composition, and digestibility for livestock in general and grazing ruminants in particular (Dove and Mayes, 1991; Mayes and Dove, 2000). Estimates of daily intake and diet composition require somewhat different approaches. Although alkanes are not completely recovered in faeces, knowledge about faecal alkane recovery rates is not neccessary for estimates of daily intake using the double marker technique because the faecal alkane recovery rate of two alkanes of adjacent chain length is similar (Dove and Mayes, 1991). However, representative samples of the ingested diet are required, which might impose time and labour consuming procedures of sampling (Berry *et al.*, 2002) and does not allow for individual selection of animals. Studies of diet composition require representative samples of all dietary components intented to be identified (e.g., plant species, plant parts, supplements). The diet composition of individual animals can be estimated by analysing alkane patterns of dietary components and faeces. The number of alkanes required for this analysis must be equal to or exceed the number of components to be identified. Thus, faecal alkane concentrations have to be corrected for their incomplete recovery (Dove and Mayes, 1996).
Estimates of diet composition *per se* do not yield information on daily intake. However, if the amount of one dietary component is known then the ingested amounts of the remaining components can be estimated.
In grazing studies, especially with dairy cattle, often supplements are allocated in exact amounts to individual animals. Many supplements like grain, legume seeds and solvent-extracted oilseed meals, do not contain enough (if any) alkanes. Hence those supplements must be provided an alkane pattern in order to include them in diet composition estimations. Beeswax is a natural wax with a distinct alkane pattern and easily applied to feeds (Dove and Oliván, 1998). The principle of estimating roughage intake by feeding a known amount of beeswax-labelled supplement has been validated for diets containing one ore more roughage components (Dove *et al.*, 2002; 2003).

Alkane pattern of beeswax

Fifteen samples of beeswax of differing origin and year have been analysed for their composition: five batches of commercially available drop pelleted beeswax (samples C; Fa. Kahl Naturwachse, Trittau, Germany; waxes of African and Asian origin), and ten samples from various bee-keepers – four of the samples contributing to a time series (1988, 1994, 1997, 2001; samples B), and twice three samples of the same area but from different bee-keepers (eastern Germany and Irkutsk, Russia; samples A and R).

Alkane analysis has been carried out according to the procedure by Elwert *et al.* (accepted). The native amount of alkanes used as internal standards (C24 and C34) in the beeswax was measured by comparing extractions (in duplicate) with and without added internal standards. In general, the alkane patterns were very similar between the fifteen samples with concentrations of 35.6, 23.8, 17.5 and 9.7 mg g^{-1} for the alkanes C27, C29, C31 and C25, respectively. Average concentrations of alkenes were 26.3 and 12.2 mg g^{-1} for the C33- and C31-alkenes, respectively.

Table 1. Concentration of selected alkanes in several samples of beeswax (mg g^{-1}).

Sample	C22	C24	C25	C27	C29	C31	C33	C34	C36
A1	0.19	0.36	8.5	36.0	24.2	17.2	2.2	-	-
A2	-[1)]	-	4.2	28.0	23.6	17.8	2.3	-	-
A3	0.19	0.42	8.7	38.0	22.8	15.7	2.0	0.44	-
B1988	0.14	0.38	8.0	34.0	23.4	16.4	2.1	-	-
B1994	0.15	0.54	10.1	35.6	23.1	15.6	1.8	-	-
B1997	0.11	0.48	8.2	34.5	23.8	17.1	2.2	-	-
B2001	0.19	0.35	8.8	39.0	26.5	19.2	2.5	0.06	-
R1	0.20	0.49	9.8	38.3	21.4	15.4	1.8	-	-
R2	0.17	0.46	9.3	39.1	21.4	15.9	2.3	-	-
R3	1.5	6.7	16.0	40.9	28.2	20.6	5.6	2.7	1.4
C1	0.98	3.0	11.3	32.8	23.1	18.5	4.3	1.2	0.57
C2	1.1	3.1	11.7	33.9	24.2	19.6	4.2	1.0	-
C3	0.79	1.9	10.1	35.2	24.9	20.1	4.7	1.1	0.38
C4	0.89	2.2	10.9	36.6	25.1	19.7	4.8	1.0	0.48
C5	0.44	1.9	10.5	36.6	27.1	21.7	5.5	1.4	0.59

[1)] - indicates traces below detection limit (0.05 mg g^{-1})

As can be seen in table 1, there were two groups of beeswaxes. One group consisted of all but one sample from individual bee-keepers and was characterized by lower concentrations of even-chained alkanes than the second group (depending upon alkane ratio of 1:5 to 1:7 between groups one and two). Whereas in group one only a few samples had detectable amounts of C32, C34, and C36, in group two the concentrations of those alkanes were 2.50, 1.35 and 0.68 mg g^{-1}, respectively. C38 was found in neither of the samples.

Discussion

Labelling a feed low in alkanes with beeswax provides a distinct alkane pattern, and thus makes it possible to include that feed in estimates of diet composition. Similarly, a synthetic alkane would provide a distinct alkane concentration to the feed. However, there are several advantages in using beeswax. Beeswax is cheaper than the corresponding amount of synthetic alkanes. Diet selection of the animal or errors in sampling procedures of the other diet components could lead to a variation of actually ingested alkane patterns as compared to assumed ones. If the supplement is labelled with a synthetic alkane only, then all information regarding the supplement lies within this particular alkane. In contrast, a beeswax-labelled supplement is characterized by more than one alkane. Thus, estimates of diet composition are more robust to variations in individual alkanes. Further, labelling a supplement with beeswax

is easier than labelling it with a synthetic alkane. In early work (Dove and Oliván, 1998; Dove *et al.*, 2002) the beeswax was melted, diluted with heptane and sprayed onto the feed under continuous mixing. Afterwards the solvent had to be allowed to evaporate for a few days. If drop-pelleted beeswax is used, then another, less time and work consuming labelling technique could be used (C. Elwert, unpublished data). The drop-pelleted beeswax and part of the supplement to be labelled are mixed thouroughly and ground together through a hammer mill. The meal is then mixed with the rest of the supplement and milled again. After a final mixing the meal can be pelleted if required. In that way large amounts of supplement up to several tons can be provided with an alkane pattern in only a few hours time. Alkanes from beeswax might have lower faecal recovery rates than the rest of the diet (Scharch and Dove, 2002), although this is not necessarily the case (Dove and Oliván, 1998). However, for estimates of diet composition faecal alkane recovery rates for the whole diet are assumed. If the proportion of labelled supplement varied in reasonable proportions, the difference in faecal alkane recoveries is negligible between animals and treatments. The same facts apply to synthetic alkanes as well, so there is no reason to favour synthetic alkanes over beeswax.
Beeswax might introduce alkanes to the diet which are commonly used as internal standard (IS) alkanes during the laboratory extraction. In some cases this contribution of native IS alkanes can reach a critical level for the determination of alkane concentrations. If no other IS alkane pair can be chosen, this native IS concentration can be accounted for in an algebraical approach if the amount of beeswax in the sample, the alkane pattern of the wax and the amount of IS used are considered. For faecal samples the different faecal alkane recovery rates have to be taken into account. The use of external standards to overcome this problem should be avoided because it requires a quantitative laboratory handling which can be very susceptible to unavoidable variations in handling. The use of internal standards makes a laboratory method robust to a range of variations in laboratory handling, such as incomplete extraction of the heptane layer and between-sample variation in the amount of solvent used. However, the main reason for using a double IS is to account for the discrimination of longer chained alkanes during the extraction process (Oliván and Osoro, 1999). Because this discrimination might vary between samples, every sample should be corrected individually.

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Nutrient content and hygienic properties of fermentation residues from agricultural biogas plants

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Abstract

Austrian biogas plants were investigated within a research project aiming to value the fermentation residues, while considering chemical and hygienic aspects as well as application properties. Compared to unfermented slurry, biogas slurry is characterised by a significantly lower content of dry matter and therefore improved application properties. Due to distinctly higher pH-values and a rising proportion of NH_4-N, there is an increasing risk for ammonia losses. The use of different external co-substrates may negatively affect the heavy metal content and the hygienic properties of the fermentation residues.

Keywords: biogas, fermentation residues, farm manure, nutrients, heavy metals, hygiene

Introduction

Energy production via biogas plants can be an efficient, alternative production system for agriculture, even in disadvantaged mountainous and alpine regions. The number of biogas plants in Austria has increased continuously, from 20 plants in 1993 up to more than 110 at the present time. Detailed and sufficient knowledge exists on technical requirements for constructing biogas plants and on economic questions. Up to now, only few data are available on the chemical composition, hygienic aspects and application properties of the fermentation residues.

Materials and methods

Within the national research project 'Nutrient content of fermentation residues from agricultural biogas systems and their utilisation on permanent grassland', all currently existing and running biogas plants in Austria were investigated. Beside a comprehensive interrogation study including questions on size, technical equipment, energy capacity, and the use of co-substrates, samples of the final fermentation residues were taken. These samples were analysed for DM, pH-value, main nutrients (N_t, NH_4-N, P, K, Ca, Mg) and trace element heavy metals (Mn, Fe, Pb, Cd, Cr, Cu, Ni, Zn, Hg). Some selected hygienic parameters (*Enterobacteriaceae*, especially *Salmonella spp.* and parasite status) were investigated as well as some important application properties like odour, viscosity and run-off behaviour.

Results and discussion

The production of biogas, consisting of methane and CO_2, is the objective of the anaerobic fermentation of farm manure and co-substrates in biogas plants. Via hydrolysis, acid fermentation, acetic acid fermentation and methane fermentation, organic material is converted into biogas and organic residues, which in practice is called biogas slurry. Table 1 shows important parameters and chemical properties, relevant for fertilisation proportionment and nutrient balancing. In comparison to unfermented cattle slurry, biogas slurry is characterized by a much lower content of dry matter (-48 %), which may increase some important application properties like run-off and infiltration behaviour. The pH-value of biogas slurry, which strongly influences the NH_3-volatilisation is an average of 8.0 units (7.3-9.1), the proportion of NH_4-N to N_t amounts to 56 % and is significantly higher than that of unfermented cattle slurry (44 %). There is therefore a higher risk for increased ammonia losses, which should be minimised by keeping important measures like near-surface spreading and application under wet and/or cool weather conditions.

Concerning the content of N, P, K, Ca and Mg, higher concentrations (N +90 %, P +58 %, K +33 %, Ca +60 %, Mg +75 %) can be observed in biogas slurry of dry matter. This seeming higher nutrient concentration is mainly caused by the dry matter reduction within the fermentation process. On a fresh matter basis the content of main nutrients is equal with the exception of phosphorus (-17 %), potassium (-32 %) and calcium (-15 %).

Table 1. Main nutrient content of biogas slurry and cattle slurry in Austria.

					g kg^{-1} DM				
	n	% DM	pH-value	N_t	NH_4-N	P	K	Ca	Mg
biogas slurry	96	3.91	8.0	81.8	46.0	12.8	66.5	30.7	12.8
cattle slurry	1639	7.51	7.4	42.7	19.3	8.1	50.1	19.2	7.3

Table 2. Average trace element and heavy metal content of slurry (biogas and cattle) in Austria.

	mg kg^{-1} DM							
	Fe	Cu	Zn	Mn	Cd	Cr	Ni	Pb
biogas slurry	3.161	97.2	396.4	363.2	0.77	23.0	9.97	6.14
cattle slurry	4.169	48.9	180.8	298.7	0.89	5.87	6.0	3.87
threshold values					1	100	60	150

Regarding trace elements and heavy metals, biogas slurry shows a lower content of iron and cadmium but much higher values for copper, zinc, manganese, chrome, nickel and lead (Table 2). Due to the existing threshold values for fermentation residues in Austria, 15 % of all biogas slurry samples showed a higher content of cadmium (1.02-19.48 mg Cd kg^{-1} DM) and 8 % of the samples exceeded the threshold for chrome (2.2-536 mg Cr kg^{-1} DM). Some of the co-substrates, which are used as important carbon sources for methane production in biogas plants, like fat or food residues, may contain high amounts of heavy metals.

To avoid an accumulation in soils, the heavy metal load via fertilisation is restricted for grassland and arable land in Austria (Table 3). With the exception of Cu and Zn, these limits will be reduced by 50 % from the year 2004. Concerning the average actual data from the biogas slurry project, there will be no danger for overstepping the heavy metal load limits, even using high application rates of 60 m^3 biogas slurry per ha and year. With such high slurry amounts before all, the limit for the nitrogen load from farm manure (170 kg N ha^{-1} y^{-1}) would be reached. Biogas slurry, exceeding the threshold(s) for heavy metals, has to be restricted in application rate to avoid an overloading.

Table 3. Limitation of heavy metal loads in g ha^{-1} in two years time (BMLFUW, 2001).

	Pb	Cd	Cr	Ni	Hg	Zn
arable land	1,250	20	1,250	750	20	5,000
grassland	625	10	625	375	10	2,500

Table 4 includes the different co-substrates, which are used in Austrian biogas plants, aiming at the optimisation of biogas and methane production. More then 50 % use food residues from the households up to restaurant kitchens, with very high amounts in some cases. Separated fat, edible fat and oil are also very favourable external co-substrates. 15 % of the sampled biogas plants don't use any external co-substrates and are therefore mainly focused on farm manure, and home grown feed stuffs like grass and silage maize.

Table 4. Different co-substrates, used for fermentation in Austrian biogas plants (m^3 y^{-1}).

	n biogas plants	% of biogas plants	mean	min	max
food residues	47	53.4	415	2	6000
grass cut, lawn cut	42	47.7	110	3	1500
separated fat	39	44.3	382	1	4000
sewage water	37	42.0	207	20	750
silage maize	29	33.0	183	10	584
edible fat	26	29.5	24	1	240
grass silage	26	29.5	181	10	1000
other organic materials	23	26.1	248	14	1300
edible oil	19	21.6	9	1	40
organic waste	5	5.7	264	52	700
dairy sewage	5	5.7	349	160	730
regrowing crude material	4	4.5	135	40	300
yeast liquid	3	3.4	158	32	365
forage residues	3	3.4	86	3	183

The use of external co-substrates not only influences the nutrient content of biogas slurry, but also the total nutrient budget on the farm. Beyond that, some of the substrates may affect the hygienic properties of the fermentation residues. Depending on the kind of co-substrates used and on the yearly amount, some hygienic analyses have to be done according to the official regulations (BMLFUW, 2001). Fermentation residues are named harmless, if in 50 g fresh mass there are no *Salmonella spp.*, in 1 g fresh mass there are not more than 5000 cfu (colony forming units) *Enterobacteriaceae* and no eggs of parasites are detected. Although most of the investigated Austrian biogas plants don't need any hygienic examination because of the small size and/or little use of co-substrates, some selected hygienic parameters were investigated. Overall, 24 % of all samples had more than 5000 cfu *Enterobacteriaceae* g^{-1} fresh mass (ranging from 6,000 to 128,000), in one third of these samples *Salmonella spp.* were also detected in 50 g fresh mass. Whereas 17 % of all samples showed *Salmonella* in 50 g fresh mass, the detection in 25 g fresh mass halved the positive findings. No eggs of harmful parasites were detected at all.

These results indicate that there is a risk for hygienic contamination of fermentation residues from biogas plants, which may be caused by the use of critical co-substrates. 2/3 of all biogas plants with positive findings for *Enterobacteriacea* used food residues and all biogas plants with positive findings for *Salmonella spp.* used either separated fat or edible fat/oil, and 40 % used food residues.

Conclusions

Fermentation residues from biogas plants contain valuable nutrients and trace elements for agriculture but may also be risky regarding heavy metal content and hygienic aspects. The use of co-substrates has to be well considered to avoid any external contamination and/or nutrient overloading on farms.

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Feasibility analysis of three different catch crops in northeast Slovenia

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Abstract

Droughts can seriously decrease forage yields. Therefore catch crops can represent a viable forage source in dry years. The aim of this paper was the analysis of cost and returns of three different catch crops that can be used in northeast Slovenia. The Italian ryegrass (*Lolium multiflorum* Lam.), cow cabbage (*Brassica oleracea* L., covar.: *acephala* (DC) Alef. var. *viridis*) and Sudan grass (*Sorghum sudanense* (Piper) Stapf) were included in the analysis. On the basis of field experiments and other available data catch crop simulation models were derived. The models allow estimation of costs and returns of the catch crops mentioned above with different input parameters. Each catch crop analysed was included in milking cow feed rations derived by a programme of mathematical optimisation. The calculated costs of the feed ration formed the basis for comparison of catch crop potential.

Keywords: catch crops, Italian ryegrass, cow cabbage, Sudan grass, feasibility study

Introduction

The occurrence of summer droughts has an important impact on forage yields, so that catch crops can represent an important forage source. Catch crops also have other environmental benefits, such leaving organic matter residues in the soil after harvesting, reduced soil water evaporation, reduced nitrogen accumulation and the prevention of erosion. The main objective of this paper is the feasibility analysis of Italian ryegrass, cow cabbage and Sudan grass. The decision which, if any, catch crop to grow is interrelated with ecological, technological and economic factors. As reported by Pavlovic (1997), Rozman *et al*. (2002), and Lisson *et al*. (2003) computer-based simulation modelling can include many of these factors and, hence, play an important decision support role.

Materials and methods

The model used is a simplified representation of an observed system, in this case catch crop production. The relationships between elements of the system are usually represented by a formal language, usually mathematical equations. For catch crop production the technical parameters of production, such as machine and manual labour used, material, are expressed in a series of technological equations. These are incorporated into a computer spread sheet program that is used to prepare an enterprise budget with different input parameters. Technical coefficients such as input usage, for instance, machine hours, per unit of area (ha) are put into the spreadsheet input tables. Using this data, costs of machine operations, costs of labour operations and material costs are calculated and transformed into enterprise budgets. The enterprise budget also contains capital costs and a proportionate share of farm fixed costs. This approach is known as technological economic simulation (Csaki, 1985) since it includes only technological and economic dimensions (yields in this case are not calculated but are derived deterministically).

The main indicators of the enterprise budget are the costs per unit of output (CU), calculated as a ratio between total production costs and yield (TC/Y) and measured in monetary units per kilo. The expected yield quantity is derived deterministically. The CU indicator can be used for comparison of production costs of different catch crops. However, due to different nutritional values of individual catch crops, the CU indicator alone is not sufficient to estimate feasibility and to choose optimal outcomes, i.e., the best catch crop for an individual farm. Hence feed rations for milking cows were calculated using a simple spreadsheet model where nutritional values of feedstuffs and CU represent input parameters. It was assumed that the basic feedstuff is maize silage and that catch crops are used as a supplement. CU values for all feedstuffs produced on the farm are used to determine costs of daily feed rations for a 650 kg cow yielding 25 l milk per day. Purchase prices were used for feeds not produced on the farm, e.g., mineral additives. The costs of feeding rations with Italian ryegrass, cow cabbage and Sudan grass were calculated, assuming that the basic feed ration consists of a maize and grass silage mixture. The nutritional values used in the simulation were derived from field experiments conducted at University of Maribor, Faculty of Agriculture (Kramberger (1998), Topolovec (1999), Podvršnik (2001)). The feed rations were calculated using the mathematical programming optimisation method aiming for the minimisation of total feed ration costs, so that the best feed ration could be found. The model operates in *Visual basic for Excel* (simulation model) and *What's best Industrial for Excel* (calculation of feeding ratios) systems and can be used for costs estimation with different farm input parameters (yields, nutritional values). The model is described in the flowchart shown in figure 1.

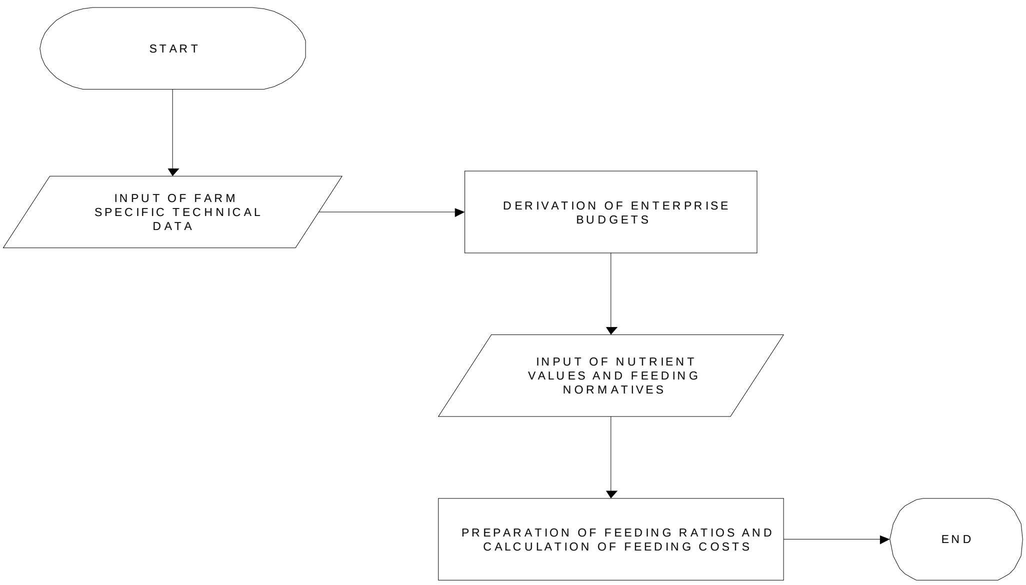

Figure 1. Flowchart of the catch crop simulation model.

Results

The main results of a simulation model are the enterprise budgets for individual catch crops. Estimations were made per hectare of each catch crop produced and costs of feed rations were calculated where individual catch crops were included to adjust feed rations.

The comparison of three catch crops using the nutritional values and assumed model input parameters shows that cow cabbage yields with least costs (Table 1). However, it should be mentioned that the length of season when cow cabbage and Sudan grass are available can be seriously decreased by early autumn frosts. Long summer droughts can also decrease catch crop yields and nutritional values decrease as the plants mature.

Table 1. Estimated production costs for the three catch crops selected.

Catch crop	Expected yield (green mass kg ha^{-1})	Production costs (€ ha^{-1})	Production cost per kg (CU) (€ kg^{-1})	Estimated costs of feeding ration (€ d^{-1})
Italian ryegrass (autumn and spring yield)	35000	717.1	0.020	2.17
Cow cabbage	35000	972.6	0.028	2.00
Sudan grass	35000	799.3	0.022	2.27

Assuming that early frosts occur in early November, the available quantity of cow cabbage and Sudan grass would be seriously decreased. In this case the unit costs of production and of the feed ration increase. The simulation for this scenario gives the costs of feed rations as follows: for cow cabbage, 2.19 € per cow per day and for Sudan grass, 2.44 € per cow per day. The simulation was not run for Italian ryegrass since its feeding period is much shorter due to lower autumn yields.

Conclusions

Three different catch crops were compared in the study, which showed that including cow cabbage into the feed ration resulted in the lowest feeding costs. However, the results should be treated with caution since yields of catch crops can be very variable in different years. The main value of this study was the application of the simulation model, enabling the evaluation of different scenarios on individual dairy farms and which can then be used as a decision support system.

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Performance of heifers offered herbage with birdsfoot trefoil (*Lotus corniculatus* L.) or white clover (*Trifolium repens* L.)

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Abstract

The present study forms part of a transdisciplinary project evaluating the potential of birdsfoot trefoil (*Lotus corniculatus* L.) as a forage crop in Sweden, with special reference to its content of condensed tannins (CT). The influence of herbage from mixed swards with approximately 550 g kg^{-1} dry datter (DM) birdsfoot trefoil (BT) or white clover (*Trifolium repens* L., WC) on the performance of 2 × 2 × 6 heifers was investigated during a four week period in August. In spring the two leys were established in the same field, where each ley was divided into seven plots. Each plot was divided into two parts, from which material was either harvested and fed indoors or grazed. Each plot was used for 3-4 days in rotation. Live weight gains (LWG) did not differ significantly between BT and WC whether the heifers were grazing (1.80 kg d^{-1} and 1.68 kg d^{-1} respectively) or were fed indoors (1.33 and 1.26 kg d^{-1} respectively). The daily *ad libitum* DM intake of the heifers fed indoors was 9.51 kg on BT and 9.44 kg on WC. The high LWG are explained by very low pre-trial gains, when all heifers grazed a semi-natural pasture.

Keywords: *Lotus corniculatus*, weight gain, dry matter intake, grazing, cattle, condensed tannins

Introduction

In order to combine preservation of the valuable characteristics of semi-natural pastures with satisfactory growth performance of grazing cattle, it may be necessary to provide the animals with high quality cultivated pastures for part of the grazing season. To prevent pest problems a crop rotation is needed with alternatives in the choice of forage legumes, especially in organic farming. Swards with birdsfoot trefoil (BT) could be an important alternative. Satisfactory LWG have been found for cattle (Nilsdotter-Linde *et al*., 2002) and lambs (Wang *et al*., 1994; Douglas *et al*., 1995) grazing BT. This may be attributed to larger herbage intakes as reported for lambs (Fraser *et al*., 2000) and a preference for BT compared to swards with white clover (WC) in grazing beef heifers (Nilsdotter-Linde *et al*., 2003). One objective of the present study was to quantify the relationships between daily voluntary intake and LWG on BT and WC.

Materials and methods

In a study conducted at Rådde organic experimental farm (57°37'N) in the south-west of Sweden, two 3.5 ha adjacent swards with either BT: [perennial ryegrass (*Lolium perenne* L. cv. Condesa, 10 kg ha^{-1}) in mixture with birdsfoot trefoil (cv. Grasslands Goldie, 7 kg ha^{-1} + Oberhaunstaedter, 5 kg ha^{-1})] or WC: [perennial ryegrass (cv. Herbie, 20 kg ha^{-1}) in mixture with white clover (cv. Lena, 3 kg ha^{-1})] were established in late April 2002. The swards were divided into seven plots. Each plot was divided into two parts, from one of which material was cut and fed to heifers kept indoors and the other was grazed by heifers. Each plot was used for 3-4 days in rotation.

Twenty-four pregnant crossbred heifers with Aberdeen Angus or Charolais as the sire breed were allocated to four treatments. The average initial live weights of the grazing heifers were 444 and 465 kg for the BT and WC treatments respectively and 408 and 432 kg for the heifers fed indoors. The swards were grazed from July 31 to October 1 in a rotational system. The heifers fed the harvested material were kept indoors, in a loose-housing system with three animals per pen, from July 31 to August 27. This period corresponds to one rotation among the seven plots. BT and WC herbage was harvested and fed *ad libitum* twice daily in controlled amounts. Student's t-test was used to evaluate the treatment differences for the grazing and indoor fed heifers respectively.

Samples of the herbage were cut at 8 cm every 15 m along a diagonal in each plot just before it was harvested or grazed. The samples were separated into sown legumes and a residual fraction before drying. After weighing the fractions were re-mixed, ground and analysed for DM, ash, crude protein (CP) and neutral detergent fibre (NDF). *In vitro* organic matter digestibility (IVOMD) was determined according to Lindgren (1979) for estimation of metabolizable energy (ME). The DM content of harvested herbage was determined twice daily from the harvested plots, and on the first and last day of grazing from the grazed plots.

Results and discussion

The proportions of sown legumes were equal in BT and WC in the period when herbage was fed indoors, but the proportion of BT decreased in the last part of the grazing period (Table 1). Similar CP concentrations were observed in BT and WC. The IVOMD and ME concentrations were smaller in BT, while the NDF concentration was larger.

Table 1. Legume content and nutrient concentrations in mixed swards with either birdsfoot trefoil (BT) or white clover (WC). Mean and standard deviation (SD).

				kg^{-1} DM			
Treatment	Statistics	No plots	IVOMD, g kg^{-1} OM	CP, g	NDF, g	ME, MJ	Sown legumes, g
Indoor feeding 31/7-27/8							
BT	Mean	7	759	190	446	9.9	550
	SD		22	4	18	0.2	107
WC	Mean	6	832	204	412	10.5	560
	SD		15	21	32	0.2	88
Grazing 31/7-1/10							
BT	Mean	7	830	204	400	10.6	330
	SD		65	44	60	0.6	145
WC	Mean	7	851	236	368	10.7	570
	SD		54	47	67	0.5	165

Similar daily LWG were recorded for the BT and WC swards whether they were grazed or harvested and fed indoors (Table 2). For the entire grazing period from July 31 to housing on October 1, weight gains were also similar. The non-significant differences in LWG correspond to non-significant differences in the daily *ad libitum* DM intake. Due to a lower estimated ME content of DM in BT, the daily ME intake was slightly, but not significantly, less in the BT treatment. The very high LWG, especially during the first part of the experimental period, may be explained by increased gut-fill and compensatory growth, as very low pre-trial gains were achieved (on average 0.14 kg d^{-1} from turnout on April 30), when all heifers grazed a semi-natural pasture.

The ME content of BT was estimated using a function intended for red clover because an approved function for BT is lacking in the Swedish ME system. The similar DM intakes and LWG in the BT and WC treatments may indicate an underestimation of the ME content of BT in relation to WC.

Table 2. Daily DM and ME intake and daily LWG of heifers fed BT and WC indoors (based on pen means) and daily LWG of heifers grazing BT and WC (based on individual records). Mean and least significant difference (LSD) for $P < 0.05$.

	Period	BT	WC	LSD
Indoor feeding				
DM intake, kg	31.07-27.08	9.51	9.44	0.70
ME intake, MJ	31.07-27.08	94.9	99.4	6.5
LWG, kg	31.07-27.08	1.33	1.26	0.82
Grazing				
LWG, kg	31.07-23.08*	1.80	1.68	0.47
	31.07-01.10	1.48	1.55	0.27

* corresponding to the indoor feeding period

Conclusions

A similarly good performance of the heifers was recorded on both BT and WC swards, despite notable differences in nutritive values. It was thus possible to compensate for the low performance on the semi-natural pasture in the first part of the grazing season and achieve a normal LWG for the heifers (about 0.70 kg d^{-1}) from turnout to housing.

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The use of *n*-alkanes to estimate grass and clover intake of lactating dairy cows

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Abstract

To estimate grass and clover intake during grazing in an ecologically managed sward, a two-months-experiment was carried out with lactating dairy cows. During the first month of the experiment, the cows were kept indoors and were offered fresh grass-clover, maize silage and concentrates. Grass-clover intake was both measured and estimated by using *n*-alkanes. During the second month of the experiment, cows grazed on grass-clover pastures and grass-clover intake was estimated by using *n*-alkanes. Samples of faeces and feeds were analysed for *n*-alkanes (C_{25} up to C_{36}) and subsequently, intake of grass and clover was calculated by regression analysis. In the first month of the experiment, calculated average grass-clover intake was nearly equal to measured intake. However, grass intake was underestimated by 1.7 kg and clover intake overestimated by 1.8 kg with the *n*-alkane method. Calculated grass-clover intake in the grazing experiment was 11.7 kg dry matter per cow per day. The estimated clover percentage (57 %) of the diet was not equal to the measured clover percentage of the sward (48 %). In conclusion, the *n*-alkane method was accurate in the estimation of the grass-clover intake of individual dairy cows.

Keywords: grass, clover, *n*-alkane method, dairy cows, intake during grazing, nitrogen losses

Introduction

In organic dairy farming, grass clover mixtures are often used to improve the nitrogen content of herbage. The clover in the sward may affect forage intake, as some animals prefer grass, whereas others prefer clover. The intake of different grass-clover ratios will affect protein intake, and thus the nitrogen balance of the grazing animal. It is important to estimate individual feed intake of dairy cows grazing on grass clover swards to be able to improve grassland management and supplementation of the diet. However, measuring intake of grazing dairy cows is difficult. In the past, intake per group of cows was estimated by comparing the amount of grass and clover on a sward before and after grazing, by counting the number of bites, and estimating bite size, or with the use of chemical markers. The accuracy of these methods may be questioned and if information on individual intake is required, other methods should be used.

Individual feed intake of grazing cows can be calculated by the use of the *n*-alkane method (Mayes *et al*., 1986). With this method, the pattern of alkanes (chemical constituents in the wax layer of plants) in different plant species is used. Each plant species has its own specific alkane composition and as alkanes are nearly indigestible, intake can be estimated from the alkane pattern in feeds and faeces. Therefore, in the experiment described in this paper, the *n*-alkane method was validated for estimation of grass-clover intake and to discriminate between grass and clover intake.

Materials and methods

The experiment lasted 2 months and consisted of a stable experiment (first month) and a grazing experiment (second month). In both experiments, three treatments with different maize silage levels (in the stable 0.0, 2.5 and 5.0 kg dry matter (DM) maize silage; in the

pasture 2.0, 4.0 and 6.0 kg DM) were administered. Six lactating dairy cows (daily milk production before the start of the experiment: 27.2 ± 2.7 kg, days in lactation at the start of the experiment: 221 ± 9.7) were used for the experiment. Both experiments were designed as a Latin square with three treatments and three periods, each of 1 week. In the stable experiment, animals were fed fresh grass clover, and in the grazing experiment, cows had limited access (8 hours d^{-1}) to grass clover swards. In both experiments, diets were supplemented with 0-6 kg DM maize silage and concentrates with and without synthetic alkane (respectively 0.8 and 2.0 kg DM cow^{-1} d^{-1}). The added synthetic alkane was C_{32} (1.0 g kg^{-1}). Faecal samples were taken twice daily before milking. Samples of feed and faeces were analysed for alkanes (C_{25} up to C_{35}) and chemical composition (crude protein and net energy content).
In the stable experiment, grass clover intake was both measured and calculated using the alkane pattern of the faeces. In the grazing experiment, grass clover intake was calculated using the alkane pattern in the faeces. The alkane pattern in the faeces was corrected for the recovery of the different alkanes (based on Dillon, 1993) and subsequently daily faecal alkane excretion (DFE) was calculated from the concentration of the marker in the faeces. Intake of alkanes with concentrates and maize silage was subtracted from DFE. Grass and clover intake was then calculated with the multiple linear regression procedure of GENSTAT, using the alkanes C_{27}, C_{29}, C_{31}, C_{33} and C_{35}. (Faecal alkane concentration as y-variables, grass and clover alkane concentration as x-variables).

Results and discussion

The alkane content in concentrates and maize silage was low compared to grass (except for C_{32} in the concentrates with synthetic alkanes). The alkane concentration of clover was higher than that of concentrates and maize silage, but lower than that of grass (Table 1).

Table 1. Alkane concentration (mg kg^{-1}), net energy (NE, in MJ kg^{-1}) and crude protein content (CP, in g kg^{-1}) of the used feeds, averages over weeks (CA = concentrates with alkanes, CS = standard concentrates, MS = maize silage) and alkane concentration of faeces (average over animals and over weeks; not corrected for recovery).

	C25	C27	C29	C31	C33	C35	C32	NE	CP
CA	1.5	1.7	3.9	3.4	2.1	1.9	1005.1	6.5	152
CS	1.3	2.0	4.2	3.3	1.0	0.0	3.2	6.5	152
MS	2.4	6.2	16.7	23.0	14.3	3.4	3.8	6.4	77
Grass	9.0	17.3	76.6	158.6	128.4	15.1	10.7	5.8	210
Clover	4.7	12.6	46.6	35.9	6.5	0.0	3.1	6.4	255
Faeces	17.7	41.5	161.9	263.0	189.4	22.0	193.6	-	-

In the stable experiment, the mean intake of grass was underestimated by 1.8 kg DM and the intake of clover was overestimated by 1.7 kg DM with the alkane method, but the mean total grass clover intake (12.7 kg DM) was approximately equal to the measured intake (12.8 kg DM) (Figure 1). The short adaptation periods may cause some uncertainty with regard to the establishment of new alkane levels in faeces, though diet changes were relatively small. The incorrect estimations of grass and clover intake may also have been caused by an incorrect assumed recovery of the different alkanes. Results of an experiment which was recently carried out with lactating dairy cows on grass based diets, suggested that the recovery of alkanes from the diets in the faeces is influenced by the presence of maize silage (not published). The overestimation of the clover intake could also have been caused by the low alkane concentrations in clover, as the chance of mistakes is higher with lower alkane concentrations (Hameleers and Mayes, 1998).

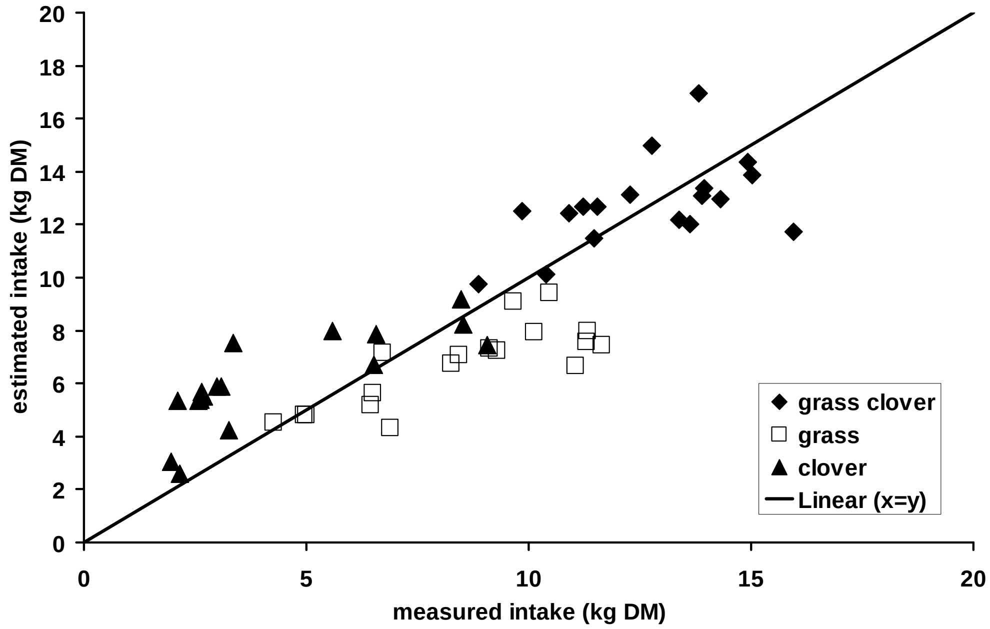

Figure 1. The measured intake in the stable versus the calculated intake in the stable.

In the grazing experiment, results could not be validated for actual intake, but the percentage of clover in the sward was compared to the percentage of clover from the estimated intake. In period 1 and 2 of the grazing experiment, the estimated clover percentage of the diet was higher than the measured clover percentage of the sward (45 and 52 % measured, versus respectively 60 and 63 % estimated), whereas in the third week, the average percentage of clover in the sward was approximately equal to the percentage of clover in the ingested forage (48 versus 47 %). The difference between estimated and measured clover percentage in the diet may have been influenced by differences in recovery and low alkane concentrations in clover. In the grazing experiment, cows also could have selected for clover.

Conclusions

Clover intake was overestimated and grass intake was underestimated with the *n*-alkane method, but the method was accurate in estimating individual grass clover intake during grazing. The method thus enables improvement of grassland management.

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Influence of body size of dairy cows on their performance in a pasture-based production system

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Abstract

In an attempt to evaluate cow body size as a relevant issue in a full time grazing system, two separate herds were formed. The first consisted of 13 bigger and heavier cows (type B, >700 kg body weight) and the other of 16 smaller and lighter cows (type S, <600 kg body weight) of Swiss dairy breeds. Both herds grazed in similar paddocks (in terms of offered grass quantity and quality) to obtain the same stocking rate (kg body weight ha^{-1}). Pasture data were collected (growth, net energy content) as well as cow data (body weight, body condition score, intake, milk production and contents) from spring 2002 onwards. Partial results of the first 18 months are presented. During the first grazing period, the intake of herd S was slightly higher than the intake of herd B. The milk production of the S-herd was higher. The net energy content of the grass in the S-paddocks became slightly better than that of the B-paddocks. Body weight changes and changes in body condition score during two lactations were not significantly higher in the B-cows. Variations within the herds were large. The trends observed in the first 18 months have to be confirmed in the following years.

Keywords: pasture, dairy cows, cow type, body condition score, body weight

Introduction

In order to reduce production costs, a growing number of Swiss dairy farmers are switching to a full time grazing system with greatly reduced supplemental feeding and block-calving in spring. The purpose of this system is to take advantage of the cheapest feed for cows: grazed grass. In this pasture-based system, it is not so important to maximise the production per cow, but to maximise the production per unit of land available. This system is relatively new for Switzerland where cows have been selected for high individual production in a barn feeding system with a balanced diet. The question arises of how the prevalent type of Swiss dairy cow adapts to these new circumstances, and particularly if cow body size is a critical factor. A big, heavy type of cow has theoretically a higher intake capacity, while the feeding requirements for a small, light type of cow are easier to satisfy.

Materials and methods

Two separate herds were formed in March 2002 with multiparous cows: the first consisted of 13 bigger and heavier cows (herd B, 726 ± 62 kg body weight of the already calved cows at turnout to pasture, 147 ± 3 cm withers height) and the second of 16 smaller and lighter cows (herd S, 558 ± 34 kg body weight of the already calved cows at turnout to pasture, 138 ± 3 cm withers height). The breeds used were Red-Holstein-Simmental crossbreds and Brown Swiss, half of the herd each; but a comparison of breeds was not an objective of this study. The individual genetic merit of the S-cows was slightly lower than that of the B-cows to reach a similar potential of production in both herds. 11.6 ha of pasture were used for the experiment, which was subdivided into 8 paddocks. Each paddock was split in half again so that the two herds had access to equivalent grazing in a rotational system and the same stocking rate (kg body weight ha^{-1}) was obtained. Additionally, each herd received 2100 kg DM of fodder beets during the winter and 2115 kg of concentrate until the end of the breeding season, which lasted ten weeks. In the following season the half-paddocks were exchanged, so that herd B grazed in the former S-paddocks and vice versa. A grass sample of the paddock to be grazed next was taken once a week during the grazing season (from late March to end October), analysed and net energy content (NEL) estimated using a regression formula (RAP, 1999). Pasture yield was measured using the Corrall and Fenlon (1978) method on two representative control plots not accessible for grazing, located half in a B-paddock and half in a S-paddock. Individual milk production and contents were recorded once a week. The cows were weighed once a week and body condition scores were recorded once a month. Individual animal intakes were estimated for 10 cows per herd three times during the grazing season (mid-May, mid-July and mid-September) using the n-alkane technique (Mayes *et al*., 1986); alkanes used were C31 naturally present in grass and C32-alkanes dosed from controlled-release capsules (Captec Ltd, Auckland, New Zealand). The results were analysed statistically with a 2-sample t-test. For the evaluation of the NEL pasture content the samples were grouped in 2 distinct periods.

Results and discussion

During the pasture season 2002, 132 resp. 146 dt DM grass grew on the two control plots. Of the grass available, herd S ate slightly more than herd B (Table 1), although the individual intakes were slightly smaller in herd S (Table 1). In the first two months of the grazing season the B- and S-paddocks had similar NEL-content. But in the second part of the season, a difference appeared in favour of the S-paddocks (+0.1 MJ NEL, Figure 1), probably due to the fact that the S-cows grazed the paddocks more severely.

Table 1. Pasture intake, milk production and feed conversion efficiency (mean ± SD) of the cow type big and heavy (B) and small and light (S) on 5.8 ha pasture each in 2002 (year 1).

	Pasture intake (kg DM d^{-1})		Milk production (kg ECM d^{-1})		Feed conversion efficiency
	per cow	per herd	per cow	per herd	(kg ECM kg^{-1} DM grass eaten)
Type B	14.3 ± 0.8	185.9 ± 10.3	21.0 ± 6.3	272.8 ± 81.8	1.5 ± 0.5
Type S	13.5 ± 1.6	216.0 ± 25.7	17.7 ± 4.7	283.8 ± 75.2	1.4 ± 0.5
	ns[1]	ns[1]	$P < 0.01$	$P < 0.01$	ns[1]

[1]ns not significant ($P > 0.05$)

Table 2. Body weight and BCS (mean ± SD) of the big and heavy cows (B) and small and light cows (S) at different stages of lactation (during 2002 and 2003).

		Type B	Type S	Significance
Body weight (kg)	pre-calving	801 ± 56	659 ± 38	$P < 0.001$
	nadir	633 ± 57	515 ± 29	$P < 0.001$
Body weight change (%)	week 2 pp[1] – nadir	-13.0 ± 3.7	-12.0 ± 3.9	ns[2]
BCS	pre-calving	3.5 ± 0.4	3.3 ± 0.3	ns[2]
BCS change	pre-calving – nadir	-0.8 ± 0.5	-0.5 ± 0.4	ns[2]
Month pp[1] of BCS nadir		3.5 ± 1.8	3.0 ± 1.2	ns[2]

[1]pp *post partum* [2]ns not significant ($P > 0.05$)

Body weight change during lactation (in % of body weight) was slightly higher (not significant) in herd B between week 2 and the nadir (Table 2). The BCS change was also slightly higher in herd B and stretched over a longer time but not in a significant way (Table 2). Due to the small animal groups no link can be clearly established between type and fertility: during the first year,

6 B-cows and 4 S-cows had to be replaced because of non-pregnancy after the breeding season. In the second year, 2 B-cows and 3 S-cows were not pregnant.
The individual milk productions were smaller in herd S, but the global herd production was 4 % higher than that of herd B (Table 1). On a herd level feed conversion efficiency in terms of kg milk produced per kg grown grass seems to be better with the S-cows. But in terms of kg milk produced per kg eaten grass (measured 3 times during the season), the efficiency was similar between the 2 herds (Table 1).

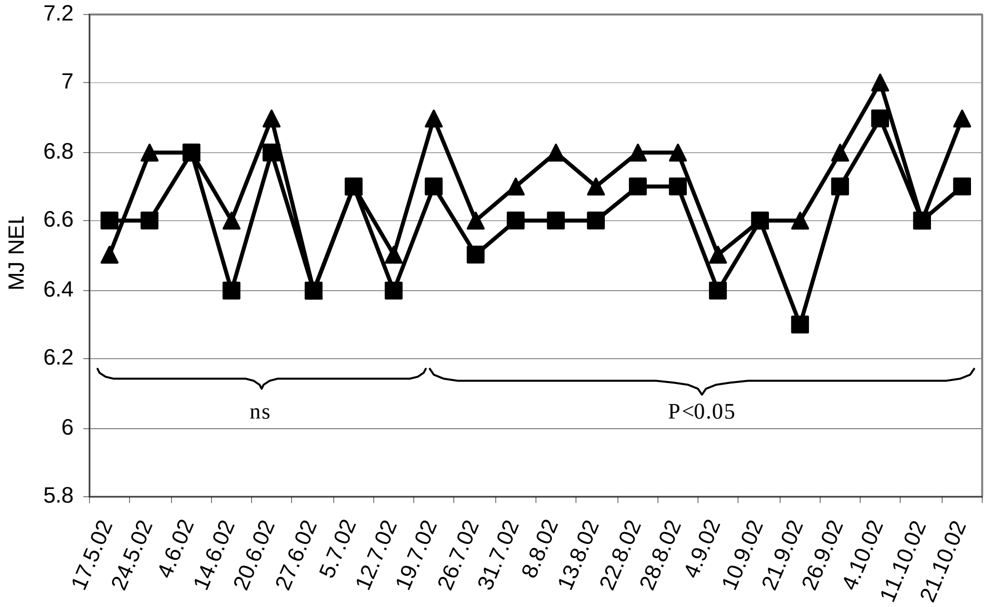

Figure 1. Grass net energy content of the paddock to be grazed next by the big and heavy cows (squares) and by the small and light cows (triangles) during the season 2002 (year 1).

Conclusions

No conclusions can be drawn on the basis of one year's results. The study will be continued until spring 2005. Variation within the herds is substantial, and may be more significant than the differences between the 2 groups.

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Energy nutrients may limit ingestion in high producing dairy cows fed highly digestible fresh ryegrass

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Abstract

The possibility of metabolic regulation of intake in grazing dairy cows has received little attention. Our objective was to determine (1) if intake of highly digestible grass can be regulated by energy nutrients in dairy cows, (2) if this regulation depends of the type of nutrient absorbed. Four treatments were compared on four dairy cows fed indoors with fresh perennial ryegrass in two Latin square designs. The treatments consisted of infusions of 1.25 or 2.5 kg of hydrated glucose in the rumen (R1.25 and R2.5), infusions of 1.5 kg of hydrated glucose in the duodenum (D1.5), or a control with no glucose (C). All the animals were infused with the same volume (36 l in the rumen and 21 l in the duodenum) and osmolarity (350 mOsm). The average dry matter intake (DMI) of grass was 15.5 kg. The DMI was lower with the three treatments with glucose infusion compared to the control (-0.85 kg, RSD = 0.66, $P < 0.05$) but no differences were observed between R2.5, R1.25 and D1.5. The DMI was markedly reduced by the infusion of glucose in the high producing dairy cows whereas glucose infusions did not affect the DMI of the low producing dairy cows.

Keywords: intake regulation, energy, fresh grass, dairy cows

Introduction

In the dairy systems of the west of Europe, grazed grass has generally high digestibility and nutritive value, comparable to that of complemented maize silage (Jarrige, 1989). However, herbage intake remains variable and often limited and so this feed does not allow high producing dairy cows to express fully their potential. This is particularly well illustrated by the fall in production observed when dairy cows change over from a winter diet to grazing. An hypothesis to explain the low herbage intake could be that, for the same quantity of energy ingested, the satiety effect of grass would be higher compared to the winter diet. It has been shown in ruminants that the volatile fatty acids (VFA) have a stronger satiety effect compared to glucose (Faverdin, 1999). The main part of the energy of highly digestible grass is absorbed in the form of VFA in the rumen whereas a part of the energy of the winter diet is absorbed in the form of glucose in the hindgut. Our objective was to determine (1) if intake of highly digestible grass can be regulated by energy nutrients in dairy cows, (2) if the regulation by energy nutrients is specific to the energy absorbed in the rumen.

Materials and methods

The experiment consisted of artificially infusing glucose in the rumen or in the duodenum and observing the consequences on herbage intake in dairy cows fed indoors. Four treatments were compared: C (Control), R1.25 (infusion of 1.25 kg d^{-1} monohydrated glucose in the rumen), R2.5 (infusion of 2.5 kg d^{-1} monohydrated glucose in the rumen), D1.5 (infusion of 1.5 kg d^{-1} monohydrated glucose in the duodenum). The amount of glucose infused in the duodenum (D 1.5) was calculated to be iso-energetic with R2.5 on a net energy basis. To isolate the specific effect of energy on the regulation of intake, all the animals were infused with the same volume (36 l in the rumen and 21 l in the duodenum) and osmolarity (350 mOsm). KCl and NaCl were used to adjust the osmolarity. The cows were fitted with a ruminal and a duodenal cannula and infused between 0900 h and 0300 h, i.e., for 18 hours with a regular flow. The treatments were compared on four Holstein dairy cows, in mid lactation, fed indoors with fresh perennial ryegrass (*Lolium perenne* L., cv. Ohio) in two Latin square designs. The first Latin square was run in May and the second Latin square was run in June. Each Latin square comprising four periods of seven days. The herbage was cut with a mower in the morning. The plots were managed to provide an average stage of maturity of 29 days for each period. The animals were fed *ad libitum* with free access to the trough. Each day, 200 g of a mineral supplement were fed and no concentrate was provided. The herbage dry matter intakes (DMI) were determined each day. In order to check that the treatments did not disturb the ruminal digestion, the digestibility of the organic matter (dMO) was determined by the faecal index method (Ribeiro Filho *et al.*, 2003). Faeces were collected by rectal sampling during the last four days of each period. The daily ruminal pH and the duration of pH < 6 were obtained from a kinetics of 17 points measured on the fifth day of each period. The blood gases were measured from a kinetics of 8 points measured on the same day. The data were analysed by analysis of variance using two models. The first model included an effect of the month, of the period in the month, of the animal, of the treatment, and of the interactions month × animal and month × treatment. The effect of the month was tested on the residual error of the effect of month × animal. Two of the four cows were high producing dairy cows with a mean stage of lactation of 215 days and a mean daily production of 31.6 kg before the experiment and the other two were lower producing dairy cows with a mean stage of lactation of 157 days and a mean daily production of 25.9 kg before the experiment. The second model included an effect of the level of production (high or low), of the animal within the level of production, of the treatment and of the interaction level of production × treatment. The effect of the animal was tested on the residual effect of the level of production. The effect of the infusion of glucose (C vs. Gluc, i.e., C vs. R1.25+R2.5+D1.5), the effect of the site of infusion (R vs. D, i.e., R1.25+R2.5 vs. D1.5) and the effect of the dose of glucose (Dose R, i.e., R1.25 vs. R2.5) were analysed by orthogonal contrasts.

Results and discussion

The quality of the offered herbage was high throughout the trial with an average digestibility above 80.0 %, an average NDF content of 486 g kg^{-1} and a crude protein content of 161 g kg^{-1} on a dry matter basis. The dry matter content was slightly higher in June compared to May (178 g kg^{-1} vs. 165 g kg^{-1}) but the other characteristics of herbage did not differ between May and June. The interaction month × treatment was never significant for the measured parameters. The herbage DMI averaged 15.5 kg (Table 1) and was lower when glucose was infused compared to the control (15.3 kg vs. 16.1 kg) whatever the site of infusion or the dose of glucose infused. The absence of a clear effect of the site of infusion of energy on the DMI was in contradiction with Faverdin *et al*. (1992) who infused glucose in the duodenum or VFA in the rumen in dairy cows fed supplemented maize silage. The substitution rates between the energy intake and the energy infused ((MJ intake with Control – MJ intake with glucose infusions) / MJ glucose infused) were respectively 0.7, 0.4 and 0.3 for R 1.25, R 2.5 and D1.5. These values were consistent with the results of Faverdin *et al.* (1992) for the duodenal infusion of glucose but were lower for the ruminal infusion of nutrients. This may be partly explained by the fact that DMI rates of fresh grass are lower compared to winter diets. Thus, the kinetics of VFA absorption may be more progressive, with less pronounced peaks, when fresh grass is fed compared to supplemented maize silage. With the high producing dairy cows, DMI decreased by 1.86 kg with the glucose infusions compared to C whereas the treatments did not affect the DMI of the low producing dairy cows (Figure 1). This would mean that the homeostasis regulation of animals with high requirements may be more easily saturated. This result is consistent with Faverdin *et al.* (1992) who observed a stronger effect of ruminal VFA perfusion on the DMI of lactating cows compared to dry cows.

Table 1. Effect of the treatments on the dry matter intake, digestibility, ruminal and blood pH.

	Treatments				Contrasts			
	C	R 1.25	R 2.5	D 1.5	C vs. Gluc	R vs. D	Dose R	SD[A]
Herbage DMI[A] (kg)	16.11	15.25	15.12	15.41	**	ns	ns	0.306
dMO[A]	0.806	0.813	0.821	0.806	*	**	*	0.0007
ruminal pH	6.32	6.27	6.25	6.39	ns	*	ns	0.116
duration pH<6 (hours)	2.63	4.13	4.5	3.38	ns	ns	ns	2.15
blood pH	7.380	7.388	7.391	7.388	ns	ns	ns	0.0108
blood HCO_3^- (mmol l^{-1})	23.48	23.69	23.52	25.13	ns	**	ns	1.089

[A] DMI: Dry Matter Intake, dMO: digestibility of the Organic Matter, SD: Standard Deviation.

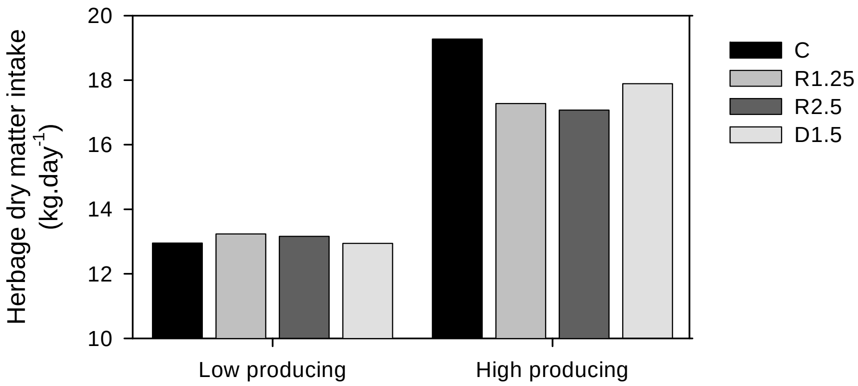

Figure 1. Effect of the treatments on DMI according to the level of production.

We did not observe any deleterious effect of infusion of glucose on ruminal digestion (Table 1). In fact, the digestibility seemed, to slightly increase with infusions of glucose in the rumen compared to the treatments C or D1.5. The daily ruminal pH was slightly lower when the glucose was infused in the rumen but the duration of low pH in the rumen (< 6) was not affected by the treatments and was on average 3.7 hours. The salts infusioned, associated with the treatments did not affect the blood pH. The blood bicarbonate concentration was higher when the glucose was infused in the duodenum compared to the three other treatments, but this may have been related to the lower amount of VFA absorbed with the treatment D 1.5. We did not observe any effect of the interaction level of production × treatment on digestibility, or on ruminal or blood parameters.

Conclusions

The experiment showed that the quantity of energy absorbed by the animal can limit intake of high producing dairy cows fed high digestibility herbage.

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Applicability of the ^{13}C method for intake estimation in grazing experiments with maize silage supplementation

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Abstract

The ^{13}C method can be used to estimate herbage intake of grazing dairy cows. With the ^{13}C method, the natural occurrence of a carbon isotope (^{13}C) in feed and faeces is used to calculate the herbage intake. This study aimed to validate the ^{13}C method for this purpose.
Red Holstein cows (n = 6) received indoors a diet consisting of maize silage, a fresh grass clover mixture and concentrates. Maize silage supplementation is often used to reduce nitrogen losses during grazing. Therefore, treatments consisted of *ad libitum* grass clover mixture, three kilograms of concentrates and three maize silage levels (0.0, 2.5 and 5.0 kg dry matter per cow per day). Grass clover intake was calculated from the ^{13}C content of faeces, the ^{13}C content and the *in vitro* digestibility of feeds and the intake of maize silage and concentrates. Mean herbage intake was 12.7 kg DM, whereas mean calculated intake was 17.3 kg DM. The calculations were inaccurate because of an uncertain correction of the ^{13}C content of faeces and *in vivo* interactions of organic matter digestibility of grass clover and maize. In conclusion, the method is not yet applicable for estimations of the herbage intake of maize silage supplemented dairy cows.

Keywords: ^{13}C method, dairy cows, intake during grazing, grass clover, maize silage, organic farming

Introduction

In grazing trials, reliable estimation of the herbage intake of grazing animals is difficult. Estimation of the individual herbage intake is necessary to obtain an estimate of variation among cows. Individual feed intake can be estimated by the ^{13}C method (Jones *et al.*, 1979). An advantage of this method is the absence of supplementation of a marker substance to the animals, which allows the method to be used in grazing trials in organic dairy farming.

The ^{13}C method can be used in situations where the ^{13}C isotope content between feeds is sufficiently different. It is known that the ^{13}C content of C_4 crops is relatively high compared to the content of C_3 crops. Temperate grasses and white clovers belong to the C_3 crops whereas maize is a C_4 crop. This difference can be used to estimate the relative intake of both types of feeds by measuring the ^{13}C content of the faeces. With the ^{13}C method the intake of one diet component can be estimated. This estimation requires measurement of the intake of the other feeds and of the digestibility and ^{13}C content of all feeds.
The content of ^{13}C isotopes is expressed as a difference ($\delta^{13}C$ value) from the $^{13}C/^{12}C$ in a standard called Pee Dee Belemnite (PDB). The $\delta^{13}C$ value is calculated with equation (1):

$$(1)\ \delta^{13}C_{sample} = (^{13}C/^{12}Csample - {}^{13}C/^{12}C_{PDB}) * {}^{13}C/^{12}C_{PDB}{}^{-1} * 1,000$$

Materials and methods

A feeding trial was carried out on a Dutch experimental farm for organic dairy farming. This feeding trial was part of a research project concerning the effects of maize silage supplementation on grass and clover intake of grazing dairy cows.

Six Red Holstein dairy cows were fed indoors *ad libitum,* a fresh grass clover mixture, three kilograms of concentrate and three levels of maize silage supplementation in a replicated Latin square design. Treatments were zero, 2.5 and 5.0 kg DM maize silage per cow per day (referred to as respectively M0.0, M2.5 and M5.0). In three periods of four days each, the intake of concentrates, maize silage and grass clover mixture was measured. Cows had adaptation periods of three days, except prior to the first measuring period (19 days). During measuring periods, daily samples were taken from feeds. Faeces were sampled twice daily (0600 h and 1700 h) on day 3 and 4 of the measuring period. These four faeces samples per cow per period were mixed proportionally, resulting in a total of 18 faecal samples of 6 cows.

During the measuring periods, grass clover was cut daily in one paddock in order to minimise quality differences between days. The clover percentage in the cut herbage was 19, 24 and 57 % in dry matter in periods one, two and three respectively. The concentrate consisted of products from C_3 crops only.
The digestibility coefficients of feeds were measured *in vitro* (the Tilley and Terry method). The expected amount of undigested organic matter for each feed is calculated with equation (2). Equation (3) is used to calculate the organic matter intake of the non-measured feed, in this case a grass clover mixture.

(2) $fcOM_{fdx} = diOM_{fdx} * (1\text{-}OMD_{fdx})$
fcOM: faeces Organic Matter (kg DM day^{-1})
diOM: diet Organic Matter (measured intake; kg DM day^{-1})
OMD: Organic Matter Digestibility (*in vitro; %*)
$_{fdx}$: feed x
$_{faec}$: faeces

(3) estimated $diOM_{fd1}$ =
$(1 * (1\text{-}OMD_{fd1})^{-1)} *$
$(((\delta^{13}C_{fd2} - \delta^{13}C_{faec}) * fcOM_{fd2}) + ((\delta^{13}C_{fd3} - \delta^{13}C_{faec}) * fcOM_{fd3})) * (\delta^{13}C_{fd1} - \delta^{13}C_{faec})^{-1}$

The $\delta^{13}C$ level of faeces can differ systematically from the expected $\delta^{13}C$ level, based on diet composition, digestibility and $\delta^{13}C$ value of feeds (Jones *et al.,* 1979). This systematic difference was corrected for using the analysed difference for the M0.0 treatment.

Results

In table 1 the crude protein content (CP), OMD (*in vitro*) and $\delta^{13}C$ value of the feeds are presented. Though the clover content of the sward differed between measuring periods, the $\delta^{13}C$ value of the grass clover mixture hardly differed between periods.

Table 1. Characteristics of feeds.

Feed	# Samples	OMD (*in vitro*; %)	CP (g kg^{-1} DM)	$\delta^{13}C$ in DM (10^{-3})
Grass clover mixture	3	74.9	219	- 29.8
Maize silage	3	73.4	77	- 11.9
Concentrate	1	81.2	170	- 26.8

The ^{13}C content of maize silage was much higher than the ^{13}C content of the grass clover mixture and the concentrate. In table 2 the average feed intake of the cows on each treatment is presented.

Table 2. Intake of feeds and $\delta^{13}C$ value of faeces on the treatments.

	M0.0	M2.5	M5.0	Lsd ($P < 0.05$)
DMI Maize silage (kg day^{-1})	0.0^{a}	2.1^{b}	2.9^{b}	0.9
DMI Concentrates (kg day^{-1})	2.9	3.0	3.0	0.2
DMI Grass clover (measured; kg day^{-1})	13.5^{a}	13.0^{ab}	11.5^{b}	1.7
Portion C_4 feeds in diet (%)	0.0^{a}	12.3^{b}	17.6^{b}	5.4
$\delta^{13}C_{faeces}$ (measured; 10^{-3})	-30.7^{a}	-29.1^{b}	-28.1^{c}	0.7
$\delta^{13}C_{faeces}$ (expected; 10^{-3})	-29.3^{a}	-27.0^{b}	-25.9^{c}	1.0
DMI Grass clover (estimated; kg day^{-1})	16.1	20.0	15.9	9.8

Only one cow reached the M5.0 maize silage level. This resulted in a low average maize silage intake on the M5.0 treatment. The grass clover intake on treatment M5.0 was significantly lower than on treatment M0.0. The portion of C_4 feeds on M2.5 and M5.0 were significantly higher than on the M0.0 treatment and the portion of C_4 feeds on M2.5 tended to be lower than on M5.0. The measured $\delta^{13}C$ value of faeces increased with the maize silage treatments and hence is clearly correlated with the portion of C_4 feeds.
The expected $\delta^{13}C$ value of faeces was calculated from diet composition, diet digestibility and $\delta^{13}C$ content of the feeds. In all cases, the measured $\delta^{13}C$ value of faeces was lower than the expected $\delta^{13}C$ value. On the M0.0 treatment this difference was 1.4 and the difference on both other treatments was 2.0 and 2.3 respectively. The systematic difference between $\delta^{13}C$ value of faeces and diet was therefore assumed to be 1.4 units of $\delta^{13}C$. The $\delta^{13}C$ value of faeces was corrected for the systematic difference (1.4 added). These corrected $\delta^{13}C$ values of faeces were used to calculate the grass clover intake according to equation (3) (final row of table 2). The estimated DMI intake of grass clover was considerably larger than the measured DMI intake of grass clover and the variation among estimates was large.

Discussion and conclusion

The ^{13}C method overestimated DMI intake of grass clover and showed large variation. It is possible that the inadequacy of the method was related to the experimental design. The adaptation periods could have been too short for establishing a new ^{13}C level in the faeces and the sampling procedure of the faeces could have been insufficient to get a representative sample of all faeces. As unpublished data on stabilisation of the ^{13}C content of faeces shows, the experimental design did not account for a significant part of the observed overestimation. Two other factors are probably of more importance. First, the individual *in vivo* digestibility of feeds and differences in digestion depression between diets with and without maize silage (Valk *et al.,* 1990) can affect the results of the ^{13}C method considerably. Secondly, the assumed correction of the $\delta^{13}C$ value of faeces is very uncertain and there can be a correlation between both the *in vivo* digestibility and the difference between expected and measured $\delta^{13}C$ value of faeces. In conclusion, the ^{13}C method discriminates on diet composition, but is yet inadequate in quantifying the effect of maize silage intake on herbage intake.

Acknowledgement

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Fermentation characteristics and nutritive value of inoculated maize silage

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Abstract

Whole plant maize (DM 241 g kg^{-1}) was ensiled into two ferroconcrete trenches of 100 t each. Two treatments were 1) untreated (UT), 2) application of 'Feedtech' (*2 Lactobacillus plantarum, 2 Pediococcus acidilactici* and *Cellulase*; F). Fermentation quality of the silages was analysed, aerobic stability measured and milk yield of dairy cows studied. The inoculant improved the fermentation quality compared to the untreated silage, increased the water-soluble carbohydrates (WSC) and lactic acid contents and decreased amounts of acetic acid, butyric acid and ammonia-N. The inoculant had a negligible effect on aerobic stability while it lowered DM losses and improved D-value. During a 100-day feeding trial, cows fed with F treated silage had a 2.3 kg d^{-1} higher milk yield (FCM) and a 1.45 kg d^{-1} DM improved intake than the UT cows.

Keywords: silage, inoculant, dairy cows, milk production, fermentation.

Introduction

The maize silage became a popular forage in dairy cow nutrition, when excellent corn hybrids with short vegetation period, high forage yield and high quality were selected. The quality and feeding value of the silages depends on the crop characteristics on the one side, and on the run of in-silo fermentation, on the other. Successful silage production depends upon the promotion of fermentation brought about by beneficial bacteria (Ziggers, 2003). Lactic bacteria, specifically homofermentative species, are considered to be good microorganisms in silage preservation (Davies *et al*., 2002). As a result, it is common practice in many countries to use inoculants containing lactic acid bacteria to control silage fermentations. The ensiling process may also be improved by the addition of cellulolytic enzymes. The research outlined in this paper describes how the inoculant 'Feedtech' ('Medipharm', Sweden) improved maize silage quality at both the laboratory and farm scales, and resulted in measurable higher milk production on a farm scale.

Materials and methods

Whole plant maize (variety 'Impact', dry matter content 241.4 g kg^{-1}) was cut in late September, with self-propelled forage harvester CASE-MAMUT-6900 and ensiled in two ferroconcrete trenches (100 t each) without and with the additive *Feedtech* (2 *Pediococcus acidilactici*, *2 Lactobacillus plantarum* and *Cellulase*). The inoculant was applied at 15 g t^{-1} (10^6 cfu g^{-1}) according to the producer's recommendation. Additionally, each variant was ensiled in 3 litres laboratory mini-silos. Five control bags of known weight and chemical composition were put into each trench for determination of DM losses. Aerobic stability was determined by placing the samples in polystyrene boxes containing holes sufficient for the passage of air into the forage. The boxes were kept in a temperature controlled room (20 °C) with forage temperature recorded daily for 10 days.
A feeding trial was completed with 10 dairy cows. After administering an identical diet for three weeks (preliminary period) the cows were separated into two groups. For the trial period of 100 days, lactation number, lactation days, milk amount, milk composition and feed intake were measured. Milk yield and feed intake were registered for 2 days every 2 weeks. Forage

samples were taken once every two weeks. Statistical analysis was carried out by means of procedures described by *STATISTICA* for *Windows* (Sakalauskas, 1998).

Results and discussion

The inoculant improved silage quality, as indicated by a smaller concentration of acetic and butyric acid and by lower proportion of ammonia-N (P < 0.05), as well as increased lactic acid and WSC (Table 1). Nutrient losses were lower by 3.4 % and D-value was higher for F-silage in comparison UT-silage. Inoculant application rate had no effect on aerobic stability.

Table 1. Chemical composition of maize and silages and fermentation value of silages.

Treatment	Maize	Silage made in trenches				Silage made under laboratory conditions			
		UT	F	SEM	*P*	UT	F	SEM	*P*
Dry matter (DM; g kg^{-1})	241.5	257.52	261.6	6.831	<0.003	226.7	228.3	7.561	NS
In DM (g kg^{-1} DM):									
Organic matter	964.2	954.1	959.0	1.787	<0.006	953.3	956.6	1.176	NS
Crude protein	88.6	88.4	89.2	3.547	NS	93.6	94.2	0.882	NS
Crude fibre	220.2	200.8	197.3	11.213	NS	221.0	202.3	12.921	NS
WSC	106.6	17.2	22.69	5.261	NS	7.61	12.45	3.528	NS
D-value	727.7	731.2	738.00	23.61	NS	718.6	731.6	3.522	NS
Total organic acids	-	73.7	76.5	7.169	NS	69.0	72.6	7.869	NS
Lactic acid	-	50.6	57.02	6.214	NS	40.0	43.4	5.62	NS
Acetic acid	-	21.7	19.4	2.706	NS	26.00	29.00	1.224	NS
Butyric acid	-	1.44	0.00	0.074	<0.02	3.00	0.20	0.636	<0.05
Ammonia N (g kg^{-1} N)	-	50.5	32.6	6.516	<0.05	37.86	29.27	0.606	<0.05
Losses during fermentation period (g DM kg^{-1} DM)	-	102.3	98.8			92.28	91.48		
pH	-	3.81	3.97	0.295	NS	3.62	3.73	0.639	NS
ME, MJ kg^{-1} DM		10.1	10.3						
Intake, kg DM d^{-1} silage	-	12.20	13.65						
Concentrate	-	4.03	4.29						
Total	-	16.23	17.94						

Animal performance benefits were closely linked with improvement in silages fermentation quality and energy contents (Huhtanen, 2002). The higher efficiency of the inoculated silage was confirmed in the feeding trials by higher feed intake and higher milk yields (Table 2). The feed intake of the F group was 1.45 kg DM higher and the energy intake was improved by 17.4 MJ ME. During the 100-day trial, the F cows produced 2.3 kg d^{-1} more milk (FCM) which tended to be higher in fat and protein content.

Table 2. Milk production and milk composition.

Group	At the end of pre-experimental period	During the experiment	Average per day, kg	In comparison with the pre-experimental period	
				kg ±	% ±
Whole milk, kg					
UT	19.40	1638.74	16.39	-3.01	-15.51
F	19.30	1764.24	17.64	-2.13	-8.60
Fat content, %					
UT	3.60	-	4.12	-	+0.52
F	3.64	-	4.52	-	+0.88
Fat, kg					
UT	0.698	67.54	0.675	-0.023	-3.29
F	0.702	79.83	0.798	+0.096	+13.68
Protein content, %					
UT	3.24	-	3.27	-	+0.03
F	3.24	-	3.39	-	+0.15
Protein yield, kg					
UT	0.628	53.28	0.533	-0.095	-15.12
F	0.625	59.34	0.593	-0.032	-5.12
4% fat milk, kg					
UT	18.23	1668.23	16.68	-1.55	-8.50
F	18.25	1901.85	19.01	+0.76	+4.16

Conclusions

The additive ‘Feedtech’ improved fermentation patterns of maize silage in laboratory mini-silos and in large trenches. These silages were stable aerobically. Its application demonstrated an improved intake and milk production with dairy cows.

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Intake and milk production of cows grazing perennial ryegrass cultivars with different crown rust resistance

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Abstract

There are many different perennial ryegrass (*Lolium perenne* L.) cultivars, which differ in crown rust (*Puccinia coronata* f.sp. *lolii)* resistance. This experiment aimed to study the effect of four diploid cultivars of perennial ryegrass with different degrees of crown rust resistance on dry matter intake (DMI), milk production (MP) of grazing dairy cows. The experiment was a repeated block design with 12 cows in 4 periods. DMI was estimated using the *n*-alkane technique.
Two cultivars (cvs. 1 and 4) with a higher expected crown rust resistance showed less infection with crown rust than the other two cultivars. Furthermore, water-soluble carbohydrate (WSC) contents of the crown rust resistant cultivars were higher. The lower crown rust infection and higher WSC contents were associated with a non-significantly higher DMI. The slightly higher DMI (n.s.) and the higher WSC content ($P < 0.05$) may have resulted in the higher ($P < 0.05$) MP of cows grazing the crown rust resistant cultivars (1 and 4).

Keywords: perennial ryegrass, cultivar, crown rust, intake, milk production

Introduction

Grass is an important source of roughage in the diet of dairy cows. In temperate climatic zones, intensively managed grasslands mainly consist of perennial ryegrass. There are many different cultivars, which vary in the degree of resistance against crown rust (*Puccinia coronata* f.sp. *lolii).* Crown rust results in retarded leaf function, eventually leading to early senescence and death, which reduces DM yield, palatability and nutritional value (Kimbeng, 1999). The aim of the present experiment was to study the effect of four different cultivars that differed in crown rust susceptibility on dry matter intake (DMI) and milk production (MP) of dairy cows.

Materials and methods

Four diploid perennial ryegrass cultivars (cvs. 1 to 4) were sown in a randomised block design with three replicates in adjacent strips. According to the Dutch recommended list of varieties, the cultivars differed in their crown rust resistance (5.5 to 8). The cutting and fertilisation regimes were similar for all cultivars. In July and August 2002, a grazing experiment was conducted with twelve Holstein-Friesian cows. Cows were in their second to fourth lactation and were 67 ± 15 days in lactation. Cows were blocked in three groups of four animals, according to their MP level. The experiment lasted eight weeks, divided into four periods of two weeks. In each period, each cow grazed one cultivar which was sown in a strip of 22 × 120 m. This strip was divided into small plots ensuring a herbage allowance of approximately 25 kg DM d^{-1}. Cows were moved daily to a new plot at noon. Cows received 3.0 kg of concentrate feed daily, which contained 280 mg kg^{-1} of even-chain length (C32) alkane, in

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equal portions at milking. Cows were milked twice a day at 0600 and 1600 h and individual MP was recorded.
On days 8 to 13 of each 14-day period, a hand-plucked sample of the grass was taken at three times of the day: 1400 h, 2000 h, and 0700 h. After 24 h of grazing, all dung patches of each cow were sampled. Grass and faeces samples were stored in the freezer at -20 °C. Grass samples were oven-dried at 60 °C for 48 h and ground through a 1 mm sieve (Peppink, Hammermill). Faeces samples were freeze dried and ground through a 1 mm sieve (Retsch ZM100). The grass and faeces samples were pooled to one sample per cow in each period. The grass samples were analysed with Near Infrared Reflectance Spectroscopy (NIRS) for organic matter (OM), crude protein (CP), neutral detergent fibre (NDF), acid detergent lignin (ADL), and water-soluble carbohydrate (WSC) content. On day 12 in periods 2 to 4, grass samples were taken before grazing to count the number of crown rust spots on each leaf. Samples of approximately 200 intact leaves with a minimum length of 10 cm were used. The severity of crown rust infection (as % of total leaves) was classified as: no spots, one spot, two to five spots, six to ten spots and more than ten spots on each leaf.
The pooled grass and faeces samples were both analysed for *n*-alkane contents to estimate the individual DMI d^{-1} in each period. Average individual MP was calculated for day 8 to day 13 of each period.
Crown rust infection was tested for differences among cultivars by probit analyses (SAS 6.12). A two-way ANOVA was applied to test for the main effects of cultivar and period for chemical composition, whereas a three-way ANOVA was applied to test for differences in DMI and MP with main effects cultivar, period and cow. The SNK test was used to separate the means of main effects.

Results

In figure 1, the severity of crown rust infection is shown. Almost 80 % of the leaves of cvs. 1 and 4 did not have crown rust spots, whereas cv. 3 was infected heavily, having less than 50 % non-infected leaves. More than 30 % of the leaves of cv. 3 were severely infected, but also cv. 2 showed a higher ($P < 0.05$) infection (21 %) than cvs. 1 and 4 with approximately 10 %. The percentage of leaves in the three classes infected with one spot, 2 to 5 spots and 6 to 10 spots on each leaf were relatively low for all cultivars, but in the class 6 to 10 spots cvs. 2 and 3 were higher ($P < 0.05$) than cvs. 1 and 4. The higher crown rust resistance of cvs. 1 and 4 than cvs. 2 and 3 is in agreement with the Dutch list of recommended varieties.

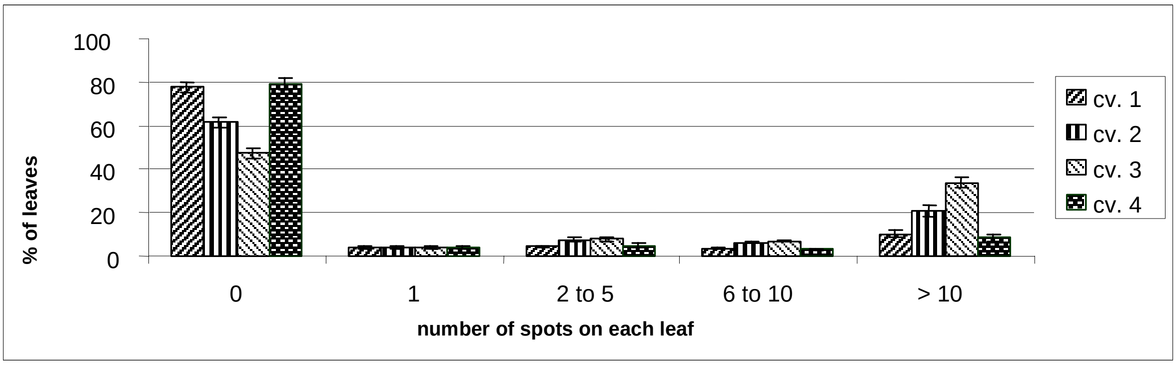

Figure 1. Crown rust infection of leaves of four cultivars of perennial ryegrass in five classes of severity.

As shown in table 1, the crown rust resistant cvs. 1 and 4 had higher WSC contents than cvs. 2 and 3, with a relatively large difference of 25 % between extremes. The difference between extremes for ADL content was lower (15 %), whereas for CP and NDF contents these were lowest (5 % and 4 % respectively). DMI was highest of cv. 4 and lowest of cv. 3 (Table 1), although differences among cultivars were not significant. The MP of the crown rust resistant cvs. 1 and 4, however, were higher ($P < 0.05$) than of the crown rust susceptible cvs. 2 and 3.

Table 1. Mean effect of cultivars on chemical composition of the grass and on dry matter intake (DMI), milk production (MP) by twelve dairy cows.

	Cultivars				SEM
	1	2	3	4	
Grass					
OM (g kg^{-1})	879.0 ^{a}	875.8 ^{b}	869.9 ^{c}	874.5 ^{b}	1.40
WSC (g kg^{-1})	145.5 ^{a}	129.8 ^{b}	111.4 ^{b}	141.4 ^{a}	13.65
CP (g kg^{-1})	186.3 ^{a}	177.2 ^{b}	184.8 ^{a,b}	180.9 ^{a,b}	4.61
NDF (g kg^{-1})	505.6 ^{b}	526.3 ^{a}	521.4 ^{a}	522.3 ^{a}	7.38
ADL (g kg^{-1})	26.7 ^{b}	27.5 ^{a,b}	29.1 ^{a}	24.8 ^{c}	5.35
Dairy cows					
DMI (kg d^{-1})	17.5	17.1	16.2	18.2	0.37
MP (kg d^{-1})	28.1 ^{b}	26.7 ^{c}	26.2 ^{c}	29.2 ^{a}	0.49

^{a,b,c} Means of cultivars within row with different superscripts differ significantly ($P < 0.05$)

Discussion

The higher crown rust infection of the susceptible cultivars (2 and 3) might have reduced DMI as cows tend to avoid rusted grass. Kimbeng (1999) reported that crown rust infection was associated with higher CP and NDF contents and lower WSC contents. In our experiment the susceptible cvs. (2 and 3) had lower WSC and higher ADL contents than the resistant cvs. (1 and 4). Furthermore, Miller *et al.* (2001) found that two cultivars differing in WSC content did not result in a significantly different DMI, but that a higher WSC content increased digestible DMI ($P < 0.05$) and that this in turn led to a higher ($P < 0.05$) MP. The higher ($P < 0.05$) MP of the crown rust resistant cvs. (1 and 4) are in agreement with these findings, which might be related with the non-significantly higher DMI and higher WSC and lower ADL contents of the resistant cultivars. The crown rust infection and the chemical composition of the cultivars were, however, confounded and therefore no direct causal relationships with DMI and MP could be established.

Conclusions

Two crown rust resistant cultivars showed a lower infection with crown rust than two susceptible cultivars that were severely infected. The crown rust resistant cultivars had higher WSC and lower ADL contents. The DMI of the resistant cultivars was higher (n.s.) than the susceptible cultivars. MP of cows grazing the crown rust resistant cultivars was also higher ($P < 0.05$), which might be associated with their slightly higher DMI and elevated WSC contents.

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Using draff in nutrition of grazed dairy cows.

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Abstract

There are more than 15 breweries in Slovakia which are located over the entire country. Therefore, draff (brewers' grains) is readily available and is used in animal production systems. The effect of draff on milk production and quality was investigated. In a research study, 2 groups of Black Pied dairy cows were grazed rotationally in paddocks during the day. Both groups were offered a concentrate supplement. The 1st group, in addition to being offered a basic feeding ration, were also offered draff. Over the grazing season, the mean daily milk yield was 20.6 and 18.1 kg head^{-1} d^{-1}, respectively. For both groups, the milk composition and quality was normal and complied with the Slovak Technical Standard (STN) specifying the properties of untreated cow's milk. A positive impact of draff was recorded for a range of milk quality parameters, e.g., increased contents of milk fat, protein, solids-non-fat and casein as well as improved milk fermentation and rennetability.

Keywords: pasture, dairy cow, milk yield, draff, milk quality

Introduction

Grasslands under good management are sources of high quality forage (digestibility 60-80 %) and high animal performance (12-20 kg milk). The disadvantage of grazing, in terms of utilisation, is dependent on growth stage and climatic conditions. During drought periods, cow performance decreases. A grass sward at optimal developmental phase is a protein forage (Kolar, 1985; Knotek *et al.*, 1990). However, grass is unable to meet total animal demands during the grazing season. Considering this, it is necessary to choose an appropriate supplementary feed.

Materials and methods

The aim of the experiment was to establish the effect of supplemented draff on milk yield and milk quality. Draff is a waste product of beer processing, it is rich in crude protein and energy. It increases the productive potential of concentrate. The experiment was carried out on sown grass sward. Black Pied cows were grazed rotationally and offered a daily herbage allowance. Animals were balanced into two groups on the base of average lactation number, lactation stage and performance previous to experiment start. Supplementary feeding was carried out during morning and evening milking as follows:
1st group: grazing *ad libitum* + 4 kg DM of draff.
2nd group: grazing *ad libitum* (control group).
Dairy cows were offered a carbohydrate supplement at 0.5 kg for each kg of milk produced above the determined daily milk production. Carbohydrate supplement balanced the feeding ration. During the experiment, forage samples were regularly taken for chemical analysis and herbage yield was determined. Individual milk yield was determined daily. To assess technological parameters of milk quality, milk samples were taken at 4 week intervals.

Results and discussion

Herbage yield and its nutrient composition changed at each grazing cycle. Mean DM yield ranged from 1.4 t ha^{-1} to 2.8 t ha^{-1} in the grazing cycles and the annual DM production was 13.59 t ha^{-1}. Mean nutrient content in herbage, draff and carbohydrate concentrate is shown in table 1.

The obtained daily cows DM intake (Table 2) met animal demands for NEL and PDI up to 85.7-125.5 % (Table 3).

Table 1. Mean nutrient content of the offered feeds.

Feed	DM g kg^{-1}	CP g kg^{-1}	Fibre g kg^{-1}	OM g kg^{-1}	NEL MJ	PDI g kg^{-1}
Herbage	210.0	170.5	224.4	872.1	5.65	89
Draff	262.0	233.4	156.0	955.3	6.96	93
Concentrate	816.2	117.3	23.63	916.6	7.15	71

Table 2. Forage intake (kg DM head^{-1} d^{-1}).

Group	Forage	Cycle 1	2	3	4	5	6	7	8	Average	Share (%)
1	Grazing	9.0	9.1	8.9	9.1	8.8	8.7	8.5	8.6	8.8	55.7
	Draff	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	25.3
	Concen.	2.9	3.3	4.0	3.1	3.7	2.9	2.5	1.0	3.0	19.0
2	Grazing	12.1	12.5	12.4	12.4	12.2	12.1	12.0	12.2	12.2	87.1
	Draff	0	0	0	0	0	0	0	0	0	0
	Concen.	2.5	2.5	2.7	2.3	2.4	1.6	0.7	0	1.8	12.9

Table 3. Comparison of intake and nutrient demands %.

Group			Cycle 1	2	3	4	5	6	7	8	Average
1	NEL	Intake	106.4	111.1	114.2	107.9	114.1	106.7	103.4	92.5	107.0
		Demand	105.8	108.3	112.6	106.8	111.0	105.7	103.2	93.3	105.8
		Coverage	100.6	102.6	101.4	101.0	102.8	100.9	100.2	99.1	101.1
	PDI	Intake	1419	1455	1371	1370	1493	1382	1508	1398	1367
		Demand	1410	1452	1421	1427	1494	1407	1364	1206	1397
		Coverage	100.6	100.2	96.5	96.0	99.9	98.2	110.6	115.9	98.5
2	NEL	Intake	93.3	96.5	95.0	92.2	95.2	88.1	81.6	79.0	90.1
		Demand	103.0	102.7	103.9	101.2	102.0	97.3	91.3	84.9	98.3
		Coverage	90.6	94.0	91.4	91.1	93.3	90.5	89.4	93.1	91.7
	PDI	Intake	1287	1348	1184	1206	1336	1232	1389	1347	1291
		Demand	1365	1362	1381	1337	1349	1272	1174	1071	1288
		Coverage	94.3	99.0	85.7	90.2	99.0	96.9	118.3	125.8	101.2

Feeding concentrate with draff met the animals demands for NEL and PDI in each cycle. However, requirements for NEL and PDI with the 2nd group were not fulfilled in virtually all cycles. The most important economic efficiency of feeding ration is gained in animal output. In dairy cows grazing systems, this criteria is represented by milk production (Sedliak, 1997). Table 4 shows the amount of milk obtained per cow per day in each cycle. Mean daily yield was higher by 2.5 kg head^{-1} with the 1st group, which was highly significant (P < 0.01).

Milk quality and composition were normal for the two groups and were in line with the Slovak Technical Standard (STN) 570529 'Untreated cow's milk for milk treatment and processing'.

Table 4. Mean daily milk production in cycles (kg head^{-1} d^{-1}).

Group	Cycle 1	2	3	4	5	6	7	8	Average
1	20.47	21.36	22.82	20.85	22.21	20.43	19.51	16.27	20.56
2	19.59	19.55	19.98	19.05	19.29	17.65	15.66	13.55	18.05
Tukey ($P < 0.05$)	+	++	++	++	++	++	++	++	++

Table 5. Milk quality parameters.

	Group 1	2	Tukey ($P < 0.05$)
Fat (%)	3.806	3.741	-
Protein (%)	3.0	2.897	-
Lactose (%)	4.515	4.522	-
Non-fat solids (%)	8.399	8.285	-
Titratable acidity (SH)	6.88	6.62	-
pH	6.549	6.633	-
Yoghurt test (SH)	27.040	25.91	+
Casein (%)	2.333	2.233	-
Rennetability (sec.)	207.4	277.0	+

Rennetability and fermentation were significantly higher when draff was supplemented. Milk quality parameters were better for draff, but differences between groups were not statistically significant.

Conclusions

Draff was found to be an appropriate feed for supplementing grazing dairy cows. The use of the draff increased milk yield significantly. Similar results were noted by Polhast (1990) and Münger and Jans (1997). In terms of milk quality, sown swards provided high quality forage for milk output of normal composition and properties. Draff supplementary feeding increased milk fat, protein, non-fat solids and ash content. Simultaneously, some quality parameters were better, e.g., milk fermentation, casein and rennetability.

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Effect of fertilisation with selenium on plasma selenium in Belgian Blue suckling cows and heifers: first results.

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Abstract

Fertilisation with selenium was used in order to increase selenium status in Belgian Blue grazing cattle. There were 2 groups of animals composed of 15 cows and their calves and 3 heifers. They grazed in pastures fertilised with nitrogen fertiliser with selenium (Se) or without selenium (C). A total amount of 210 kg ha^{-1} nitrogen and 15 g ha^{-1} selenium was spread in five applications to the pastures. The selenium content in grass was higher in pastures with the fertiliser containing selenium than in control grass (0.29 vs. 0.06 mg kg^{-1} dry matter). Live weight gains were not significantly different. Glutathion peroxydase activity expressed in selenium equivalent in cow's blood increased during the grazing season and was significantly higher in Se group (65.9 vs. 29.5 µg l^{-1}; $P < 0.01$). At weaning, selenium contents in calve's blood were also significantly higher in Se group (81.1 vs. 33.7 µg l^{-1}; $P < 0.001$). Vitamins C and E were lower in Se calves. There were no differences for reduced or oxidized glutathion or for peroxidized lipids. It seemed that the calves used mainly glutathion oxidation pathway as a defence mechanism against free radicals explaining the lower vitamin C and E concentrations since it is used in the regeneration of glutathion in Se group.

Keywords : selenium, fertilisation, Belgian Blue cows, calves, glutathion peroxydase

Introduction

The importance of selenium for animal and human health has been highlighted in recent years. Selenium is characterized by many antioxidant properties when it is associated with enzymes. For example, protective effects against prostate cancer have been shown by Duffield-Lillico *et al.* (2003). In cattle, it is involved mainly in myopathy and reproduction. In Belgium, selenium content in products from agriculture is low. A technique to increase selenium in animals and their products and consequently intakes by the population in order to improve health is the addition of selenium in fertiliser. By doing so, selenium increases in the food chain. This trial aims to study the impacts of selenium fertilisation in pastures grazed by Belgian Blue suckling cows on selenium contents in grass and selenium status in animals. Some metabolites related to the antioxidant status were also determined.

Materials and methods

Two permanent pastures were divided into two plots. In the first pasture, each plot was grazed by 12 Belgian Blue cows and their calves. In the second pasture, each group consisted of 3 cows and 3 heifers. There were also 2 calves in one group in the second pasture. One plot of each pasture was fertilised with mineral fertiliser containing selenium (Se) and the other one with the same fertiliser without selenium (C). During the preceding winter the animals of the Se group, except some heifers, were offered a diet with barley and grass silage grown with selenium, while animals grazing in C received barley and grass silage fertilised without selenium. The flora of the pasture was composed mainly of gramineae (±70 %) and white clover (15 %). Grass samples were taken in order to determine chemical composition and selenium content. Grass heights were measured once per month with a settling plate instrument. The live weights were recorded at the beginning and the end of the grazing season and twice during the grazing season. At each weighing date, a blood sample was taken from the cows and heifers to determine glutathion peroxydase activity which was expressed as selenium equivalent. A blood plasma sample was taken from the calves at the beginning of the grazing season and at weaning at about 6 months. They were removed from the pasture at weaning. The glutathion peroxydase activity, vitamin C, vitamin E and cholesterol contents were determined in the calves' blood plasma. One way analysis of variance was used according to the methods described by Dagnelie (1975).

Results and discussion

During the whole grazing season, nitrogen fertiliser with or without selenium was applied on 5 occasions in C and Se pastures. The total amount of nitrogen was 210 kg ha^{-1} in C and Se and the amount of selenium was 15 g ha^{-1} in Se. Grass silage was produced on part of the pastures at the end of May. At the beginning of the grazing season, the stocking rate was 4.98 cows and heifers ha^{-1} and at the end of the grazing season, it was 2.97 cows and heifers ha^{-1}. Hay was offered in July and August when grass availability was decreased due to dry weather conditions. Mean grass heights were 8.6 cm. Nitrogen and acid detergent fibre contents in grass were 172 and 342 g kg^{-1} dry matter. Selenium content was higher in grass of the Se pasture during the whole season, the concentration being much larger at the beginning of the season (Figure 1). The fertilisation with selenium allowed an increase of mean selenium content by almost 5 times in Se grass as compared with C grass (0.29 vs. 0.6 mg kg^{-1} dry matter).
The live weights of cows and calves at the beginning of the trial were 651 and 153 kg respectively. The live weight gains of cows and calves were not significantly different (Table 1).

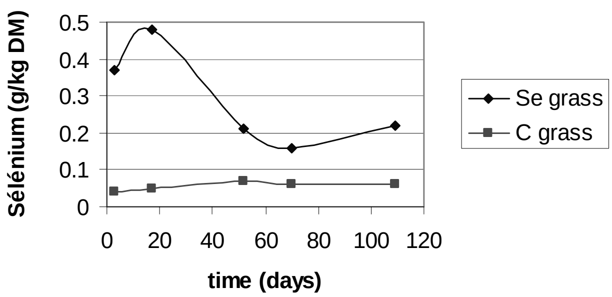

Figure 1. Evolution of the selenium content in grass during the grazing season.

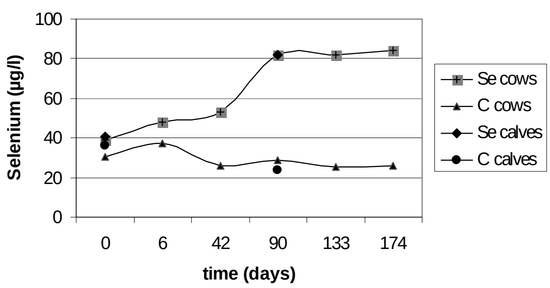

Figure 2. Evolution of blood selenium measured as glutathion peroxydase in cows and calves during the grazing period.

At the beginning of the trial, glutathion peroxydase activity in blood plasma expressed in equivalents of selenium was 38.4 and 30.2 µg l^{-1} (P < 0.05) in Se and C cows respectively (Figure 2). These values and the calves concentration at the beginning of the trial were very low and can be considered as deficient (Hain *et al*., 2003). This significant difference was due to winter feeding when animals had received grass silage and barley grown with or without selenium fertiliser.

Table 1. Cows and calves performance and blood plasma metabolites in calves at weaning.

	Control	Selenium	Significance
Liveweight gains cow (kg day^{-1})	-0.08	-0.08	NS
Liveweight gains calves (kg day^{-1})	0.79	0.98	NS
Metabolites in calves blood			
Blood selenium (µg l^{-1})	33.7	81.1	$P < 0.001$
Vitamin C (µg ml^{-1})	7.3	4.5	$P < 0.05$
Vitamin E (µg ml^{-1})	8.2	5.9	$P < 0.01$
Cholesterol (g l^{-1})	1.8	1.5	$P < 0.05$
Reduced glutathion (µmol l^{-1})	1043	1001	NS
Oxidized glutathion (µmol l^{-1})	6.0	5.8	NS
Peroxidized lipids (µmol l^{-1})	25.3	34.0	NS

During the grazing season, the concentrations increased considerably after 3 months in Se cows ($P < 0.05$). They decreased slightly in C cows. There was a delay in the response in Se group as compared to the response of selenium content in grass (Figure 1). The delay can be attributed to the incorporation of selenium from the diet in the red cells which requires from two to three months. The mean selenium content in the blood plasma of the cows was significantly higher in the Se group than in the C group (65.9 vs. 29.5 µg l^{-1}; $P < 0.001$). There were no significant differences between calves at the beginning of the grazing season but in the middle of the season, selenium concentration was significantly higher in Se group ($P < 0.001$). Cholesterol, and vitamins C and E concentrations were significantly lower in Se calves but peroxidized lipids, reduced and oxidized glutathion were not different. The Se calves probably used the glutathion peroxydase oxidation pathway to a greater extent as defence against free radicals than C calves. So, the lower vitamin E and C contents in Se calves can be explained by a higher request for glutathion peroxydase regeneration.

Conclusions

In this first trial, fertilisation with selenium induced higher selenium contents in grass. The grazing of such a sward by cows and their calves induced higher status in plasma selenium and decreased plasma concentration in vitamins used in glutathion peroxydase regeneration. Interactions between antioxidants should be investigated in Belgian Blue cattle.

Acknowledgements

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Feed preferences and voluntary intake of dairy heifers fed grass silage and hays offered singly or as a matter of choice

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Abstract

The knowledge of preferences between forages can help to improve the way of mixing them in diets and of offering them to animals. Twelve dairy heifers (mean weight 568 kg) were offered grass silage (S), first cut hay (H) and re-growth hay (R), either singly or in pairs, in two successive 3 × 3 Latin square designs, for 6 and 9 weeks respectively. Despite different nutritive values, voluntary intakes of all forages were very similar when they were given separately (9.22 kg DM). Where heifers were offered paired forages they always selected to feed from both. Voluntary intake was similar whatever the paired forages were offered with a mean value of 10.12 kg DM. Feed preferences varied during the course of the day. On a daily basis heifers preferred dry forages to silage (choice ratio 59/41 and 66/34 for R/S and H/S diets respectively), although they preferred silage in the morning during the two hours following feed distribution (choice ratio 38/62 and 45/55 for R/S and H/S diets respectively). Thus diversified forage diets and a free choice situation could better satisfy nutritional and behavioural needs of ruminants and may offer a way of improving forage utilisation.

Keywords: forage, feed preferences, voluntary intake, heifers.

Introduction

Ruminant diets often contain more than one forage, offered either mixed or separately. Optimising forage utilisation thus requires a better knowledge of the effects of mixing forages on feeding behaviour and voluntary intake. Particularly, knowing and understanding of animal preferences between forages should help to improve the way of mixing them in diets and of offering them to animals. At the meal level, choice tests indicate that forages are preferred according to the maximum voluntary intake that they allow, which is dependent on their nutritive value and quality of conservation (Baumont *et al*., 1999). However, preference can change during the day (Rutter *et al*., 2000) and the diet selected is generally composed of more than one component. Moreover, availability of a choice has been shown to stimulate intake (Ginane *et al*., 2002). In this trial we investigated the voluntary intake and feed preferences of dairy heifers between three harvested forages (grass silage, first cut hay and regrowth hay), either on a short time scale (2 hours) or over the day.

Materials and methods

We used three forages riginating from permanent pasture: a grass silage (S) harvested with addition of formic acid, a re-growth hay (R) harvested on the same plot, and a first cut hay (H) harvested on another plot. Their nutritive value was assessed by chemical composition analyses and by *in vivo* measurements of digestibility in sheep (Table 1). We used twelve 2-year-old Holstein dairy heifers weighing 532 kg (SE 9.1) at the beginning and 623 kg (SE 9.2) at the end of the experiment.
The experiment was conducted in two parts: first heifers were offered the forages, singly and *ad libitum* with 10 % refusals in a 3 × 3 Latin square of three 2-week-long periods. Then, forages were offered as a choice in 2-way combinations (S/R, R/H and S/H), in a 3 × 3 Latin square of three 3-week-long periods. During the whole experiment forages were allocated

twice a day (in the morning and in the afternoon) in one trough, which was divided in two equal parts in treatments where animals had a choice. During each experimental week, voluntary intake was measured individually for five subsequent days. Heifers live weight was measured at the end of each experimental period. For analyses of intake, we only considered the last week of periods, so as to allow heifers adaptation to the diet. For four subsequent days within these weeks, voluntary intake over the first two hours was recorded individually. We tested on voluntary intake data the effects of diet, period and animal by performing an analysis of variance according to the latin square design. Feed preferences were analysed using the Wilcoxon test for paired data. As heifers live weight increased during the experiment, we adjusted intake data to their live weight and intake capacity during the first part of the experiment, according the fill unit system (INRA, 1989).

Results and discussion

Silage and re-growth hay chemical compositions were close to each other (Table 1). In contrast the first-cut hay had a slightly higher crude fibre content, a much lower crude protein content and lower digestibility.

Table 1. Chemical composition on a dry matter basis (DM) and *in vivo* digestibility measured in sheep of the three forages used in the trial.

	Silage (S)	First-cut hay (H)	Re-growth hay (R)
Dry matter (g kg^{-1} fresh matter)	264	838	836
Ash (g kg^{-1} DM)	104	71	97
Crude fibre (g kg^{-1} DM)	297	310	301
Crude protein (g kg^{-1} DM)	142	95	141
DM digestibility (g g^{-1})	0.621	0.566	0.606

Voluntary intakes of the three forages offered singly were similar over the day (mean value 9.22 kg DM, $P > 0.05$, Figure 1a) even if intake of silage was significantly lower than the intake of the hays during the first two hours of feeding (2.2 vs. 2.8 kg DM, $P < 0.05$, Figure 1b).

When allowed to select heifers always choose a mixed diet. Voluntary intake over the day was similar whatever the pair considered ($P > 0.05$, Figure 1a), with a mean value of 10.62 kg DM and of 10.12 kg DM after correction for increase in intake capacity due to the increase in live weight (545 kg during the single feed periods and 591 kg during the choice feeding periods). Feed preferences varied during the course of the day. On a daily intake basis (Figure 1a), heifers preferred hays to silage (6.7 vs. 3.5 kg DM ($P < 0.01$) and 6.0 vs. 4.1 kg ($P < 0.01$) for H/S and R/S combinations respectively). There was no significant preference between hays (4.7 vs. 5.4 kg DM). In contrast, considering the first two hours of intake (Figure 1b), heifers preferred silage to hays (1.7 vs. 1.4 kg DM ($P < 0.01$) and 2.1 vs. 1.3 kg ($P < 0.01$) for H/S and R/S combinations respectively).

This study confirms that ruminants prefer a mixed diet in a choice situation and reveals that preferences between silage and hay can vary during the course of the same day. We can hypothesize that selecting a mixed diet rather than a single forage of better digestibility may be due to some benefit in terms of digestive comfort (Forbes and Provenza, 2000). This may be particularly the case with silage, as the preference for this forage varies during the day. Preference for silage in the morning is consistent with the hypothesis of preference for the feed of highest digestibility in the morning and for more fibrous feeds in the evening (Rutter *et al*., 2000), unless it is related to the relative DM contents of forages. It is worth noting that during the 2 hours following allocation, silage intake in choice situation was close to silage intake when offered alone and that there was little substitution between hay and silage. However, it is also known that intake of silage can be limited by the negative effects of fermentation products (van Os *et al.*, 1995), which could explain the increasing preference for hays during the day. In addition, intake data corrected by live weight suggest that free choice situation may increase voluntary intake by 10 % in accordance with the study by Ginane *et al.* (2002) with Aubrac heifers fed hay diets.

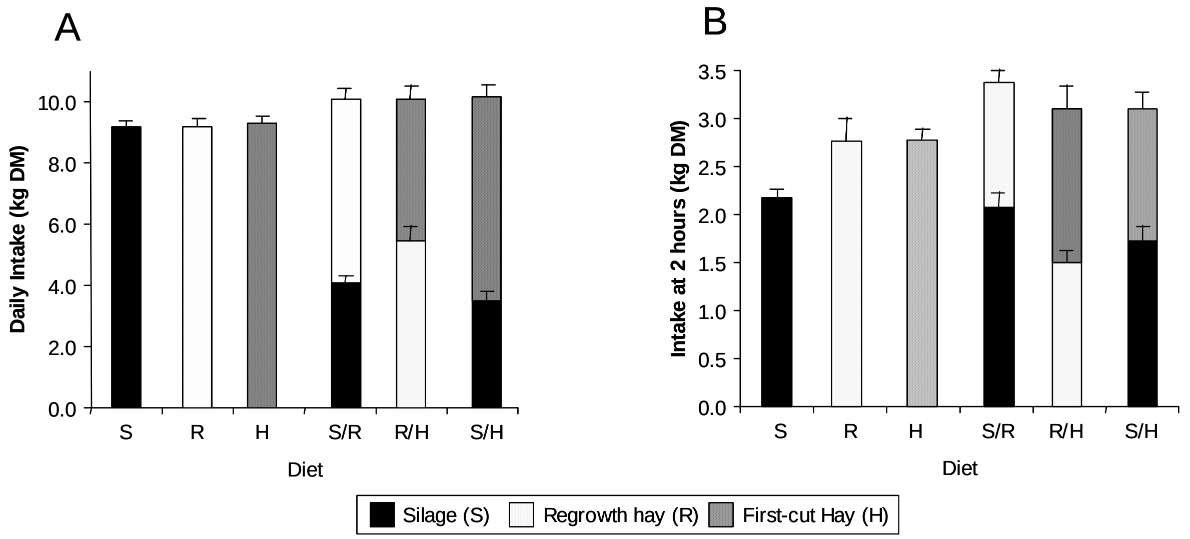

Figure 1. Mean values and standard errors of daily voluntary intake (A) and during the first 2 hours following the morning distribution (B) of heifers fed forages as a single feed or as pairs offered in free choice.

Conclusions

In choice situation animals choose mixed diets and not solely the forage of highest nutritive value. Preference between silage and hays varies during the course of the day. Thus diversified forage diets and a free choice situation could better satisfy nutritional and behavioural needs of ruminants. This may offer a way to improve forage utilisation in ruminant feeding.

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Impact of winter feeding on the grazing performance of Belgian blue white heifers: effect of dietary protein and fibre contents

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Abstract

The aim of the study reported here was (1) to determine the impact of winter diet on the performance of growing heifers during the subsequent grazing period and (2) to promote early calving with an optimal valorisation of grass and harvested forages. From 2000 to 2003, 8 month old Belgian blue white (BBB) heifers were submitted to 2 winter basal diets: forage-based diets (60 to 77 % forage) and concentrate-based diets (concentrates and wheat straw). These basal diets were proposed at 2 daily nitrogen levels (300 or 345 g of digestible protein in the intestine (DVE according to the Dutch system)). The results show that winter basal diet had an effect on subsequent grazing performances. Heifers fed with forage-based diets recorded the best grazing performances with an ADG of 0.709 kg against 0.537 kg for heifers that had received concentrate-based diets. Nitrogen supplementation didn't appear to have any effect on subsequent grazing performance although heifers fed with a high level of protein had the best winter performances. Concentrate-fed heifers were heavier than forage-fed heifers at turnout but at the end of the grazing period their weights were similar: 435 kg and 433 kg respectively for the first and second ones. Both forage and concentrate winter diets facilitated an ADG of 0.8 kg per day across the year. So it appears possible to promote a 2 year old first calving based on such feeding schemes.

Keywords: heifers, early calving, grazing, protein and fibrous levels of diet

Introduction

To increase profits, farmers can reduce feeding expenses, which represent about 70 % of their production costs. In suckling cattle systems, management of heifers for early calving can help to reach this target. Indeed this practice reduces by 6 to 12 months the unproductive lifetime of breeding animals and so their global feeding costs. Albeit technically feasible, this practice is not common in BBB breeding systems where many primiparous cows calve at 30 months (BBB Herd Book). The main factor restricting early calving remains heifers live weight at first insemination. Indeed, they must reach 70 % of their adult weight, to say 400 to 420 kg, at 14-15 months (Rychembush 2000a; 2000b). To reach such a goal heifers must have an ADG of 0.7 at 0.8 kg from birth to first insemination. The question is if forage and grazed grass are adequate feeds to reach such an objective. With this in mind our objectives were to determine the impact of winter diet on heifer performance during the subsequent grazing period and to promote 24 month calving with an optimal valorisation of grass and conserved forages.

Materials and methods

Main results presented in this paper emanate from trials held in Libramont (Belgium's Ardennes, altitude 480 m) during the winter and grazing seasons 2000-2001, 2001-2002 and 2002-2003. Per year, 4 groups of 8 month old, spring born heifers (n = 61 for the 3 years) were submitted to 2 winter basal diets; forage-based (FOR) or concentrate-based (CON) diets proposed at 2 daily nitrogen (N) levels (100N or 115N). In theory, the 100N diets were to meet the protein requirements of heifers such that there was 300 g of digestible protein in the intestine per day according to the Dutch system (DVE). The 115N diets supplied 345 g of DVE per day, i.e., 15 % over the nitrogen needs. Forage diets contained pre-wilted grass silage or pre-wilted grass silage mixed with hay complemented with spelt (*Triticum spelta* L.) and growing concentrate. In FOR diets, forage proportion represented more than 50 %, on a dry matter basis. CON diets contained only dry foods (growing concentrate and Spelt) and Wheat straw. Diets were distributed as mixed diets at *ad libitum* level. Table 1 details the characteristics of the feedstuffs together with the composition and nutritional values of winter diets. In spring (May for 2001 and 2003 and April in 2002), heifers were allocated to pastures in a rotational grazing system of 3 paddocks with one mowed in spring. Sward composition was about 50 % perennial ryegrass and 40 % white clover. The average spring stocking rates were, respectively for 2001, 2002 and 2003, 1807, 1624 and 1691 kg of live weight per ha or 4.8 to 5.1 heifers per ha. Each year, each paddock was grazed 2 or 3 times. Heifers remained a mean of 19 days on each paddock per rotation. The average resting time was 55 days. Mean initial sward surface height was 13.7 cm whilst mean final sward surface height was 6.0 cm. For all diets, total grazing times were similar and were 119, 159 and 124 days in 2001, 2002 and 2003 respectively. Pasture fertilisation was 54 units of P_2O_3 54 units of K_2O, and 30 units of N per hectare at the end of each grazing rotation. During the whole experiment, heifers were weighed monthly. During winter, daily intake was also measured at the feedlot scale. Winter diets were sampled once a week and grass was sampled biweekly. Dried and grounded samples of grass and winter diets were submitted to near infrared reflectance spectroscopy analysed to estimate their chemical composition and nutritional value. The different parameters recorded were analysed according to a standard analysis of variance with 3 fixed factors (year, basal diet and nitrogen level). Means comparisons were performed using a Newman and Keuls test (Statistica software).

Table 1. Characteristics of feedlot and winter diets (averaged values for the 3 years).

	FOR-115N	CON-115N	FOR-100N	CON-100N
Characteristic of heifers				
number	16	16	15	14
Initial weight (kg)	232 ± 30	231 ± 30	233 ± 32	230 ± 27
Initial age (month)	8.2 ± 1.2	8.2 ± 0.7	8.8 ± 1.7	7.6 ± 0.8
Size at withers (cm)	99 ± 4	98 ± 3.5	99 ± 4.5	98 ± 3.1
Thorax diameter (cm)	143 ± 6.5	143 ± 7.5	144 ± 7	143 ± 8
Composition of winter diets (% on a dry matter basis)				
Pre-wilted grass silage and hay	59.7	/	78.5	/
Spelt and growing concentrate	40.3	88.8	21.5	86.7
Wheat straw	/	11.2	/	13.3
Characteristic of winter diets in the Dutch system				
DM (%)	58.24	86.6	59.5	86.8
CP (%)	14.22	13.5	13.6	11.5
CF (%)	20.3	16.1	24.3	16.4
DVE (g kg^{-1})	65.1	74.0	61.8	65.6
VEM (kg^{-1})	870	921	831	882

N = number of heifers; DM = dry matter; CP = crude protein; CF = crude fiber; DVE = digestible protein in the intestine; VEM = energetic value.

Results and discussion

The main results of the experiment are summarised in table 2. Winter ADG was significantly influenced by the basal diet (FOR or CON) and by the level of N supplementation (115N or 100N) with no interaction between these factors. Concentrate-fed heifers were heavier, more developed and had better feed efficiency. Differences in live weight at the end of winter were 20 to 30 kg at the benefit of heifers receiving concentrate-based diets. Even if size at withers was similar between the 2 basal diets, carcass development (thorax diameter) was superior with concentrate-based diets. The same observation can be made for the nitrogen level of diet: 115N diets had the best growing performances. Nevertheless, from an economical point of view, forage-based diets remained the more attractive with an averaged daily cost of 0.91 euro per animal. CON diets were 0.20 euros more expensive with an averaged daily cost of 1.11 euros per animal. For the 4 winter diets, ADG decreased at the beginning of grazing season. However this decrease was sharper for heifers previously fed with concentrate. Indeed, their ADG was negative during the 15 first days of grazing. Heifers previously fed with forage diets maintained their level of performances with an ADG of about 0.850 kg in spring. At the end of the grazing season heifers fed during the previous winter, with forage-based diets were as heavy as heifers fed with concentrate-based diets. The liveweight was, at this time, 433 and 435 kg respectively for heifers that had previously received FOR and CON winter diets. Grazing ADG was not influenced by N level of winter diets. On average for the 4 diets, grazing performances were similar at 0.65 kg per day. This level of performances was possible without supplementation and with a grass of good quality (943 VEM, 16.5 % CP and 89 g DVE). For the 4 diets, heifers reached 420 kg at 16.5 ± 1.8 months and, at this moment, could be inseminated. Heifers fed winter concentrate-based diet or protein supplemented diets reached this weight 1 month earlier ($F_{(1,47)}$ = 5.01 and 6.99 respectively for basal diet and N level) but with higher feeding costs.

Table 2. Growing performances during winter period and at grazing: impact of winter diets (FOR vs. CON and 115N vs. 100N).

	FOR 115N	CON 115N	FOR 100N	CON 100N	Basal diet FOR	Basal diet CON	Nitrogen level 115N	Nitrogen level 100N
Winter performances								
ADG (kg)	0.821	1.030	0.686	0.796	0.755a	0.920b	0.926a	0.739b
Daily DM Intake (kg)	5.78	5.95	6.08	5.33	5.93	5.63	5.86	5.70
Daily DM Intake (% live weight)	2.00	1.97	2.17	1.86	2.08	1.91	1.98	2.01
Feed efficiency	7.08	5.79	9.25	6.99	8.16	6.39	6.43	8.12
Weight at end of stabulation (kg)	348	376	331	345	340a	362b	362a	337b
dsize (cm)	11.6	12.0	10.1	10.5	10.8	11.3	11.8a	10.3b
dth.diameter (cm)	23.3	28.2	20.3	23.3	21.9a	25.9b	25.8a	21.8b
Grazing performances								
Spring ADG (kg)	0.849	0.592	0.884	0.669	0.866a	0.625b	0.721	0.788
Summer ADG (kg)	0.579	0.483	0.549	0.443	0.564a	0.463b	0.531	0.502
Weight at grazing end (kg)	440	446	427	425	433	435	443	426
Estimated age at 420 kg	16.2	15.6	17.6	16.3	16.9a	15.9b	15.9a	17.0b
dsize (cm)	5.2	5.4	5.9	4.5	5.5	5.0	5.3	5.2
dth. diameter (cm)	18.4	13.5	17.7	11.6	18.1a	12.7b	15.9	14.7

FOR = average values of FOR-115N and FOR-100N; CON = average values of CON-115N and CON-100N; 115N = average values of FOR-115N and CON-115N; 100N = average values of FOR-100N and CON-100N, Feed efficiency = kg of food per kg of weight gain; dsize = increase of size at withers between start and end of experimental period; dth. diameter = increase of thorax diameter between start and end of experimental period; For columns 'basal diet' and 'nitrogen level' values differently signed were significantly different (α = 0.05).

Conclusions

Since the weight of 420 kg, necessary for a first insemination, was reached at 15-18 months for both modalities, the itinerary based on the valorisation of self-produced forages and on grazing facilitated this objective more economically. An increase of winter diet nitrogen level was not necessary to improve the growing performances at grazing. In addition, according to the results of the first experimental year, all heifers (breeders' decision) were inseminated between 15 and 19 months with a conception rate of 95 % underlining the feasibility of such practices.

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The study of utilisation of forages from bog meadows in agriculture and forestry farms

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Abstract

Bog grasslands in Poland have high natural landscape value unparalleled in Western Europe. Usually they are not utilised which means that they remain in a natural state. These unique areas need to be protected and maintained by appropriate management. The aim of this study was to evaluate the quality and nutritive value of big bale silage harvested from bog meadows. The bog meadow sward was composed of different *Carex* species and was harvested for ensilage in 2002. Part of herbage was ensiled with inoculant (LAB + enzyme). Silage and hay produced from bog herbage and silage from cultivated grasses were tested. Feeding experiment with 32 heifers (322 kg) divided into four groups was carried out for 40 days. Animals were supplemented with 1.5 kg of concentrate along with the tested forages. The silage, particularly that made using the inoculant, improved the nutritive value of forage compared to hay. The bog-silage made using inoculant had similar nutritive value to that of the silage made from the cultivated grasses. The following live weight gains were obtained in successive groups: 0.575, 0.695, 0.385, 0.717 kg. The palatability was also improved in the result of food conservation. The daily intake by heifers was 7.47, 8.30, 5.94, 7.81 kg of DM per head respectively.

Keywords: bog grasslands, silage, hay, nutritive value, gains of heifers

Introduction

Bog meadows and pastures came into being and remain in a semi-natural state as a consequence of systematic mowing or pasturage. They are inhabited by unique plant communities that are no longer found in many other European countries. The most precious are communities of *Molinion* alliance of wet meadows, *Magnocaricion* of flooded meadows, also *Calthion* alliance from more dry meadows with abundance of low sedges (Oświt, 1991; Oświt 2000; Wasilewski, 2002). In the last years due to their unique natural and landscape value they have been protected as national and landscape parks, nature reserves and areas of protected landscape. Bog meadows were mown exclusively for hay and used mostly for horse feeding. Because of the high silica content and structural fibre cattle are reluctant to eat it (Denisiuk, 1980; Moraczewski, 1996; Nowiński, 1966). Recently, agricultural use of bog areas has been abandoned and this has caused the disappearance of bog meadows. They become overgrown by natural generation of trees and shrubs and develop into coppice communities. This study was aimed at finding the ways of improvement the palatability and nutritive values of feeds by ensilage with the use of rolling up presses and at considering the possibility of sedge silage use in agriculture and forest farms.

Materials and methods

The study was carried out since 2002 in the Experimental Station of IMUZ at Biebrza in Podlaskie province. Ensilaged plants were harvested from 2 bog meadows situated in and near Biebrza National Park. It was the vegetation of *Calthion* alliance consisting in 70 % of low sedges *Carex panicea, Carex oederi, Carex fusca* (meadow I) and herbage of *Magnocaricion* alliance from flooded meadow, composed in 80 % of sedges, mostly *Carex gracilis* (meadow II). To protect nesting bird the meadows were mowed only in the middle of June. After mowing the herbage was pre-wilted on swath until it contained 500 g DM kg^{-1}. Plants were harvested with the rolling up press. Half of ensilaged material was inoculated during the harvest with Polmazym (LAB +enzymes) at a rate of 1 l t^{-1} of herbage. During the winter period different forages were fed to 32 heifers (age: 18-23 months and mean starting body weight: 322 kg), divided into 4 feeding groups. These groups were group I – fed with sedge silage, group II – sedge silage supplemented with Polmazym, group III – hay of sedges and group IV – silage from cultivated meadow. The feeding experiment lasted 40 days. Animals were fed as a group. The forages were offered in amounts not largely exceeding the standard rates (9-10 kg of DM per head per day). Feeds were given two times a day and leftovers were recorded. Along with the forages the animals received 1.5 kg concentrate per head and day. In order to evaluate silage intake by wild animals in the winter, they were offered the food in forests close to meadows from where it had been taken. To verify the zero hypothesis on body gains of animals the Fisher-Snedecor F test was used.

Results

The quality of silage prepared from sedges and from sward of cultivated meadows was very good. They obtained very good assessment according to Flieg-Zimmer scale. No butyric acid was found (Table 1). That resulted from intense pre-wilting of herbage before harvest (over 500 g DM kg^{-1}), preventing the development of butyric acid producing micro-organisms. The content of lactic acid in the silage prepared from sedge herbage, both with and without Polmazym, was similar to that in silage made from cultivated meadow sward. Polmazym treatment caused only a small increase of acetic acid content. The higher content of this acid had no influence on the palatability of the silage since consumption of the silage made using Polmazym by the group of animals was higher than any of the other groups. Daily intake of DM by animals was from 5.94 kg of hay to 8.30 kg of silage with Polmazym addition (Table. 2). The silage prepared from sedges contained considerably more crude protein in DM than hay prepared from similar herbage. Also the content of crude fat and phosphorus was higher and that of crude fibre was lower. Ensilage significantly improved the nutritive value of feeds (Table 2). Particularly high value was found in silage with Polmazym. The enzymes caused the decay of plant membranes and liberation of cell contents (McDonald *et al.*, 1991). The value of this silage was similar to the value of silage made of cultivated meadow sward. The contents of crude protein and crude fat were similar, and the content of crude fibre was even a little lower. In all feeds from sedge meadows, both hay and silage, the phosphorus content was lower than in the silage from cultivated meadow.

Table l. Chemical evaluation of tested silage.

	Type of silage		
	sedge	sedge + Polmazym	cultivated meadow
DM (g kg^{-1})	553.7	523.7	661.9
pH	5.00	4.90	5.60
Content of acids in fresh mater (g kg^{-1})			
- lactic	27.0	26.7	27.9
- acetic	2.4	3.3	2.2
- butyric	0.0	0.0	0.0
Sum of acids	29.4	30.0	30.1
Evaluation according to Flieg-Zimmer scale	very good	very good	very good

Statistical analysis of body gains of animals showed significant differences between groups. Animals receiving silage of sedges attained higher live weight gains than animals fed with hay. However, the former did not differ from the gains of animals fed silage from cultivated meadows. The body gains were positively correlated with the nutritive value of feeds. It was confirmed by the results of chemical analysis of feeds (Table 2).

Table 2. Nutritive value of tested feeds.

	Feeding groups			
	I	II	III	IV
Content in DM (g kg^{-1}) of:				
Crude protein	151.0	186.3	134.8	190.7
Crude fibre	229.1	257.3	323.3	286.6
Crude fat	37.5	37.6	35.6	37.9
Phosphorus	2.4	2.7	2.3	3.4
Daily gains of animals (g head^{-1})	575ab	695a	384b	717a
Daily intake (kg head^{-1}):				
silage	7.81	8.30	5.94	7.81
concentrate	1.47	1.47	1.47	1.47

Testing feeds on heifers was carried out simultaneously with observations of the intake of sedge silage by wild animals. It was observed that during 40 days animals ate 4 bales. The most often met animal was *Capreolus capreolus*. Probably the greater intake of this type of feeds could be recorded in regions of *Cervus elaphus* and *Bison bonasus* occurrence.

Conclusions

The quality and nutritive value of silage and obtained body gains of animals demonstrate that ensilage of sedge herbage was a better method of food preservation than haymaking. Well-prepared silage from sedge herbage had a value similar to that of feeds from cultivated meadow grasses and was suitable for feeding farm animals. The addition of Polmazym to ensiled sedge herbage significantly improved the nutritive value of silage. Feeds made of sedge herbage contained lower phosphorus Silage of sedge herbage is eaten by wild animals.

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Beef production models with Charolais and Angus heifers using semi-natural grasslands in summer

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Abstract

Only limited knowledge exists on how to raise cattle, when using semi-natural grasslands, to produce beef of high carcass quality. The objectives of these factorially designed studies were to determine the effects of indoor feed intensity (low vs. high) and slaughter age (18 vs. 22 months) on performances and carcass qualities of beef heifers, which where raised from weaning until slaughter and grazed on semi-natural grasslands from May until October. In the first trial, 56 Charolais heifers were used, of which 28 heifers were fed only grass / clover silage at *ad libitum* intake (low; CL), and the other 28 heifers were fed 2.0 kg of grain daily in addition to the silage (high; CH). In the second trial, 28 Angus heifers were fed grass / clover silage at 80 % of *ad libitum* intake (low; AL), and another 28 heifers were fed silage at *ad libitum* intake (high; AH). From weaning until slaughter, AH had higher average daily gains (ADG) than AL (693 vs. 573 g, $P < 0.0001$). Heifers of both breeds had higher carcass weights and fat classes, and, in addition, Charolais heifers had higher conformation classes at 22 months than at 18 months of slaughter age ($P = 0.0033$). In conclusion, indoor feed intensity affected ADG, whereas carcass traits were mostly affected by slaughter age.

Keywords: beef heifers, feed intensity, slaughter age

Introduction

Semi-natural grasslands are very important from a biodiversity point of view, as many rare and endangered plant and animal species only exist here, and there is a general interest in preserving them. In Sweden today, there are too few grazing livestock to preserve these acreages, despite the presence of economical compensations for grazing them. Heifers have a lower weight gain capacity than bulls and they should be fed relatively extensively to avoid excessive fatness at low live weights. Therefore, heifers are adapted to graze and preserve semi-natural grasslands. The objective of this study was to find production models for beef heifers, which combine utilisation of large acreages of semi-natural grasslands with production of high-quality carcasses.

Materials and methods

The experiment was conducted from 2000 to 2003 at Götala Research Station, at the Swedish University of Agricultural Sciences in Skara, and included two trials, in which suckler heifers were raised from weaning until slaughter. Trial 1 (2000-02) included 56 heifers of at least 75 % Charolais breed, and trial 2 (2001-03) included 56 heifers of at least 75 % Angus breed. Both trials had a 2 × 2 factorial design, where two levels of feed intensity and two levels of slaughter age were used per breed. No comparisons between breeds were done, because the two trials were not conducted simultaneously. In trial 1, half of the Charolais heifers was fed grass / clover silage (Table 1) at *ad libitum* intake, combined with 2.0 kg of grain (65 % oat and 35 % barley) per head and day during the indoor periods (high feed intensity; CH). The other half of the Charolais heifers was fed grass / clover silage only (low feed intensity; CL). In trial 2, half of the Angus heifers was fed grass / clover silage at *ad libitum* intake (high feed intensity; AH) whereas the other half of the heifers was fed grass / clover silage at 80 % of *ad*

libitum intake, i.e., 80 % of the intake for high intensity heifers at the same live weight (low feed intensity; AL). The grass / clover silage contained of 90-95 % grass (*Lolium perenne, Festuca pratensis, Pleum pratense*) and 5-10 % clover (*Trifolium repens* and *T. pratense*).
All heifers were kept together in one group during the two grazing periods. The heifers grazed in total 38 hectares of mainly opened, semi-natural grasslands, dominated by *Dactylis glomerata*. Sward height measurements and herbage sampling were undertaken according to Frame (1993). The pasture sward height was, on average, 4.7 (SD 2.3) and 6.1 (SD 2.8) cm for trial 1 and 2, respectively. After the grazing periods, the grazing pressures were classified, from a nature preservation point of view, as having been good, especially in trial 1. The overall average nutrient concentrations of the pasture were 9.7 and 9.2 MJ metabolisable energy, 156 and 129 g crude protein and 550 and 570 g neutral detergent fibre per kg of dry matter (DM) for trial 1 and 2, respectively. Half of the heifers of both breeds were slaughtered at the end of the grazing period at 18 months of age, whereas the other half was slaughtered, after an indoor finishing period, at 22 months of age. Conformation, fatness and weight of the carcasses were judged according to the EUROP classification system (SJVFS, 1998).

Table 1. Chemical composition (mean and standard deviation) of grass / clover silage fed to 56 Charolais or 56 Angus heifers during indoor period 1 (IP 1) and 2 (IP 2), respectively.

	Charolais				Angus			
	IP 1		IP 2		IP 1		IP 2	
	mean	SD	mean	SD	mean	SD	mean	SD
Dry matter (%)	27.3	2.9	22.9	2.0	26.0	4.0	24.7	1.6
Metabolisable energy (MJ kg^{-1} DM)	11.1	0.2	10.6	0.1	10.2	0.4	9.5	1.3
Crude protein (g kg^{-1} DM)	142	12	136	11	148	9	151	15
Neutral detergent fibre (g kg^{-1} DM)	497	70	558	22	540	25	549	25
Ash (g kg^{-1} DM)	83	3	89	9	89	6	92	12
NH_4-N (% of total N)	15.9	1.0	23.3	6.6	25.4	4.3	33.9	12.3
pH	4.2	0.1	4.0	0.1	3.7	0.2	4.3	0.3

Results and discussion

The higher total daily DM intake by heifers at the high feed intensity during indoor periods 1 and 2 (Table 2) resulted in a higher daily feed intake by heifers at the high than at the low feed intensity, when averaged over the two indoor periods (7.53 vs. 6.76 kg DM, $P < 0.0001$, and 5.89 vs. 4.19 kg DM, $P = 0.0004$, for Charolais and Angus, respectively). Also, daily feed intake, expressed as a percentage of live weight, was on average over the two indoor periods, higher on the high than on the low feed intensity (1.84 vs. 1.70 % for Charolais, $P = 0.0002$ and 1.97 vs. 1.58 % for Angus, $P = 0.0005$).
Average daily live weight gain (ADG) from weaning until slaughter was higher in AH than in AL (693 vs. 573 g, $P < 0.0001$), whereas no difference in ADG from weaning until slaughter was shown between CH and CL (mean 752 g). No differences in ADG from weaning until slaughter were shown between heifers of both breeds slaughtered at 18 vs. 22 months of age. The low weight gains in the last months on pasture affected the ADG of both breeds over the whole rearing period. The low ADG for Charolais heifers during the grazing period could have been due to the high gains during the previous indoor period. Another reason could have been the high grazing intensity at the end of the period, which could have been avoided by a lower stocking rate or grazing of aftermath. The low ADG in indoor period 2 for Angus heifers could have been caused by the low nutritional and hygienic quality of the silage.
The carcasses were heavier in heifers slaughtered at 22 months of age than in heifers slaughtered at 18 months of age (324 vs. 256 kg, $P < 0.0001$ for Charolais, and 244 vs. 196 kg, $P < 0.0001$ for Angus). Carcasses were also heavier in heifers at high feed intensity

than in heifers at low feed intensity (297 vs. 284 kg, *P* = 0.0372 for Charolais, and 233 vs. 207 kg, *P* = 0.0006 for Angus). Charolais heifers slaughtered at 22 months of age had higher conformation and fatness classes than heifers slaughtered at 18 months of age (conformation class 8.9 vs. 7.3, *P* = 0.0033 and fatness class 9.6 vs. 5.9, *P* < 0.0001). In Angus, heifers slaughtered at 22 months of age were fatter than heifers slaughtered at 18 months of age (class 10.2 vs. 7.2, *P* < 0.0001), whereas no differences could be found in conformation (mean 6.3).

Table 2. Daily feed intake (amount and % of live weight) and average daily live weight gain (ADG) during two indoor periods and ADG during a grazing period for 56 Charolais and 56 Angus heifers at low feed intensity (Charolais: silage at *ad libitum* intake; Angus: 80 % of *ad libitum* intake) or at high feed intensity (Charolais: silage at *ad libitum* intake and 2 kg of grain d^{-1}; Angus: silage at *ad libitum* intake) with slaughter at 18 or 22 months of age.

	Feed intensity			Slaughter age		
	low	high	*P value*	18 mo	22 mo	*P value*
	Charolais					
Indoor period 1						
Intake (kg of DM)	6.07	6.70	0.0006	6.58	6.19	0.0039
Intake (% of LW)	1.72	1.84	0.0008	1.84	1.72	0.0013
ADG (g)	910	1045	0.0012	1012	943	NS
Grazing period						
ADG (g)	479	418	NS	466	431	NS
Indoor period 2						
Intake (kg of DM)	8.84	10.03	0.0006	-	9.44	-
Intake (% of LW)	1.61	1.75	0.0009	-	1.68	-
ADG (g)	985	1168	NS	-	1080	-
	Angus					
Indoor period 1						
Intake (kg of DM)	3.69	5.22	< 0.0001	4.36	4.55	0.0476
Intake (% of LW)	1.63	2.02	0.0002	1.81	1.85	NS
ADG (g)	416	840	< 0.0001	606	650	NS
Grazing period						
ADG (g)	798	600	0.0132	686	713	NS
Indoor period 2						
Intake (kg of DM)	6.0	8.51	0.0372	-	7.26	-
Intake (% of LW)	1.38	1.82	0.0472	-	1.60	-
ADG (g)	261	608	0.0039		430	-

Conclusions

It is possible to rear beef heifers by utilising semi-natural grasslands combined with production of high-quality carcasses. Furthermore, indoor feed intensity had a greater effect on feed in-take and gain than slaughter age had, whereas slaughter age had more effect on carcass traits.

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Effective grassland utilisation focused on live-weight gains and carcass data of calves

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Abstract

Grassland utilisation, and live-weight gains and carcass data of suckler cows and calves were measured. Research trials were conducted in semi-production conditions on extensive permanent grasslands throughout the entire grazing season. Measurements of live weight have shown higher growth ability of bulls in comparison with heifers. Over the grazing season the mean daily live-weight gain was 1.057 kg head^{-1}, 0.907 kg head^{-1} for heifers and 1.258 kg head^{-1} for bulls. After control slaughter, the heifer carcasses were classified as R1-02 and bulls carcasses as R1-R2 classes. Killing-out proportion, fat content and fat portion of live-weight were significantly higher for bulls than for heifers, achieving 53.1 %, 3.24 kg and 1.15 %; 50.8 %, 2.7 kg and 1.17 %, respectively. Generally, the meat was assessed as standard meat of young beef cattle with high qualities.

Keywords: grazing, suckler cows, live-weight gains, carcass data, meat quality

Introduction

Livestock systems involving cattle grazing represent an effective connection of functional parts of the food chain. To reach high live-weight gains of calves which correspond with their performance abilities (Brestensky, 1999), large grassland areas are essential for grazing calves with sucklers. Calf growth and development up to one year is very important. Utilisation of growth potential during this period of life results in healthy calves suitable for breeding (heifers) or producing animals for slaughter (realisation in EUROP system). In relation to the coming entrance to the European Union and Common Agricultural Policy, extensification of agriculture production is very topical. It is necessary to focus attention on environmentally friendly agricultural systems in upland and mountain areas. The object of this experiment was to assess grassland utilisation and live-weight gains and carcass data in calves with suckler cows.

Materials and methods

Research trials were conducted in semi-productional conditions on extensive permanent grassland during the entire grazing season. A total of 8 suckler cows and 8 two-three-month-old calves of which half were heifers and half bulls were used in this study. The breed used was Slovakian spotted. All animals grazed herbage *ad libitum* with mineral licks supplied throughout the season, without concentrates. Suckler cows were rotationally grazed with calves in electric fenced paddocks, and had free access to water all day. Hay was supplemented at the beginning of grazing season, during the transition period (changing from the winter feeding ration to the summer one) and during the summer-autumn period. Once per month over the research period, live-weight gains were recorded, and herbage samples taken and analysed for composition and nutritive value. Nutritive value of the sward was calculated from nutrient concentration in the sward using the equation specified in the Decree of the Ministry of Agriculture No. 39/1/2002-100 Annex No 8. When the grazing season was over, the bulls and heifers were slaughtered.

Warm carcass weights were recorded 30 minutes after slaughtering. The cold carcasses were assessed according to the amended Slovak Technical Standard STN 466 120 'The slaughter cattle' and the meat quality and fat content were classified in compliance with the EUROP system. After cooling for 24 hours, carcasses were split in two halves. The right half-carcass was dissected to determine the proportion of meat, bones and separable fat. Carcass characteristics were calculated from obtained data.

Results and discussion

Stocking rate shows grassland utilisation. The highest stocking rate was in Cycle 1 1.01 LU ha $^{-1}$ (1.99 head ha-^{1}). During the grazing season stocking rate decreased until average stocking rate was 0.92 LU ha $^{-1}$ (1.54 head ha-^{1}). Nutrient content and the nutritive value of herbage is given in table 1, and was affected by regime of utilisation, sward developmental stage and weather. Gallo (1998) suggested that successful grazing required nutrient-rich herbage, namely: 18-22 % dry matter (DM) content, fibre 220-260 g kg^{-1} DM, crude protein (CP) 150-170 g kg^{-1} DM and energy content of 6.0-6.2 MJ NEL. The lowest nutritive value was found in Cycle 2 whereas in the next cycles the values increased. The highest nutritive value was found in Cycle 4. DM content varied from 264 to 320 g kg^{-1} and CP content ranged from 113 to 142 g kg^{-1} of DM. Variation in nutrient content and nutritive value (statistical significant difference between grazing cycles) were recorded in relation to micro-climatic conditions over grazing cycles, when higher nutritive value of new grassland herbage was influenced by the weather and atmospheric precipitation (increase of sward nutritive value in Cycle 4).

Table 1. Nutrient content and feeding value of sward in each grazing cycles.

Cycle	From-to	DM	CP	CF (g kg^{-1} DM)	PDIN (g kg^{-1} DM)	PDIE	NEL	NEV (MJ kg^{-1} DM)	ME (MJ kg^{-1} DM)
1	2 May-23 June	264.62	120.10	203.15	87.7	93.5	5.98	5.92	9.82
2	24 June-31 July	319.96	112.65	237.91	73.9	83.6	5.68	5.56	9.58
3	1 August-13 Sept.	274.05	138.56	194.19	85.1	90.8	5.87	5.80	9.85
4	14 Sept.-12 October	270.90	142.04	193.05	91.4	93.8	6.07	6.06	10.13
Tukey (P < 0.05) Cycle		++	++	++	++	++	++	++	++

Live-weight gains of calves are shown in figure 1. The results show higher bull growth potential in comparison to heifers. Heifer finishing growth intensity is lower by 15-25 % compared to bull finishing.

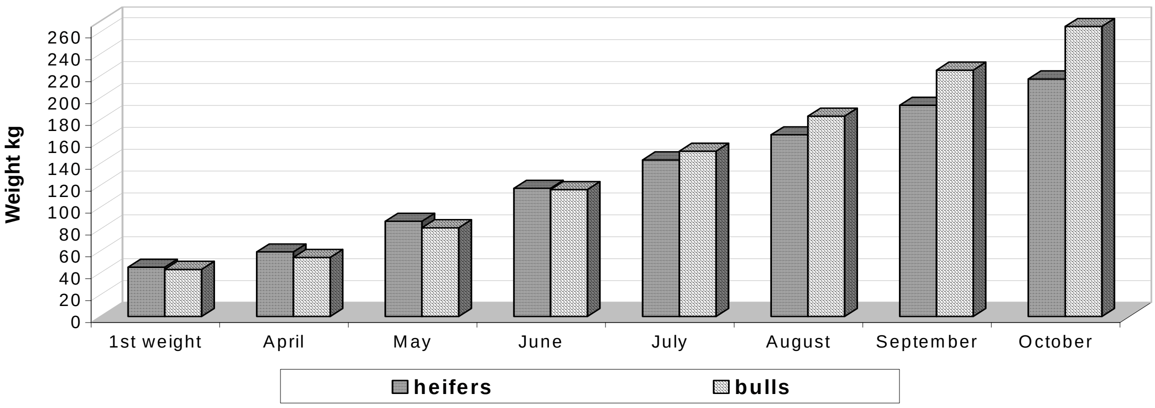

Figure 1. Increase of live weight of heifers and bulls during the grazing season.

Influence of sex is mostly shown in the different temperament and intensity of metabolic processes of male and female. Mean daily live-weight gains are given in table 2.

Table 2. Mean daily live-weight gains of calves at pasture (kg).

Group	Months						
	May	Jun	Jul	Aug	Sep	Oct	Mean
Heifers	0.955	0.955	0.708	0.750	1.034	1.162	0.907
Bulls	1.095	1.192	1.011	1.063	1.770	1.588	1.258
Tukey ($P < 0.05$)	+	+	++	++	++	++	++

Over the grazing season, the mean daily live-weight gains were 1.057 kg head^{-1} for calves, 0.907 kg head^{-1} for heifers and 1.258 kg head for bulls. Similar data (1.1 kg head^{-1}) with calves were reported by Bjelka (2002). Killing-out proportions and carcass characteristics are shown in table 3. Mean killing-out proportions, quantity of total (visceral) fat and fat proportion (of live-weight) were 50.8 %, 2.70 kg, 1.17 % for heifers and 53.1 %, 3.24 kg, 1.15 % for bulls, respectively. The carcass assessment indicated significantly higher killing-out proportion and quantity of total (visceral) fat from bulls. Fat proportion (of live-weight) was not significantly higher from heifers. Using the EUROP classification, heifers were classified as R-O (meatiness classes) and as 1-2 (fat classes). Bull carcasses were classified as R (meatiness classes) and as 1-2 (fat classes). Generally, the meat was assessed as standard meat of young beef cattle having a very high quality. Livestock grazing systems on permanent grasslands allow appropriate production intensity, together with a positive influence of the animal on the landscape.

Table 3. Carcass characteristics.

Parameter	Heifers	Bulls	Tukey ($P < 0.05$)
Slaughter weight (kg)	231	282	
Warm carcass weight (kg)	117.5	149.5	
Killing-out (%)	50.8	53.1	+
Total (visceral) fat (kg)	2.70	3.24	++
Fat of live-weight (%)	1.17	1.15	-
Cold carcass weight (%)	56.3	74.3	
Meat of carcass (%)	72.69	73.06	-
Bones of carcass (%)	22.54	22.30	-
Separable fat of carcass (%)	4.78	4.65	-
EUROP classification	R1-O2	R1-R2	

Conclusions

Carcass data and growth potential of suckler calves with their mothers in extensive grasslands were found to be very high and can compare with calves of meat breed. It is concluded that, this type of grazing system may effectively utilise grasslands, produce meat of high nutritional and dietetic quality, and support sustainable development of upland and mountain areas.

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The effect of inoculant application on legume-grass big bale silage and performance of fattening bulls

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Abstract

Second cut legume-grass (72 % red clover, 20 % timothy, 8 % other, DM content 180 g kg^{-1}) was harvested on 23 August, ensiled using a baler and wrapped with 6 layers of stretch film. The inoculant ‘Feedtech’ *(2 Pediococcus acidilacticci* and *2 Lactobacillus plantarum* and *Cellulase)* was applied using a commercial pump HP-20. After 70 days of storage, the bales were weighed for calculating DM loss and samples were cored out. The inoculant ‘Feedtech’ improved the quality of fermentation of the legume-grass big bale silage by enhancing the production rate and the concentration of lactic acid, reducing fermentation losses and increasing energy value of silage. The inoculated silage contained less butyric acid and ammonia N.

A feeding trial (126 days) with fattening bulls was carried out. Fourteen bulls were assigned on the basis of age and initial weight into two groups and fed silages *ad libitum.* Feed intake was increased by 0.61 kg DM per animal per day when bulls were fed the inoculated silage and resulted in higher weight gain of 94 g per animal and day.

Silage made by applying inoculant did not affect the chemical composition of ground meat and long dorsal muscle.

Keywords: big bale, inoculant, fermentation, lactic acid, live weight gain, meat.

Introduction

During recent years, there has been an increased interest in the use of legumes for silage in low input systems of animal production in northern Europe. Legume crops can be difficult to ensile due to a high buffering capacity and a low water-soluble carbohydrate (WSC) content. In addition, extensive degradation of protein can occur during ensilage. In Lithuania, weather conditions do not always permit sufficient wilting of crop. Formic acid based additives were recommended to ensure good fermentation of wet crops. The use of biological additives can improve the fermentation characteristics and quality of silages (Speijers, 2002).

The number of natural lactic acid bacteria on plants is usually too small in relation to other micro-organisms of epiphytic bacterial flora (Andrieu *et al*., 1996). In order to facilitate and ensure the correct course of the ensilage process, bacterial inoculants are used as additives. The aim of the study was to evaluate the influence of the inoculant ‘Feedtech’ containing lactic acid bacteria and enzyme on the fermentation profile and nutritive value of silage made in big bales and the effect of inoculated silage on the performance of fattening bulls.

Materials and methods

Second cut legume-grass (72 % red clover, 20 % timothy, 8 % other, DM content 180 g kg^{-1}) was cut on 23-24 August and ensiled using a ‘GREENLAND-RF-130’ baler and wrapped with 6 layers of stretch film. Fifty round big bale silages were made without additive (C group) and 50 treated with the bacterial inoculant ‘Feedtech’ (2 *Pediococcus acidilactici*, 2 *Lactobacillus plantarum* and *Cellulase*, Medipharm, Sweden), 10^6 cfu g^{-1} grass (F group). Due to the rain, DM content was low. During ensilage, samples of herbage were collected to determine its chemical composition. Five additive-free bales and five inoculated bales were

weighed after wrapping and after 70 days storing for measuring DM losses. Bales were opened and the fermentation quality and chemical composition of silages were measured.
Each silage was offered *ad libitum* to Lithuanian Black- and- White fattening bulls during a 126-day-trial following 20 days preliminary period. Concentrates were offered at the same level to both groups of bulls. Silage intake was recorded once per week and the bulls were weighed each month. After the feeding period, three bulls from each group were slaughtered and the carcass weight and dressing percentage determined. A sample of *M. longissimus dorsi* (11-13th *thoracic vertebrae*) was collected from the left side of each carcass for meat quality analysis. The meat from the left side of each carcass was ground, and the average sample of 400 g ground meat was taken for analysis. Statistical analysis was carried out by means of procedures described by *STATISTICA* for *Windows* (Sakalauskas, 1998).

Results and discussion

Dry matter content of the legume-grass at harvest was 180 g kg^{-1}. The nutrient contents of the green material per kg^{-1} DM were: 166 g crude protein, 250 g crude fibre and 97 g WSC.
For the legume-grass of the second cut, the inoculant was very efficient and improved the quality of the silage (Table 1). The inoculated silage was subject to more extensive acidification (lower pH-values 0.38 unit). The application of the inoculant significantly enhanced the lactic acid content of the silage (higher 16.9 g kg^{-1} DM). Extensive proteolysis was apparent in the C silages, with ammonia nitrogen contents approximately 10 % of total nitrogen. Use of the inoculant ‘Feedtech’ reduced protein decomposition to ammonia (lower ammonia-N proportions 2.86 %). Inoculation was effective in reducing butyric acid fermentation (lower 0.4 g kg^{-1} DM) and DM losses (lower 2.13 %) in silage. The inoculant 'Feedtech' contains enzymes, which degrade cellulose and hemicellulose. The content of NDF of the inoculated silage was lower by 2.70 % in comparison with the control silage. The energy value of the inoculated silage was 10.6 % higher than that of C silage.

Table 1. Chemical composition and fermentation quality of silages.

	DM g kg^{-1}	Concentration (g kg^{-1}) in DM								pH	NH_3-N % N	DM losses %
		crude protein	crude fibre	NDF	ADF	WSC	lactic acid	acetic acid	butyric acid			
C	214	146	270	518	400	44	32.9	27.2	0.5	4.90	9.67	11.41
F	237	166	231	504	394	46	49.8	13.8	0.1	4.52	6.81	9.28
sed	6.21	3.70	4.21	2.1	3.4	1.5	2.7	0.7	1.2	0.03	0.45	1.2
sig	NS	*	NS	NS	NS	NS	*	**	NS	***	NS	NS

Statistical significance at probably levels *$P < 0.05$, **$P < 0.01$, ***$P < 0.001$

The results of the feeding trial indicated that the average daily intake of the ‘Feedtech’ treated silage was by 0.61 kg^{-1} DM more than that of the control bulls (Table 2). The value of metabolizable energy of the control silage was 8.67 MJ 1 kg^{-1} DM and of the ‘Feedtech’ treated silage 9.59 MJ 1 kg^{-1} DM. The daily contribution of metabolizable energy was 4.9 MJ higher for animals in the F group. Besides, intakes of digestible protein were 0.08 kg d^{-1} higher, too, in comparison with the C group (1 kg^{-1} DM control silage contained 91.41 g digestible protein and 1 kg DM ‘Feedtech’ silage 98.18 g).
The animals in both groups consumed the same daily amount of concentrated feed (1.86 kg^{-1} DM), molasses (0.52 kg^{-1} DM) and hay (0.85 kg^{-1} DM). The growth rate of bulls in both groups was high, and the average daily gain was from 1.120 to 1.214 kg d^{-1}. However, the body weight gain of the bulls fed ‘Feedtech’ treated silage was 8.36 % higher than that in the C group.

Table 2. Results from feeding trials with fattening bulls.

	Intake kg d^{-1}				ME MJd^{-1}	BW gain		Weight kg^{-1}	Control slaughtering data		
	Silage DM	Concentrate DM	Total DM	Digestible protein		kg d^{-1}	Total kg		Killing out, %	Carcass and abdominal fat yield, %	Muscling score, unit
C	7.86	1.86	11.09	0.95	106.6	1.120	141.2	488.3	51.0	53.0	4.22
F	8.47	1.86	11.70	1.03	111.5	1.214	153.0	461.7	51.7	53.8	4.51
sed	0.07	0.0	1.21	0.02	6.21	0.0271	2.31	18.9	0.53	0.46	0.07

Different silages had little influence on several carcass quality traits. The C bulls tended to have lower carcass yield. The meat:bone ratio in the F group was insignificantly higher than that in the C group, leading to the muscling score for this group being 0.29 unit higher. The chemical composition of ground meat and *M. longissimus dorsi* showed no significant differences between the groups. There was a tendency towards lower content of dry matter, protein and fat in the ground meat and higher content of this nutritive matter in the long dorsal muscle in the F group in comparison with the C group. There were no significant differences between the groups for the composition of high molecular weight fatty acids in the long dorsal muscle, althoughh there was a 0.58 % increase of polyunsaturated acid C 18:2 in the fat in the F group. Acid 18:2 is part of the group of omega 6 acids (Wood, 1997), which restrict the risk of coronary heart disease with increasing mean serum LDL-cholesterol levels (Aro, 2002).

In the F group, the pH-values of the long dorsal muscle were lower by 0.41 ($P < 0.001$) unit, colour coefficient was 84.67 ($P < 0.001$) higher, water binding capacity was 0.05 % higher, cooking losses were 0.73 % lower and protein value index was 0.22 ($P < 0.025$) unit higher in comparison with the C group. The nutritive value of this muscle was higher.

Conclusions

Application of inoculant 'Feedtech' had a positive effect upon the quality of the fermentation process and the nutrient levels in legume-grass silage with a low content of DM (21-24 %).

Silage treated with the inoculant had a positive influence on the growth of animals. The daily gain of bulls fed the inoculated silage was higher by 8.36 %, but the inoculant did not affect the chemical composition of ground meat and *M. longissimus dorsi*.

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Performance of finishing Friesian bulls fed TMR based on maize silage or clover hay

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Abstract

A comparative feeding trial was carried out using Friesian bulls to investigate the effect of high energy ration based on maize silage and given at 100 % (T_1) and 85 % (T_2) of *ad libitum* level vs. low energy ration based on clover hay and given at the same respective levels T_3 and T_4, on fattening performance of the bulls. Digestibility analyses were conducted to evaluate the digestibility and feeding value of the experimental rations. Some ruminal parameters and dressing percentage were also investigated. Digestibility of all nutrients were significant higher for rations T_1 and T_2 than those of T_3 and T_4. *Ad libitum* rations (T1 and T_3) had significant higher digestibility of all nutrients than those of restricted ones (T_2 and T_4). An improvement of daily gain was found due to the high energy ration (T_1) compared to the low one (T_3), however, the difference was not significant. Rate of daily gain declined due to the restriction of intake by 85 %. Feed conversion was better with high energy than for low energy rations. Restricting feed to 85 % caused animals of groups T_2 and T_4 to have better feed conversion than those of T_1 and T_3. Dressing percentage was superior for high energy rations and non significant differences were found owing to the restriction of intake.

Keywords: fattening bulls, high energy, restricting feed, maize silage

Introduction

Making silage from maize has become dominant in most developed countries primarily because of its higher nutritive value compared to hay. In Egypt, there are increasing trends towards using a total mixed ration (TMR) system of maize silage, clover hay and concentrates to replacing more conventional rations that mainly consisted of concentrate mixture plus straw as a feeding system for fattening bulls. The maize silage system resulted in superior nutritional and economical value, better daily gain and feed efficiency compared with the traditional concentrate-straw ration. Furthermore 50 % of concentrates could be replaced by maize silage (El-Sayes *et al*., 1997). The objective of this study was to determine the effect of two levels of energy based on maize silage/clover hay using TMR system and two levels of intake, on fattening performance of Friesian bulls.

Materials and methods

The whole maize crop was harvested at dough stage of maturity (~ 90 d after cultivation), chopped at 2-2.5 cm length, ensiled without any additives in bunker silo, fully pressed and isolated by plastic sheet. Third cut of Egyptian clover (*Trifolium alexandrinum*, ‘Meskawi’) was harvested at a height of about 50-60 cm and an age of 50 days before flowering. The traditional method (field-sun cured) of drying on the ground in heaps was employed. Heaps were turned upside and down every two days and baled when moisture content reached to 14.5 % for storage. A feeding trial was conducted using 24 yearling Friesian bulls of an average initial weight of 265 kg. Animals were divided into four similar groups and fed the experimental rations for 225 days in a randomized complete block design. Rations were formulated to be in an isonitrogenous state. They had two different levels of energy based on total digestible nutrients (TDN) value. These were a high energy ration (70 % TDN) based on maize silage and given at 100 % (T_1) and 85 % (T_2) of *ad libitum* level vs low energy one based on clover hay given at the same respective levels T_3 and T_4. Rations were offered to the animals using the TMR feeding system. The ingredients of the experimental rations are presented in table 1 and their chemical composition in table 2.

Table 1. Ingredients (%) of experimental rations, DM basis.

Ingredients	High energy ration	Low energy ration
Concentrate mixture	32.16	64.00
Corn grains	31.80	-
Soybean meal	12.95	-
Clover hay	6.45	32.07
Maize silage	16.64	3.93

Table 2. Chemical composition (g kg^{-1} DM) of rations ingredients.

Ingredients	Dry matter g kg^{-1}	Crude protein	Ether extract	Crude fibre	Nitrogen free extract	Ash
Concentrate mixture	909	164	37	123	594	81
Corn grains	899	86	30	27	843	15
Soybean meal	915	390	15	79	427	80
Clover hay	911	133	28	263	483	93
Maize silage *	336	74	26	173	636	90

*Fermentation properties were pH (4.01), lactic acid (4.22 % of DM), TVFAS (2.12 % of DM) and ammonia-N (5.11 % of total N).

The concentrate mixture (16 % CP) consisted of 32 % undecorticated cotton seed cake, 5 % lineseed cake, 22 % corn grains, 26 % wheat bran, 12 % rice bran, 2 % molasses, 0.5 % limestone and 0.5 % salt. Animal growth rates were measured at regular intervals. At the end of the feeding experiment, a slaughter test was done on two animals from each group after 16-h fasting period. Digestibility trials were conducted simultaneously to assess the feeding value of the rations. Feeds and feces were analysed according to A.O.A.C. (1990). ANOVA was used for analysing the results and LSD for testing the significance.

Results and discussion

Nutrient digestibilities were significant higher ($P < 0.05$) for rations T_1 and T_2 than those of T_3 and T_4 (Table 3). Restricting feed intake to 85 % of the *ad libitum* level (T_2 and T_4) did not increase the digestibility of dry matter and its nutrients but the opposite happened. These results are in agreement with those obtained by Mostafa *et al*. (1993) who found that increased energy diet increased DM digestibility and Albin and Durham (1967) who showed that the digestibility of DM, CP and energy was better with *ad libitum* than with restricted feeding (90 % of *ad libitum*). However, Hicks *et al*. (1990) did not detect any differences in diet digestibility with 20 % reduction in daily feed intake. Feeding value as TDN and DCP had similar trends to that of digestibility among treatments. Regarding ruminal parameters, with increasing levels of energy in rations, pH value was decreased. The 85 %-intake markedly increased pH value. Ammonia-N concentration was lower for the high energy rations than the low ones. This might be in part attributed to the more readily soluble carbohydrates that enhanced the pool ammonia-N for conversion to microbial protein. Ammonia-N was increased slightly with T_2 and significantly with T_4. Hungate (1966) demonstrated that rumen microorganisms utilise more NH3-N when more energy sources are fermented. Intake of DM was significantly higher with animals fed low energy rations than those fed the high energy ones. Improvement of daily gain was found due to the high energy ration (T_1) compared to the low one (T_3) however, the difference was not significant. Daily gain was slightly declining due to the restriction of intake to 85 %. Comparable results were obtained by El-Sayes *et al.* (1997) who investigated two different energy rations with buffalo calves. Feed conversion was ranked better with high energy than with low energy rations. Restricting the diet to 85 % enabled animals in groups T_2 and T_4 to have superior feed conversion. Results consistent with that were obtained by Mostafa *et al*. (1993). Dressing percentage was superior for high energy rations and non significant differences were found due to the restriction of intake. Fat deposition was significant higher for T_1 and T_2 than that of T_3 and T_4. Feed restriction significantly reduced total fat content with the high energy rations but not with the low energy ones. Similarly, Mostafa *et al*. (1993) found an increase in carcass fat with increasing the energy in ration. Murphy and Loerch (1994) concluded that carcass fat was reduced, whereas carcass protein was increased with reductions in daily intake with steers.

Table 3. Digestibility, feeding value, some rumen parameters and fattening performance of bulls fed experimental diets.

Items	T_1	T_2	T_3	T_4
Digestibility, g kg $^{-1}$ DM				
Dry matter	707^a	686^b	656^c	645^c
Crude protein	739^a	706^b	672^c	650^d
Crude fiber	606^a	588^b	558^c	539^d
Feeding values, g kg $^{-1}$ DM				
TDN	724^a	711^a	647^b	620^c
DCP	113^a	108^b	101^c	98^d
Rumen pH	6.52^d	6.64^c	6.71^b	6.74^a
Rumen NH_3-N (mg/100ml)	17.98^c	18.24^{bc}	18.79^b	19.16^a
DM intake (kg d^{-1} h^{-1})	9.04^b	7.68^c	10.44^a	8.87^b
DM intake (g kg $^{-1}$ $w^{0.75}$)	101^b	88^c	121^a	105^b
Daily gain (g)	1097^a	1013^{ab}	982^{ab}	899^b
Kg DM kg $^{-1}$ gain	8.24^b	7.58^b	10.63^a	9.86^a
Dressing percentage	61.0^a	59.2^{ab}	58.3^b	58.4^b
Carcass fat, %*	12.21^a	10.93^b	10.15^{bc}	9.54^c

Different litters within rows indicate statistically significant differences ($P < 0.05$).
* % of fasting live body weight (LBW).

Conclusions

It can be concluded that mild feed restriction to 85 % of *ad libitum* intake with a relatively high energy ration seemed to be most suitable and effective regime for fattening bulls.

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Nutritive value of hays made from different species of cereal for sheep

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Abstract

The Mediterranean semi-arid area is characterised by high seasonality of forage production. In this region, whole crop cereals constitute an alternative for forage because they can be used during the whole phenological cycle, both as grazing and as preserved forage at the last stages of the cycle. Given that inter-specific differences in chemical composition and *in vitro* dry matter digestibility are more important than differences within species, the aim of this study was to compare the feeding value of barley (Albacete), oats (Prevision), rye (local population) and triticale (Trujillo) hays in a digestibility and intake trial. Crops of barley, oats and triticale were cut at milk stage and rye at dough stage. Dry matter digestibility (DMD), organic matter digestibility (OMD) dry matter intake (DMI) and digestible organic matter intake (DOMI) were calculated. The OMD of oats (0.70), barley (0.71) and triticale (0.68) was significantly ($P < 0.001$) different from rye (0.57). Average daily intake (g DMI/BW$^{0.75}$) of oat and triticale were similar ($P > 0.05$) (67.70 and 64.43 respectively) and greater ($P < 0.001$) than for barley (53.80) and rye (54.53).

Keywords: whole-crop cereals, *in vivo* nutritive value, oats, barley, rye, triticale

Introduction

The Mediterranean semi-arid area is characterised by high seasonality of forage production. Different studies have shown that producing cereals for cattle feed is very interesting, due to its high dry matter production, high nutritive quality and possibility of use throughout the whole phenological cycle, both for grazing and forage preserved in the last stages of the cycle. (Helsel and Thomas, 1987). Under the conditions of Aragon, it has been observed that the inter-specific differences with respect to chemical composition and *in vitro* digestibility of dry matter of the winter cereals are more important than the intra-specific differences. The *in vivo* nutritive value of different cereals is unknown, and according to different authors, the results are very variable (McCartney and Vaage, 1994).
The aim of this work is to compare the feeding value of the most important species of cereal grown in Aragon and preserved as hay.

Materials and methods

In autumn 1995, in a semi-arid region of Aragon (Spain), four fields of 4 ha were seeded either with barley (*Hordeum vulgare* Albacete), oats (*Avena sativa* Previsión), rye (*Secale cereale* Local population) or triticale (*Triticosecale Wittmack* Trujillo). All plots were cut the 20 May 1996. The phenological state of barley, oat and triticale was milk stage (code 71 according to Zadocks *et al*. (1974)) and rye was at soft dough stage (code 73). Then the forage was sun-dried under natural conditions till the forage reached a maximum of 20 % humidity.
Samples of each species were taken for determination of ash, crude protein (CP) (AOAC, 1990), neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) (Goering and Van Soest, 1970). Hays were offered to 6 Rasa Aragonesa wethers castrated in order to evaluate the *in vivo* digestibility coefficients (dry matter, (DMD) organic

matter (OMD) and neutral detergent fibre (NDFD)) (Demarquilly *et al*., 1995) and intake (dry matter intake (DMI) and digestible organic matter intake (DOMI)).

Results and discussion

In table 1 the chemical composition data are presented for different species of cereals. The lower value of CP and higher values of NDF and ADF of the rye stands out from the rest of the treatments. The more advanced state of maturity may explain these values. On the other hand attention is called to the quantity of lignin in the triticale hay (2.96) compared with the rest of the species. Khorasani *et al*. (1997) and McCarney and Vaage (1994) also obtained higher quantities of lignin in the triticale than in the forage of barley and oats.

Table 1. Ash, crude protein (CP), neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) (%) of whole crop cereals hays (g kg^{-1} DM).

	Ash	CP	NDF	ADF	ADL
Barley	5.70^{a}	8.02^{a}	59.03^{b}	25.56^{b}	1.71^{b}
Oats	5.93^{a}	7.96^{a}	55.89^{b}	31.89^{b}	1.46^{b}
Rye	5.48^{a}	6.78^{c}	70.79^{a}	42.91^{a}	1.49^{b}
Triticale	5.85^{a}	7.47^{b}	50.37^{b}	28.92^{b}	2.96^{a}
TE	ns	*	*	*	*
SE	0.36	0.11	2.18	1.80	0.14

TE = treatment effect; ns $P > 0.05$; * $P < 0.05$; SE = standard error. Means in the same column with different letters were significantly different ($P < 0.05$).

The results obtained from the analysis of variance for the DMD, OMD, NDFD, DMI and DOMI are given in table 2. Concerning the values of DMD, OMD and NDFD, the barley hay presented higher values ($P < 0.05$) than the rye and triticale hays and higher digestibility coefficient of the dry matter and of the neutral detergent fibre ($P < 0.05$) than those of the hay made from oats. McCartney and Vaage (1994) also observed that the digestibility coefficient of the dry matter of barley was higher than that of the oats and triticale, attributing this to the higher grain percentage of the barley. In our experiment, the percentage of barley ears (35 %) was higher ($P < 0.05$) that that of triticale (31 %), but it was similar to the percentage of oats and rye grain (36 and 34 % respectively).

Table 2. Dry matter digestibility (DMD), organic matter digestibility (OMD), neutral detergent fibre digestibility (NDFD), dry matter intake (DMI) (g/kg $BW^{0.75}$) and digestible organic matter intake (DOMI) (g/kg $BW^{0.75}$).

Number of cut	DMD	OMD	NDFD	DMI	DOMI
Barley	0.69^{a}	0.71^{a}	0.65^{a}	53.80^{b}	38.26^{b}
Oats	0.67^{b}	0.70^{ab}	0.62^{b}	67.70^{a}	47.11^{a}
Rye	0.56^{c}	0.57^{c}	0.56^{c}	54.53^{b}	31.48^{c}
Triticale	0.65^{b}	0.68^{b}	0.56^{c}	64.43^{a}	43.67^{ab}
TE	***	***	***	**	***
SE	0.01	0.01	0.01	6.61	4.76

TE = treatment effect; ** $P < 0.01$; *** $P < 0.001$; SE = standard error. Means in the same column with different letters were significantly different ($P < 0.05$).

Concerning the DMI, the amounts of oats and triticale hays ingested were higher ($P < 0.05$) than those of barley and rye. The differences between cereal forages obtained by different authors are attributed to differences in palatability (McCartney and Vaage, 1994), presence or absence of awns (Demarquilly, 1970; Hadjipanayiotou and Economides, 1983) or different phenological state (Borowiec *et al*., 1998; Crovetto *et al*., 1998). This one can explain partially the lower intake of rye compared with the others hays. However, the differences in chemical composition can also explain the different intake between oats and triticale and barley.

Conclusions

The digestible organic matter intake of oats hay was similar to that of triticale hay and higher than the feeding value of the other species of whole crop cereal hays.

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Quality and feeding value of berseem (*Trifolium alexandrinum* L.) ensiled with crushed corn grains or molasses

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Abstract

The objective of this work was to study the effect on silage quality, silage digestibility and lamb performance of adding crushed corn grains at 40 and 60 g kg^{-1} (CG_{40} and CG_{60}) or molasses 50 g kg^{-1} (M_{50}) to berseem (*Trifolium alexandrinum* L.) silage. The silages were fed *ad libitum* to 24 Rahmany lambs in four similar groups arranged as a randomised complete block design. Three groups were fed the silages along with concentrate feed mixture (CFM) at 10 g kg^{-1} live weight (LW) and the fourth group was fed the traditional ration of CFM at 20 g kg^{-1} LW plus rice straw *ad libitum*. Good silage was obtained with both CG_{40}, CG_{60} and M_{50} additives, as indicated by low pH values (3.8-4.0) and good restriction of the de-amination process. CG_{40} and CG_{60} additives significantly ($P < 0.05$) increased nutrient digestibility and feeding values as total digestible nutrients (TDN) and digestible crude protein (DCP) over M_{50} or the traditional ration. The animals fed CG_{40} and CG_{60} silages consumed more DM and TDN and produced more body weight ($P < 0.05$) than when fed with M_{50} or the traditional ration (average daily gains were 132, 136, 100 and 85 g, for the CG_{40}, CG_{60}, M_{50} and traditional rations respectively). Conserving berseem with CG_{40} and CG_{60} is recommended.

Keywords: berseem, feeding value, lamb performance, silage additives

Introduction

Berseem (*Trifolium alexandrinum* L.) is the main forage crop in Egypt from December to May. Its production exceeds livestock requirements during this period. It is advisable, therefore, to conserve the surplus forage as hay or silage to be used during the summer period when animals are usually suffering from a shortage of summer feeds. Making hay from berseem using traditional methods is wasteful, mostly due to leaf losses and subsequent nutrient losses of up to 70 % (Abdel-Malik, 1972). Making silage appeared to be more promising by reducing losses to 17-20 % (Etman *et al*., 2000, Etman *et al*., 2002). However, ensilage of berseem is difficult without suitable additives. The objective of this work was to study the effects of adding crushed corn grains (CG) at 40 and 60 g kg^{-1} berseem or molasses (M) at 50 g kg^{-1} berseem. The quality and feeding values of the silages, and their effects on lamb performance, were compared with the traditional summer ration which consists of rice straw *ad libitum* plus costly concentrate feed mixture (CFM) at 20 g kg^{-1} of live weight.

Materials and methods

The 4th cut of berseem was harvested prior to flowering when about 50 cm high at Ismailia Agricultural Research Station of the Ministry of Agriculture. The forage was chopped to 3-5 cm and mixed with the assigned additive and conserved in 20 t capacity trench silos, pressed by a tractor and covered with plastic sheet. Corn grains were crushed and molasses were applied as a 1:1 aqueous solution. Silages were stored in silos for three months before being opened for feeding.

The four experimental rations were evaluated in a 100 day feeding trial using 24 Rahmany lambs divided into four similar groups, arranged as a randomized complete block design.

Three groups were fed the assigned silages *ad libitum* along with 10 g kg^{-1} CFM and the fourth group was fed the traditional ration of 20 g kg^{-1} CFM plus rice straw *ad libitum* for comparison. The animals were weighed at the beginning of the trial and biweekly there after. The digestibilities of the experimental rations were evaluated using digestibility trials comprising 12 rams (3 rams each) and a total collection method. Representative samples from feeds used, faeces and silage pH were chemically analysed according to A.O.A.C. (1990) procedures. Statistical analysis and comparisons among means were carried out using methods described by Snedecor and Cochran (1982).

Results and discussion

The chemical composition of feed ingredients and experimental rations are shown in table 1. The data indicated higher OM digestibility values for the CG silage or M silage than for those of the traditional ration. While CP and CF digestibilities for the traditional ration were significantly ($P < 0.05$) higher than those for the remainder (Table 2). These increases in nutrient digestibility might be responsible for the increase in DM intake since ruminant intake is positively correlated with the digestibility of the diet (Waldo and Jorgensen, 1981). TDN and DCP of the silages increased with increasing level of CG additive. Hathout and Radwan (1996) reported the same trend. Good berseem silages were obtained both with CG_{40}, CG_{60} and molasses additives, identified by low pH values (3.8-4.0) and good restriction of the de-amination process.

Corn grain additives CG_{40} and CG_{60} and M_{50} significantly increased ($P < 0.05$) nutrient digestibility and feeding values as total digestible nutrient (TDN) and digestible crude protein (DCP) in comparison with the traditional ration. The animals fed CG_{40} and CG_{60} silages consumed more DM and TDN, resulting in higher ($P < 0.05$) average daily gain than those fed either M_{50} silage or the tradition ration, with 132, 136, 100 and 85 g respectively. However, lambs fed CG_{40} silage showed better feed conversion than those fed either CG_{60} or M_{50} as additives.

It was concluded that conserving berseem with CG_{40} and CG_{60} resulted in silage of high quality and enhanced nutrient digestibility and nutritive value. This resulted in better lamb performance and can effectively replace the traditional ration with a substantial reduction in feeding costs of ruminants. Moreover, M_{50} treatment allowed better feed utilisation than the traditional ration. After the recent sharp increase in price of concentrates the choice of whether to use CG_{40}, CG_{60} or M_{50} needs to be based on up-to-date economic comparisons.

Table 1. Chemical composition of feed ingredients used and the experimental rations.

Item	Chemical composition (g kg^{-1} DM)						
	DM	OM	CP	EE	CF	Ash	NFE
4^{th} cut of berseem	216	870	166	26.2	152	130	525
Rice straw	904	831	42	22.0	323	169	444
CFM	879	918	176	40.9	99	82	602
CG_{40} Silage	264	881	119	31.9	168	119	562
CG_{60} Silage	289	895	129	34.4	172	106	559
M_{50} Silage	243	871	149	31.7	161	129	529

Table 2. Digestibility coefficients, nutritive values and lamb performance when fed the experimental rations.

Item	Experimental rations			
	CG_{40} Silage	CG_{60} Silage	M_{50} Silage	Traditional ration
Digestibility coefficient:				
OM, g kg^{-1}	703^{a}	686^{b}	704^{a}	680^{b}
CP, g kg^{-1}	678^{b}	679^{b}	668^{b}	711^{a}
CF, g kg^{-1}	303^{c}	363^{b}	360^{b}	451^{a}
Nutritive values (g kg^{-1}):				
TDN	656^{a}	663^{a}	660^{a}	611^{b}
DCP	99^{a}	100^{a}	109^{a}	78^{b}
Av. Daily intake (g DM)	587	653	537	965
Av. Daily TDN intake (g)	385	433	354	589
Av. Daily DCP intake (g)	58	65	58	75
Average daily gain (g)	132^{a}	136^{a}	100^{b}	85^{b}
Feed conversion:				
Kg TDN kg^{-1} gain	2.92^{b}	3.18^{b}	3.58^{b}	6.93^{a}
Kg DCP kg^{-1} gain	0.44	0.48	0.59	0.88

Means on the same row with the same superscript do not differ significantly.

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Optimizing the offer of selenium and iodine to sheep in different mountain areas of South Bulgaria during the suckling and grazing period

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Abstract

The experiments were carried out with 24 ewes of the Rhodope Zigay breed, divided into two groups (2 x 12). During the winter period, the animals were fed with meadow hay and grain concentrate mixture. Complete diet contained low levels of selenium (0.074 mg kg^{-1} DM) and iodine (0.126 mg kg^{-1} DM). The control group received additionally 0.25 mg Se d^{-1} in the form of $NaHSeO_3$ and 0.10 mg I d^{-1} as KI during the investigation period (150 days).
The insufficient Se and I offer during pregnancy and the first 56 days of lactation led to decreased milk production and daily fat and protein secretion (19 %, 17 % and 21 %). During the grazing period the average Se and I offer was estimated after a detailed mapping (May-September) of two different pasture areas. From May to July, the unsupplemented ewes produced 10.8 % less milk with natural fat content daily and 12 % less milk protein in comparison to the supplemented group. The daily fat production was decreased by 7.2 %. For normal milk performance in lactating sheep reared in the mountain regions, a correction in the Se and I offer was needed.

Keywords: sheep, pasture grass, Se-I-deficiency, milk composition, Se-I-requirements

Introduction

Most of the investigations in Bulgaria have dealt with milk yield, fat and protein content (Kafedjiev *et al*., 1998; Mihaylova and Dimov 2000; Pertova *et al*., 1998a), and had not taken into account the influence of the trace element offer on milk performance. The effect of trace element supplementation in feed ration of different sheep breeds on the milk yield and milk performance during the lactation period has not yet been investigated. The established imbalance of the basic essential elements (Se, I, Zn, Co) in the flora of the mountain areas have been shown negatively to affect the milk production and status of ewes (Petrova *et al*., 1999; Angelow *et al*., 2000). The objective of the present study was to establish the effect of Se and I supplementation to the feed of lactating sheep (Rhodope Zigay breed) on the milk, fat and protein production during the suckling period (56 days) and after the weaning of lambs (60-150 days).

Materials and methods

The experiments were carried out with 24 ewes of Rhodope Zigay breed, divided into two groups. During the winter period the animals were fed with 1.8 kg meadow hay and 0.6 kg concentrate mixture. The complete diet contained low levels of selenium (Se) – 0.074 mg Se kg^{-1} DM and iodine (I) – 0.126 mg I kg^{-1} DM. During the grazing period depending on the vegetation stage of the flora, the animals were grazed on pasture with different amounts of selenium and iodine. From 15 May to 15 July the pasture grass contained on the average 0.085 mg Se kg^{-1} DM and 0.093 mg I kg^{-1} DM. During the investigation period (150 days) the control group received 0.25 mg Se d^{-1} additionally in the form of $NaHSeO_3$ and 0.10 mg I d^{-1} as KI.
Milk samples were taken on the 14th, 28th, 42nd, 56th day (suckling period) and on the 60th, 90th, 120th, 150th day (grazing period). Milk protein was determined using Milk tester of Foss

Electric (Denmark) and milk fat by Gerber's method. Statistical analyses were performed using the 'General Statistic Pack' of Hewlett Packard.

Results and discussion

The effect of selenium and iodine supplementation on the milk production was investigated during the first 56 days of lactation (Table 1).

Table 1. Effect of selenium and iodine deficiency on milk production and some parameters of ewe's milk during the suckling period (1-56 day).

Parameter $n_{1,2}$ = 48; 48	Control group* $\bar{x}$	$\pm S_{\bar{x}}$	Se-I-deficient group** $\bar{x}$	$\pm S_{\bar{x}}$	*P*	%
milk (ml d^{-1})	686.2	26	554.4	25	< 0.001	81
fat secretion (g d^{-1})	29.3	0.89	24.4	0.78	< 0.001	83
protein secretion (g d^{-1})	36.6	1.34	29.2	0.95	< 0.001	79
fat content (%)	4.27	0.13	4.40	0.09	> 0.05	103
protein content (%)	5.34	0.07	5.27	0.25	> 0.05	99

*control=100 %, **deficient=X %

The milk produced by the control and deficient ewes differed significantly. At any time the control animals secreted more milk (76-163 ml d^{-1}) with natural fat content compared to the deficient ewes. The Se and I deficiency during the first 56 days of lactation led to an inhibition of milk yield of the experimental animals by 19 % (686 ml d^{-1} vs. 554 ml d^{-1}). The decreased milk yield affected negatively the daily fat and protein secretion in the ewe's milk.
From the 14th to the 56th day of lactation the deficient animals secreted milk with higher fat percentage (4.40 vs. 4.27). In spite of that a highly significant difference ($P < 0.001$) of 17 % was determined in the average daily butterfat yield between the two groups (29.3 g d^{-1} vs. 24.4 g d^{-1}). The low milk yield led to a suspension of protein synthesis. The unsupplemented animals produced on the average 21 % less milk protein in comparison to the control group (36.6 g d^{-1} vs. 29.2 g d^{-1}).
The permanent grassland on gneiss and syenite weathering soils contained low concentrations of Se (0.085 mg Se kg^{-1}) and I (0.093 mg I kg^{-1}) during the whole period (May-July) and affects in a similar way, but to a smaller extent, the milk performance after the suckling period of lambs.

Table 2. Effect of selenium and iodine deficiency on the milk production and some parameters of ewe's milk after the suckling period (60-150 day).

Parameter $n_{1,2}$ = 48; 48	Control group* $\bar{x}$	$\pm S_{\bar{x}}$	Se-I-deficient group** $\bar{x}$	$\pm S_{\bar{x}}$	*P*	%
milk (ml d^{-1})	362	19	323	20	> 0.05	89.2
fat secretion (g d^{-1})	25.1	2.9	23.3	3.0	> 0.05	92.8
protein secretion (g d^{-1})	22.5	0.85	19.8	0.7	< 0.05	88.0
fat content (%)	6.94	0.15	7.20	0.17	> 0.05	104
protein content (%)	6.20	0.08	6.14	0.11	> 0.05	99

*control=100 %, **deficient=X %

The amount of milk produced by the control and deficient ewes differed significantly only during the first period (Table 2). At any time the control group produced more milk (19-86 ml d^{-1}) with natural fat content in comparison to the deficient one. The average daily milk production was reduced by 11 % (362 ml d^{-1}, respectively 323 ml d^{-1}). The milk yield obtained was similar to the results for the South Corriedale breed: 293-298 ml d^{-1} (Todorova

and Petrova, 1994) and the estimated data for the Karakachan breed – 210 ml d^{-1} (Odjakova *et al*., 2002).
At all measured points the unsupplemented ewes produced milk with a higher fat content in comparison to the control group. The selenium and iodine deficiency led to an increase of the milk fat content by 0.26 points during the whole investigation period. These results correlated very well with the findings established by Petrova (1998). The control group produced insignificantly more milk fat daily than the deficient one (25.1 g d^{-1} vs. 23.3g d^{-1}).
The same effect was found concerning the changes in the protein content and the daily protein secretion between the two groups. In principle, the Se-I deficient sheep produced lower protein milk in comparison to the control animals (apart from the second period – 90th day). The protein secretion of ewes without Se- and I-supply was negatively influenced. The average daily protein secretion differed significantly only for the 1st and 2nd measured points. During the whole period the supplemented animals produced more milk protein, than the deficient ewes ($P < 0.05$).

Conclusions

The supplementation of ewes during the suckling and grazing period, with 0.25 mg Se per day and 0.10 mg I per day, had a positive effect on milk yield and composition. From the 1st to the 56th day of lactation (suckling period), the supplemented animals produced 19 % more milk, 21 % more milk protein and 17 % more milk fat ($P < 0.001$). After the weaning period (April-July), the Se-I-deficient ewes produced 11 % less milk with natural fat contents and 12 % less milk protein daily. During the grazing period the daily fat production decreased by 7.2 %. The results obtained showed that a correction in the Se and I offer in the ration of lactating sheep was needed to improve milk performance.

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Effect of slurry application on grass and silage quality and intake in sheep

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Abstract

The effect of cattle slurry (40 t ha^{-1}) spread on the grass surface or injected into the soil and NPK fertiliser (60 kg N ha^{-1}) with or without irrigation on grass voluntary intake in sheep was studied in two years. The timothy-meadow fescue ley was fertilised after the first cut, mown 40 and 36 days after the treatments in Exp. 1 and 2 and frozen for palatability experiments using six sheep in a 6 × 6 Latin square design. Surface application of slurry decreased significantly grass intake and grass crude protein content in both years compared with injection of slurry or NPK fertiliser. Irrigation had no significant effect. Grass mixture leys for silage fertilised in three years with surface application or injection of slurry (40-60 t ha^{-1}) supplemented with mineral fertiliser (37-60 kg N ha^{-1}) were compared with NPK fertilisation (80-100 kg N ha^{-1}). The grass was harvested with a flail harvester and ensiled using acid or no additive. The silages were offered to six sheep using a 3 × 3 Latin square design. The fermentation quality of all the silages was good, but the intake and the microbiological quality varied. Compared with injection the surface application of slurry decreased significantly the silage intake in one experiment and increased clostridia spores in two experiments.

Keywords: slurry, grass, silage, quality, intake, sheep

Introduction

Specialization in grass production on expanding dairy farms increases the need to spread slurry on grassland. However, slurry application may have adverse effects on the quality and intake of grass and silage. Harmful and/or pathogenic microbes in the slurry may constitute a risk for food safety in the milk production chain from field to table.
The aim of this study was to investigate the effects of cattle slurry application by spreading on the grass surface or by injecting into the soil and NPK fertilisation on grass intake (2 trials) or silage fermentation and microbiological quality and intake (4 trials) in sheep.

Materials and methods

In two experiments in successive years timothy-meadow fescue ley on a sandy clay soil was fertilised after the first cut in June with 20, 40 or 60 t ha^{-1} of cattle slurry by broadcast spreading on the surface of the grass or by injecting into the soil (12 cm depth) or with 200 and 400 kg ha^{-1} NPK fertiliser (20-4-8). Half of the grass plots were irrigated with 30 mm of water during the night following fertilisation. The rainfall between fertilisation and cutting was 86 and 68 mm in Exp. 1 and 2. The grass was cut 40 or 36 days after the treatments in successive years using a Haldrup 1500 experimental mower. Grass cut from each of the slurry surface or injection plots of different application rates (20 + 40 + 60 t ha^{-1}) and grass from the NPK fertiliser plots (200 + 400 t ha^{-1}) were combined and mixed thoroughly to obtain sufficient grass for animal trials. Thus the mean fertilisation of the grass was 40 t ha^{-1} of slurry (containing 80 kg soluble N ha^{-1}) or 60 kg N ha^{-1} of NPK fertiliser. The fresh grass was frozen (-20 ºC) prior to the palatability experiment. Grass was given *ad libitum* according to a 6 × 6 Latin square design to six Finnsheep wethers in both trials. The experimental period was 7 days in Exp. 1 and 6 days in Exp. 2. In three successive years, mixture leys for silage on a clay soil were fertilised after the first cut in June with cattle slurry by surface or injection application of 60, 40 and 60 t ha^{-1} supplemented with 37, 52 and 60 kg N ha^{-1} as calcium nitrate or NPK fertiliser, respectively. The slurry treatments were compared with NPK fertiliser giving 80, 102 and 100 kg N ha^{-1}. The grass was harvested 36, 40 and 36 days after the treatments and during that time the rainfall totalled 68, 140 and 54 mm in the three years, respectively. The grass was direct cut with a flail harvester and ensiled in fibreglass tower silos with a formic acid-based additive (800 g kg^{-1} formic acid + 20 g kg^{-1} orthophosphoric acid) applied at a rate of 5 l t^{-1} (Exp. 1 and 4) in the first and third year. In the second year, no additive (Exp. 2) or an acid-lignosulphonate mixture (formic acid 250 g kg^{-1}+ acetic acid 155 g kg^{-1} + hydrochloric acid 95 g kg^{-1} + lignosulphonate 500 g kg^{-1}) applied at a rate of 6 l t^{-1} (Exp. 3) was used. The silos were opened 133, 71, 104 and 84 days after ensiling in Exp. 1-4, respectively. The silages were offered *ad libitum* to six wethers according to a 3 × 3 Latin square design. The experimental period was 14 days in Exp. 1, 3 and 4, and 7 days in Exp. 2. The digestibility of the silages was measured in Exp. 1. The data were analysed statistically using the SAS GLM procedure. Animal, period and treatment effects were used in the model, and the sums of squares for the treatment effects were further divided into contrasts.

Results and discussion

Soil injection of slurry raised the crude protein content of the grass and silage more than surface application, reflecting a poorer N utilisation in slurry surface treatment which was found in previous studies (Kemppainen, 1989). The crude protein content of grass treated with NPK, slurry surface and injection application was 131, 115 and 138 in Exp. 1 and 131, 113 and 141 g kg^{-1}dry matter (DM) in Exp. 2, respectively. Otherwise differences between treatments were small. Slurry surface application decreased grass DM intake on an average 25 % and 32 % in Exp. 1 and 2, respectively, compared with slurry injection and NPK fertilisation (Table 1). The effect of irrigation was variable and non-significant.

Table 1. Effect of NPK, slurry surface and injection application with (+) or without (-) irrigation on voluntary DM intake of grass g d^{-1} in sheep in two experiments (ls means).

Experi-ment	NPK-fertilisation		Slurry application				SEM	Significance (P-values)		
			Surface		injection			NPK / surface	NPK / injection	surface / injection
	-	+	-	+	-	+				
Exp. 1	1492	1335	1059	1118	1512	1466	83-120[1)]	0.009	0.498	0.001
Exp. 2	1641	1590	1066	1138	1568	1647	60-68[1)]	<0.001	0.900	<0.001

[1)] The higher SEM values are for treatments with two missing values in Exp. 1 and one missing value in Exp. 2.

All the silages were well preserved regarding fermentation quality. The formic acid silages were less fermented than the other silages, having higher water-soluble carbohydrate (WSC) and lower lactic and acetic acid contents (Table 2). The silages without additive had lactic acid-dominated fermentation supported by a higher number of acid-forming bacteria (7.6-7.8 log colony-forming units (cfu) per g) compared with the other silages (4.7-5.3 log cfu g^{-1}). Only traces of butyric acid were found in silages from slurry surface-treated grass in three experiments, and once in NPK-silage without additive. In spite of a low butyric acid content the number of clostridia spores was high (>1000 most probable number (MPN) g^{-1}) in all the silage samples from slurry surface-treated grass in Exp. 1 and 2, the highest numbers being >11000 MPN g^{-1} in Exp. 1 and 4500 MPN g^{-1} in Exp. 2. The number of coliform bacteria was below the detection limit <10 cfu g^{-1} in all the samples except for two samples in Exp. 2. Yeasts counts were high in the silages without additive from all the treatments. Mould counts were low except in silage from the slurry surface treatment in Exp. 3. The silage organic matter digestibility of the NPK, injection and surface treatments in Exp. 1 were 0.709, 0.703 and 0.695, respectively, being lower ($P < 0.02$) in slurry surface- than NPK-treated silage.

Table 2. Effect of NPK, slurry surface and injection application supplied with N or NPK fertilisation on silage composition and quality using different silage additives (parentheses).

Chemical composition and quality	Exp. 1 (formic acid)			Exp. 2 (no additive)			Exp. 3 (acid-lignos)			Exp. 4 (formic acid)		
		Slurry			Slurry			Slurry			Slurry	
	NPK	sur-face	injec-tion	NPK	sur-face	injec-tion	NPK	sur-face	injec-tion	NPK	sur-face	injec-tion
DM, g kg^{-1}	216	232	223	173	175	168	173	179	164	237	222	221
Ash, g kg^{-1} DM	115	125	122	84	93	89	87	91	95	91	99	108
Crude protein "	132	130	147	140	142	164	141	128	160	149	155	160
Crude fibre "	289	282	263	302	291	293	288	288	282	281	282	282
pH	3.98	3.92	3.89	3.94	3.85	4.06	3.88	3.79	3.83	3.81	3.76	3.75
WSC,g kg^{-1} DM	70	74	79	7	13	11	27	36	17	61	46	56
Lactic acid "	56	51	49	111	106	109	83	81	85	68	64	53
Acetic acid "	11	9	10	20	19	24	19	20	20	11	10	9
Butyric acid "	0	0.1	0	0.6	0.6	0	0	0.5	0	0	0	0
Ethanol "	6	5	3	8	9	7	4	7	5	4	5	3
NH_4-N g kg^{-1} N	56	52	45	49	52	53	56	53	49	35	42	35
Clostridia spores log MPN g^{-1}	1.5	>3.5	<1.3	2.1	3.3	2.7	<0.5	0.9	<0.5	<0.6	<0.9	<1.1
Yeasts log cfu g^{-1}	<2.0	<1.7	<1.7	6.6	6.8	7.2	4.9	4.4	3.2	<3.0	3.9	3.7
Moulds "	<2.0	<1.7	<1.7	<2	<2	<2	<2.5	4.2	2.6	<1	<1	<1.1

Propionic acid was found only in silages without additive (Exp. 2): 0.6, 1.0 and 0.2 g kg^{-1} DM, respectively

Surface application of slurry affected silage intake inconsistently and less than grass intake. (Table 3). Surface application decreased the silage DM intake significantly (20 %) compared with injection only in Exp. 1. There was no significant difference between the treatments in Exp. 2. In Exp. 3, surface application resulted in a higher silage intake than injection, and a similar tendency was seen in Exp. 4, where the highest silage intake was found with the NPK treatment. The rainfall after slurry application in Exp. 2-3 was more than twice that in Exp. 1 and 4, which may have affected the results.

Table 3. Effect of NPK, slurry surface and injection application supplied with N or NPK on silage voluntary DM intake in sheep in four experiments with different silage additives.

Expt. No.	Silage additive	NPK	Slurry application		SEM	Significance (P-values)		
			surface	injection		NPK / surface	NPK / injection	surface / injection
		g d^{-1}	g d^{-1}	g d^{-1}				
1	formic acid	1168	1026	1291	59	0.127	0.178	0.013
2	no additive	914	1010	1002	42-49[1)]	0.180	0.179	0.907
3	acid-lignos.	1069	1175	1047	36	0.072	0.671	0.036
4	formic acid	1753	1686	1597	32	0.173	0.008	0.083

[1)] The higher SEM value is for surface-treatment with one missing value

Conclusions

Surface application of slurry on grass by broadcast spreading is not recommended due to lower intake of grass and poorer N utilisation compared with soil injection of slurry or NPK fertilisation. In spite of good fermentation quality of silages made from grass treated with slurry surface application, they may contain high amounts of clostridia spores, decrease intake of silage and constitute a hygienic risk. However, the results may be variable partly due to weather conditions. Chemical composition or fermentation quality does not always indicate palatability differences of grass or silage made from slurry-treated grass.

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Pig production responses to a grassland based outdoor system

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Abstract

An experiment was conducted to examine the effects of grassland-based rearing of Pannonhybrid F1 gilts on their performance. The experiment started with 28 gilts kept outside on pasture day and night and 28 gilts kept in an indoor system. After the first artificial insemination pastured gilts were kept on pasture for their gestation. For some of the pastured gilts for farrowing individual huts were provided on pasture. At first farrowing seven sows and at the second one four sows were taken there. The rest of pasture-reared sows were taken to indoor farrowing crates just like indoor-reared sows. After weaning these pasture-reared sows were taken back to pasture again. Age of sows at first farrowing was higher by 41.4 days in Indoor group (402.8 vs. 361.4 days, $P < 0.01$). At the first farrowing the weight and number of piglets and at the second farrowing the number of piglets were higher for the outdoor-reared and farrowed sows.

Keywords: farrowing, grassland, hut, outdoor, sorting out, sow

Introduction

Nowadays, the indoor system is characteristic of the intensive Hungarian pig farms. It has been getting clear, that intensive, closed housing system of gilts and breeding sows results in higher reproduction and injury problems (Dagorn and Aumaitre, 1979; Kovács, 1981; Kovács and Rajnai, 1987). These increase a lack on animal welfare and rate culling of breeding sows. In addition the increasing demands of consumers for healthier food makes pressure on research for alternative production methods in pig industry. Because of above mentioned facts farmers are considering outdoor pig production, which could be an interesting solution (Larsen and Kongsted, 1999). In a series of investigations indoor and grassland based outdoor pig production systems were compared. Results on concentrate consumption, daily live weight gain, insemination pattern of the age at first insemination and fertility rates of the gilts from the two systems has already been reported (Alexy *et al.*, 2003). This time results on reproductive performances of sows will be presented. The comparison of the two systems will include litter size and piglets' weight at birth, numbers and weights of piglets at 21st day and at weaning, piglets mortality till weaning, culling rates and reasons of sows.

Materials and methods

In October 2000, 1.5 ha perennial ryegrass (*Lolium perenne*) ley was established for the gilt rearing experiment. The area belonged to a conventional, intensive pig farm in southeastern Hungary. In July 2001, the well established grassland was divided into three paddocks with electric fences. Soon thereafter, 28 gilts (Pasture group) were placed out to the first paddock. At the same time 28 gilts of the same age (Indoor group) were selected from the indoor farm animals and were put to barns with outruns. Gilts of the Pasture group have sisters in the Indoor group, and all belonged to Pannonhybrid F1 motherline (Hungarian Largewhite x Hungarian Landrasse). Average starting weight of the gilts was 55.4 kg and 55.6 kg in the Pasture and Indoor groups, respectively.

The Pasture group was provided with a self-feeder (made of steel, roofed), a drinker (authomatic, three-nipples in Summer, a trough in Winter), and a 24 m^2 wooden hut with plenty of straw litter. Feeding technology, feeding times and concentrates offered were the same in the two groups. During the first phase of rearing *ad libitum* feeding was applied, which lasted for 90 days form 11 July till 11 October. Thereafter daily rates of concentrates was decided and fed according to the nutrient requirement standards of the gilts. Artificial insemination was used for both groups. Pastured gilts were kept on pasture for their gestation period as well. The Pasture group (A) was subdivided into two groups: farrowing on pasture in individual huts (A_1) and farrowing in crates indoor (A_2) as like Indoor group (B). The age of sows at first farrowing was recorded. Numbers and individual weights of piglets were measured at birth, on day 21 after birth and at weaning. Data were analysed with SPSS 11.0 and Microsoft Office 2000 Excel. Statistical analysis included variance analysis, regression and covariance.

Results and discussion

The age at first farrowing is shown in table 1. We found that the Pasture group (A) was 41.4 days younger than Indoor group (B) (P < 0.01). This difference is explained by the higher number of sows in indoor group which came back to oestrus (three and seven gilts for Pasture and Indoor group, respectively).

Table 1. Age at the first farrowing.

	Pasture group (A)	Indoor group (B)
Age at first farrowing (day)	361.4	402.8
$LSD_{0,01}$	11.1	

Weights of piglets at birth were the same in the two groups. Numbers of piglets at first farrowing were also the same. At second farrowing Pasture group (A) had higher numbers of piglets. However, it was not significant either.

Table 2. Number and weights of piglets at birth during two farrowings.

Number of farrowings	litter size (no. piglets)		sig.	weight at birth (kg piglet^{-1})		sig.
	A	B		A	B	
first	9.6	9.5	ns	1.54	1.54	ns
second	11.4	9.8	ns	1.65	1.50	ns

For the first (spring) farrowing weights and numbers of piglets on day 21 after birth and at weaning are presented in table 3. There were significant differences in weight and number of piglets on day 21 after birth and at weaning between A_1 and A_2 group (P < 0.5). Between A_1+A_2 and B group significant differences were just in weight of piglets on day 21 after birth and at weaning (P < 0.5). There was no significant difference in piglets' mortality (P > 0.5).

Table 3. Weight and number of piglets on day 21 and at weaning at first farrowing.

	A_1	A_2	sig. A_1-A_2	B	sig. A_1+A_2–B
average on day 21 after birth					
weight kg piglet^{-1}	6.3	5.6	P < 0.5	5.6	P < 0.5
number (n) of piglets	9.6	8.1	P < 0.5	8.6	ns
average at weaning					
weight kg piglet^{-1}	10.7	8.3	P < 0.01	8.6	P < 0.5
number (n) of piglets	9.4	8.1	P < 0.5	8.6	ns
mortality until weaning (%)	8.5	9.3	ns	9.8	ns

For the second (autumn) farrowing (Table 4) there were significant differences in weight and number of piglets on 21st day age and at weaning between A_1+A_2 and B group ($P < 0.5$). However, there was no significant difference in weight of piglets at weaning between A_1 and A_2 group. The comparison of A_1+A_2 and B treatments showed significant differences in piglet numbers in favour of pastured groups. Piglet weights however were significantly higher in B treatment.

Table 4. Weight and number of piglets on day 21 and at weaning at second farrowing.

	A_1	A_2	sig. A_1+A_2	B	sig. A_1+A_2 - B
average on day 21 after birth					
weight (kg)	6.0	6.4	$P < 0.5$	6.7	$P < 0.5$
number (n) of piglets	11.5	10.0	$P < 0.5$	9.5	$P < 0.5$
average at weaning					
weight (kg)	9.2	9.1	ns	9.4	$P < 0.5$
number (n) of piglets	10.8	9.9	$P < 0.5$	9.3	$P < 0.5$
mortality until weaning (%)	10.4	2.8	ns	4.5	ns

Conclusions

The results presented demonstrate comparable gilts and sows performances in free range and indoor pig systems. Considering some previous results in grazing pig systems (Mortensen *et al*, 1994; Wülbers-Mindermann *et al.*, 2002), outdoor pig production is responding to some new social demands (animal welfare, food safety and security, slurry depositioning, etc.) and seems a real alternative for small pig farms.

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Goose production responses to grass based diets in 2003

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Abstract

A feeding trial with 4 week-old goslings was conducted in 2003, using different proportions of chopped grass and grain pellets in the diet. Proportions of chopped grass and grain pellets in diets for Treatments 1, 2, 3 and 4 were 25:75; 50:50; 75:25 and 0:100, respectively. Weekly and final live weights of geese and the feather quality were measured. Treatments with higher grain contents produced higher live weights, and better feather quality.

Keywords: chopped grass, feeding, feather quality, goose, live weight

Introduction

Goose meat and feather production are important elements of farming in Hungary. Traditionally, goose flocks begin grazing at four weeks of age and are supplemented with grain throughout the season. To date, there were no available data on grass intake by geese or the production potential of grass in goose farming. Therefore, we conducted a series of experiments between 2000 and 2003 on goose production responses to grass based diets at Debrecen University. This university is located in the heart of a large goose farming area. Below, we provide the results from 2003.

Materials and methods

In July 2003, a feeding trial was conducted at the Animal Research Station of the Debrecen University Agricultural Sciences Centre. Four week-old growing geese of the Andocsi White breed were included in the trial. Previously, goslings had been intensively reared with complex grain pellets. We investigated goose production responses to different grass proportions in the diet. The feeding treatments were as follows:

- treatment 1: 25 % complex grain pellets and 75 % chopped grass,
- treatment 2: 50 % complex grain pellets and 50 % chopped grass,
- treatment 3: 75 % complex grain pellets and 25 % chopped grass,
- treatment 4: 100 % complex grain pellets.

Each group consisted of 25 geese. Geese were kept indoors with free exit to an open yard. Drinking water was available throughout the experimental period. Food was offered twice a day, half the daily ration in the morning and half in the evening. Chopped grass, offered and left, was precisely measured. Grass for feeding was cut every day from a mixed sward. Primary growth was cut beforehand, so leafy regrowth was cut for feeding. A self-propelled rotary motor scythe was used, which was able to collect cut and chopped grass. Chopping made it easier for geese to consume the grass. Data were recorded on offered and rejected grass daily, and on live weight gain weekly. Feather production of ten geese from each group was individually collected during the first picking. The feather quality was judged by a trading company according to the regular commercial evaluation procedure. After picking diets were changed, corn and wheat mix were fed *ad libitum* for each group of geese for 5 weeks. Final live weights before slaughtering were measured individually. Live weight gains and feather parameters were statistically analysed by analysis of variance.

Results and discussion

Weekly live weights of geese during the experiment are presented in table 1. Throughout the experimental weeks, the average live weight of geese was significantly lower in treatments 1 and 2 (75 % and 50 % chopped grass in the diet) compared to other treatments. As a result, the final live weights for Treatments 3 and 4 were significantly higher than for treatments 1 and 2. These results are probably due to the higher energy concentration of the diet. The obtained results confirmed those from previous goose feeding trials with the same treatments (Gyüre *et al*., 2003): diets with lower grass proportions resulted in poorer live weight gains and final live weights.

Table 1. Average live weight of geese in the weeks of the experiment (kg per goose).

Treatments (proportion of chopped grass)	Weeks 1	2	3	4	5
75 %					
mean value	2.41	2.47	2.46	2.68	2.82
s.e.	0.16	0.16	0.20	0.25	0.33
50 %					
mean value	2.41	2.70	2.77	2.97	3.23
s.e.	0.24	0.41	0.34	0.31	0.33
25 %					
mean value	2.47	2.81	3.21	3.60	3.86
s.e.	0.23	0.28	0.31	0.33	0.41
0					
mean value	2.38	2.79	3.25	3.52	3.85
s.e.	0.38	0.28	0.38	0.32	0.33
$LSD_{0.05}$	0.08	0.12	0.13	0.12	0.14

s.e. – standard error of mean ; LSD – Least Significant Difference

Final live weights of geese after five weeks of grain feeding, second phase of the experiment, are presented in table 2. Due to higher energy concentration of daily feed, geese fed grass in the diet during the first period of experiment were able to compensate their live weight loss.

Table 2. Final live weight of geese in after 5 weeks of grain feeding (kg per goose).

Treatments (% of chopped grass in diet at the first phase of experiment)	1 (75 %)	2 (50 %)	3 (25 %)	4 (0)	$LSD_{0.05}$
Average live weights of geese	4.01	4.05	4.51	4.08	0.42
Average live weight gains of geese in the grain feeding phase	1.19	0.82	0.65	0.23	0,1

LSD – Least Significant Difference

Feather production of geese was the highest in treatment 4 (Table 3), the down feather content, which is the most valuable feather type, was significantly higher in treatments 3 and 4, compared to treatments 1 and 2. This time, the results differed from those of our previous experiment, which measured feather production at the second picking (Gyüre *et al*., 2003). The difference may be due to the different breeds of geese included in the trial (Friezeled Hungarian goose, Andocsi White Goose), and to the fact that, this time, the first picking was investigated, which usually contains less of the valuable down feather.

Table 3. Parameters of the feather quality after the first picking (2003).

Treatments (% of chopped grass in diets)	1 (75 %)	2 (50 %)	3 (25 %)	4 (0)	$LSD_{0.05}$
Down feather content (%)	18.14	17.17	20.76	20.64	2.02
Mature feather content (%)	47.83	49.40	48.4	51.55	6.14
Immature feather content (%)	29.92	32.21	29.27	25.09	4.82
Contour feather content (%)	0.23	0.48	0.79	0.98	0.47
Residual (%)	0.76	0.76	0.71	0.73	0.16
Feather (g $goose^{-1}$)	65.76	79.60	85.97	96.1	8.26

LSD – Least Significant Difference

It is well known that geese are typically grazing waterfowl. They can utilise grass quite effectively, as microbial degradation of fibre during digestion provides energy for maintenance and production. The digestive system of geese not only utilises, but requires 4-10 % fibre in the diet, depending on age (Anrique *et al.*, 1982). Fibre requirement of geese can be met by grazing grass and other herbs (Mihók, 1997). Our previous results indicated that pure grass diets did not meet daily nutrient requirements of young geese (Nagy *et al.*, 2001). For reasonable meat and feather production, grazing meat-geese need at least 15 % grain supplementation during the grazing season (Nagy and Mihók, 1992). Our present and latest results indicate the possibility for farmers to include grass (chopped or grazing) in goose farming in a limited proportion (cc. 25 %). A higher proportion of grass in the diet would result in both poorer live weight gains and final live weights, as well as lower feather production and down feather content, at first picking. However, live weight losses during grass feeding period may be compensated if only grain feed is applied during the 5 weeks preceding slaughtering.

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Switching from grass to maize diet changes the C isotope signature of meat and fat during fattening of steers

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Abstract

In an experiment with steers, we investigated the effect of different diets (maize silage compared to grass silage) during fattening on live weight gain and on the stable C isotope signatures of meat and fat. In a parallel survey, beef samples were obtained from a slaughter house to investigate the variability of isotope composition of beef on a regional scale. Feeding maize caused a significant change in C-isotope composition of meat and fat. Even after a 230 day feeding period a complete turnover of muscle tissue C by 'new' food C was not achieved. The C-isotope composition of meat samples from the slaughter house indicated the expected large contribution of maize to regional beef production.

Keywords: beef, grassland, authentication, diet composition

Introduction

In the past, milk and beef production in Europe was mainly based on fodder production from grassland. This has resulted in large areas of grassland vegetation cover in many European countries. The current economic environment in agriculture has led to increased milk production per cow or daily live weight gain in finishing animals, which requires a high nutrient concentration in the ruminants diet. This was achieved by an increased use of concentrates and the introduction of silage from cereals (mainly maize). But, in 'grassland' regions the excessive use of concentrates can result in a nutrient accumulation (e.g., N and P) on the farm level, which may increase the risk of nutrient losses to the environment (Anger and Kühbauch, 1999). Therefore, the use of concentrates on a grass farm should be restricted if the slurry cannot be transported to farms with arable crops. Thus, in areas where maize cultivation is not successful due to altitude, shorter growth period or high rain deposition, the production of milk and meat is under increasing economic pressure. As a result the proportion of these foods produced by 'true grazers' is decreasing in agricultural practice despite recent studies showed that increased contributions of fresh grass to the animal's diet may increase the nutritional value of beef and milk (Jahreis, 1997; Enser *et al.*, 1998). Besides advantages in human nutrition, the milk and beef production in grassland is relatively environmental friendly (low use of fertilisers, almost no use of pesticides, no erosion, carbon storage in soils, increased species diversity) and the grazed ruminants are allowed to realise their species specific behaviour. These advantages may justify a higher economic return for animal products produced from grassland. To convince consumers to accept higher prices for food produced from grassland the origin of the product has to be proven. During the last years stable isotope analysis has gained huge importance in the control of food authenticity. Stable isotope signatures in animal products reflect the stable isotope composition of the diet modified by the animal's metabolism (fractionation effects). The utilisation of maize in the ruminants diet can be detected by the analysis of the C isotope composition of the animals products, because maize is a C_4 plant and thus due to the involved 'CO_2 pumping' mechanism the C isotope discrimination during CO_2 fixation is much lower. Therefore, maize has a higher ^{13}C content than most of our common grassland (C_3) species (cf. Farquhar *et al.*, 1989). As a consequence, the utilisation of maize in the ruminants diet results in high relative ^{13}C contents in the animal tissues, whereas animal products from diets dominated by grassland should have lower ^{13}C contents. To test this relationship we investigated the effect of feeding a maize based diet to previously grazed steers during fattening on the C isotope composition of different animal tissues.

Materials and methods

On the experimental grassland research station Rengen (Daun, Eifel, Germany) previously grazed steers (Limousin breed) were fed either with maize silage (90 % of dry mass as maize silage plus 10 % soya bean oil meal; ~10.7 MJ ME kg^{-1} DM) or solely with grass silage (~9.6 MJ ME kg^{-1} DM) during a 230 days fattening period (feeding experiment Rengen). Live weight gain was determined at regular intervals. When animals were slaughtered (seven steers per feeding treatment), muscle tissue from the dorsal muscle (close to the 11th rib) and fat tissue adjacent to the kidneys was collected and analysed. To demonstrate the variability of C isotope composition in regional beef production, 77 meat samples from 17 different farms were kindly provided by a local slaughterhouse. Samples were freeze dried and C isotope composition was determined. C-isotope composition was measured against reference (PDB) gauged standard material and expressed as $\delta^{13}C$ as per mill (‰) (Farquhar *et al.*, 1989). Statistical analysis was conducted using the feeding treatment as the main factor. When necessary, logarithmic transformation was applied to achieve variance homogeneity.

Results and discussion

At the start of the experiment live weight was similar (~400 kg) in both groups. When the steers were slaughtered the maize fed steers had on average a 100 kg higher live weight (data not shown). Combined with the lower carcass yield (Table 1) the exclusive feeding of grass silage resulted in a significantly lower carcass weight compared with the maize silage fed steers. The difference in live weight gain between the grass and the maize fed group was striking and could not be attributed to the difference in energy content per kg food DM alone. The reason for the lower conversion of food energy into live mass gain in the grass fed group (data not shown) was unclear.

Table 1. Mean carcass weight of steers, relative carcass yield and C isotope composition of meat and fat of steers fed either with maize or grass silage. Values represent means ±SE. Treatment effects were statistically significant ($P < 0.01$) for all presented variables.

	Maize	Grass
Carcass weight (kg $steer^{-1}$)	382 ± 22	311 ± 8
Carcass yield (%)	57 ± 0.4	55 ± 0.3
Meat ($\delta^{13}C$, ‰)	-16.9 ± 0.2	-27.1 ± 0.3
Fat ($\delta^{13}C$, ‰)	-22.4 ± 0.5	-32.7 ± 0.1

Feeding maize silage changed C isotope composition in muscle (meat) and fat tissues to a similar extent (~ 10.2 ‰). This shift in C isotope composition was close to the difference in C isotope composition of the two feeds. Thus, much more food C was introduced into animal tissues than could be expected from the increase in live weight during fattening, which is attributable to the C turnover in tissues exchanging ‘old’ tissue C by ‘new’ food C. But, not all C present in the maize fed steers at slaughtering was exchanged by C from maize as indicated in figure 1. In muscle tissue a higher relative live weight gain was associated with a stronger shift in C isotope composition. Thus, even after 230 days of fattening with maize there was still some ‘old’ C from the previous grazing period present in the muscle tissue. Such a relationship was not observed in the fat tissue (data not shown), which might be attributable to relatively late fat deposition during the fattening period.

The field survey indicated the large contribution of maize to regional beef production (Figure 2). The meat produced on the organic farm ‘a’ had a C isotope composition similar to the C isotope composition of steers fed solely on grass silage in Rengen. In most samples ^{13}C content of meat was higher than in our feeding experiment with maize. Whether the higher ^{13}C content was attributable to a longer feeding period with maize or to an even higher concentration maize in the animals diet is subject to further investigation.

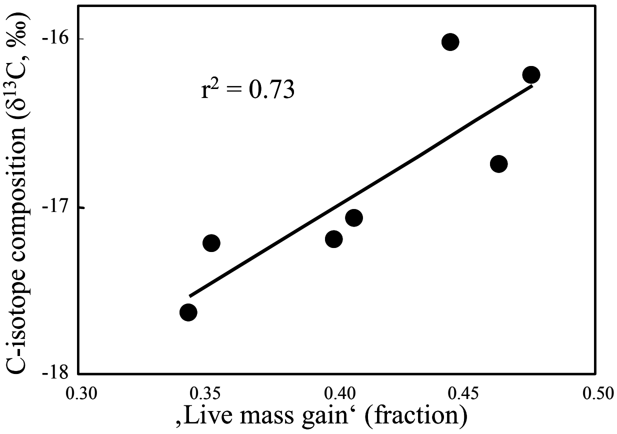

Figure 1. Relationship between the live weight gain (weight increase during fattening as a fraction of live weight at slaughtering) and C isotope composition of meat of previously grazed steers fed with maize during fattening.

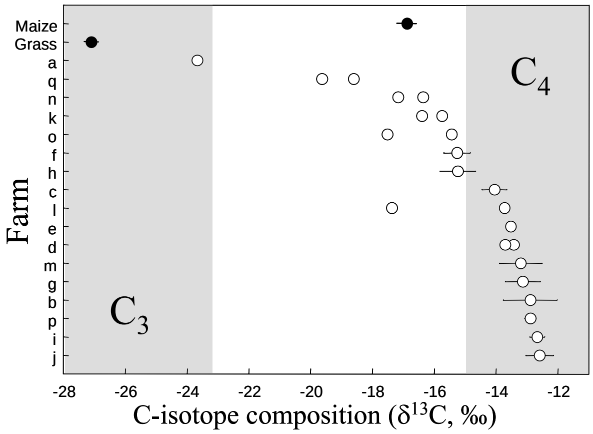

Figure 2. C isotope composition of meat derived from the feeding experiment (● maize or grass) and C isotope composition of meat samples derived from the field survey (○). Horizontal lines indicate ±2SE for means with more than two slaughtered steers per farm. Shaded areas indicate typical ranges of $\delta^{13}C$ values for C_3 and C_4 plants, respectively.

Conclusions

The C isotope composition of meat and fat changed significantly with the introduction of maize into the steers diet. The analysis of C isotope composition of meat is suitable for the detection of maize in the animals diet. But, the C isotope signature can not uncover intensive fattening by use of other cereals (e.g., wheat) due to similar photosynthetic pathways of most grassland plants and cereals. Whether other stable isotopes signatures (^{15}N, D and ^{18}O) of the consumable product may give additional information about the composition of the animals diet deserves further investigation. The present study corroborates the lower economic return of beef production in grass based feeding systems. Given the advantages associated with the utilisation of grassland in beef production, a higher price for these products seems justified. A better knowledge of the relationships between isotope signatures in the diet and the products could help to develop marketing strategies, which advertise these advantages and increase the consumer’s trust in ‘grassland based’ foodstuffs.

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The effect of different legume-based pastures on the fatty acid composition of sheep milk with focus on CLA

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Abstract

A randomised block design with three replicates per treatment was used to assess the effect of three grass-legumes mixtures on the fatty acid composition of sheep milk. The mixtures consisted of a common grass, *Lolium rigidum,* and different legumes, namely *Medicago polymorpha* (mixture BM); *Hedysarum coronarium* (mixture SU) and *Trifolium subterraneum* (mixture SC). Plots were rotationally grazed by groups of Sarda sheep. Milk yield was undifferentiated between the groups ($P > 0.05$) while bulk milk fat was higher in SC and BM than SU ($P < 0.05$). CLA (CD18:2, 9cis, 11trans) was high in all groups: 19.08 (BM); 20.44 (SC); and 18.85 mg g^{-1} of fat (SU), $P > 0.05$. Results are discussed with reference to the botanical composition of the pastures.

Keywords: CLA, milk, fatty acids, grazing, nutrition

Introduction

Pasture is the main feeding source for around 3.5 million sheep raised in Sardinia (Italy). Grazing green forages can enhance a number of milk micro-components which has been proven to promote consumers' health. Particular attention has recently been paid to milk fatty acids collectively named as conjugated linoleic acid (CLA). CLA (CD18:2 9cis, 11trans) which is yielded by rumen microbes from the isomerization of linoleic acid (C18:2 9cis, 12cis). Post-rumen synthesis of CLA from desaturation of vaccenic acid (C18:1 11trans), a common metabolite of linoleic and linolenic (C18:3 9cis, 12cis, 15cis) rumen bio-hydrogenation, also occurs in the mammary gland *via* Δ^9 desaturase activity. The aim of this study was to assess the effect of pasture mixtures based on different legumes on the fatty acid composition of sheep milk with particular reference to CLA and related metabolites. Another objective was evaluating the relationships between pasture botanical composition and milk fatty acids.

Materials and methods

The experiment was carried out at Bonassai experimental farm (NW Sardinia, average annual rainfall: 547 mm). The experimental area consisted of 6.75 ha divided into three blocks with three 0.75 ha replicated plots in each block. These plots were sown in October 2002 with grass-legume mixtures consisting of a common grass, the annual ryegrass (*Lolium rigidum* Gaudin, cv. Nurra) and different legumes, namely burr medic (*Medicago polymorpha* L., cv. Anglona, mixture BM), sulla (*Hedysarum coronarium* L., cv. Grimaldi, mixture SU) and subclover (*Trifolium subterraneum* L., cv. Antas, mixture SC). The seeding rate was 35 kg ha^{-1} for the legumes and 14 kg ha^{-1} for the grass. All plots were divided by fences into two equal sized sub-plots. On January 2003, nine groups of lactating Sarda sheep, previously blocked by live weight and milk yield, were randomly allocated to the experimental plots. The groups rotationally grazed the sub-plots up until May, with the grazing period of 14 d. A 'put and take' method was used to adjust the number of sheep per plot to pasture growth, using the compressed sward height as reference (not shown). No supplement was offered to the sheep. Before each grazing period, pasture botanical composition was measured by cutting at ground level four quadrats of 0.50 m^2 per sub-plot and separating them into the sown spp. and weeds and, within species, into their structural components. Milk yield of each group was measured every fortnight on 7 occasions (n = 21 per treatment). Bulk milk was sampled and assayed for fat (infrared method) and fatty acid content (gas chromatographic method). The effects of pasture mixtures on milk yield and milk composition were analysed using repeated measurements analyses after selection of the best variance / covariance structure. Fixed effects were pasture mixture (PM), date of sampling (DS) and their interaction, random effect was the replicate within treatment group. Differences between treatment means were assessed using the *t* test for multiple comparisons. Correlation and regression analyses were used to study the relationships between the variables.

Results and discussion

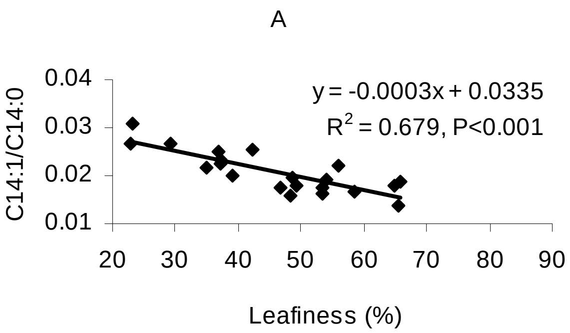
The average proportion of legumes, ryegrass and other species in the biomass on offer were respectively 46.8, 45.7 and 7.5 % DM (BM); 29.2, 62.4 and 8.4 % DM (SU) and 19.6, 62.6 and 17.8 % DM (SC). Weeds included a daisy forb palatable to sheep (*Chrysanthemum coronarium*). The total proportion of leaves averaged 46.1 (BM); 61.7 (SU) and 49.7 % DM (SC). Milk yield was on average undifferentiated between the groups ($P > 0.1$, Table 1).

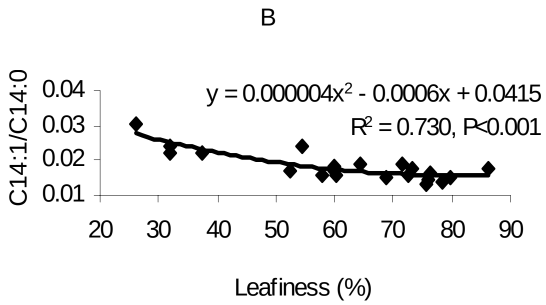
Table 1. The effect of pasture mixture on milk yield, milk fat and fatty acid composition.

	Treatment groups				Significance of the effects[1]		
	BM	SU	SC	SEM	PM	DS	PM x DS
Milk yield (ml)	1663	1656	1620	108	NS	0.001	0.001
Milk fat (%)	6.43 a	6.14 b	6.52 a	0.15	0.008	0.001	0.001
C18:2 (mg g^{-1} fat)	12.42 ab	11.39 b	13.27 a	1.87	0.009	0.001	0.035
C18:3 (mg g^{-1} fat)	15.38	17.38	15.83	1.32	NS	0.001	0.002
C18:1 11t (mg g^{-1} fat)	32.39	33.30	33.86	2.10	NS	0.001	0.001
CLA (mg g^{-1} fat)	19.08	18.85	20.44	0.64	NS	0.001	0.010

[1] Effects of pasture mixture (PM), date of sampling (DS) and their interaction; NS: $P > 0.10$; different letters in the same row indicates significant differences at $P < 0.05$ level.

Milk fat was higher in SC and BM than SU ($P < 0.01$). In both cases there were interactions between PM and DS. On average SC outperformed SU for milk C18:2, with BM being intermediate. In particular, from the third sampling date (end of February) onwards both BM and SC were higher than SU ($P < 0.05$ for the interaction between DS and PM). In contrast, SU showed higher C18:3, particularly during early growth ($P < 0.05$ for the interaction). CLA was high in all groups. C18:1 11trans was correlated ($P < 0.01$) with CLA: r = 0.864 BM; 0.658 SC; and 0.629 SU. No effect of treatments was detected on CLA/C18:1 11t or C14:1/C14:0 ratios ($P > 0.10$). The latter ratio can be regarded as an index of Δ^9 desaturase activity. Pooling the data on botanical composition by treatment plot, a negative relationship was found between proportion of sulla in the pasture and milk CLA content (r = -0.452, $P < 0.05$). This is in line with results by Piredda *et al*. (2002) who found a decreasing trend in milk CLA along with an increase of the time allocation on sulla pasture in grazing sheep. A negative relationship was also found between the proportion of sulla and the C14:1/C14:0 ratio (r = -0.593, $P < 0.01$). This could be related to the inhibition effect of milk linolenic acid on Δ^9 desaturase activity (Sessler and Ntambi, 1998). In the SC group, a positive relationships was found between the weed proportion and both CLA and the C14:1/C14:0 ratio (r = 0.456, r = 0.435, $P < 0.05$, respectively). *Chrysanthemum coronarium* intake could be evoked as a major reason for such a response as it has been proven to enhance milk CLA (Addis *et al*., 2002).





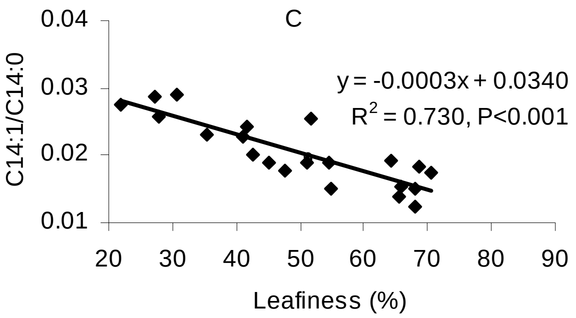


Figure 1. The relationship between pasture leafiness and C14:1/C14:0 ratio in milk of sheep grazing grass-legume mixtures including burr medic (A), sulla (B) or subclover (C).

The leafiness of the pasture (expressed as sum of leaf proportion of the grass and the legume) was correlated with milk C18:1 11t in SU group (r = 0.699, $P < 0.001$). The leafiness was also consistently negatively related with the C14:1/C14:0 ratio in all groups (Figure 1). High leafiness is usually associated with a growing stage of the herbage, which in turn is featured by a high level of CLA precursors (Dewhurst *et al.*, 2001, Piredda *et al.*, 2002). Therefore the above regressions suggest the hypothesis that a very high supply of CLA precursors might reduce the post-ruminal CLA synthesis.

Conclusions

Different grass-legume pasture mixtures result in relatively high and similar CLA content in sheep milk. Nonetheless different responses between SU and the other mixtures are evident in milk fat and poly-unsaturated fatty acids. Finally, pasture leafiness is probably negatively correlated with Δ^9 desaturase activity.

Acknowledgments

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Rapid decline of contents of beneficial omega-7 fatty acids in milk from grazing cows with decreasing herbage allowance

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Abstract

Fresh herbage of perennial ryegrass cv. Barlet with a higher α-linolenic acid (C18:3) content than of cv. Magella might affect milk fatty acid (FA) composition. Two groups of 6 cows grazed a cultivar mixture at a high herbage allowance. Then the area was reduced by 50 % and the cows grazed pure cultivars for 2 periods of 3.5 days in a change-over design. Milk production was stable, suggesting a constant intake. No effect of cultivar on milk FA composition was measured, perhaps due to the short measurement period. However, very quick changes occurred in milk FA composition under grazing, probably due to the declined herbage allowance, greater depth of the grazed horizon and associated changes in α-linolenic acid content and herbage quality. The content of rumenic acid (C18:2 c9, t11) in milk fat declined on average by 36 % within a week and similar rapid changes were found for vaccenic acid (C18:1 t11).

Keywords: herbage allowance, grazing, milk fatty acids, CLA, n-7

Introduction

In 2000, a stall-feeding experiment was carried out with two groups of cows using fresh herbage of perennial ryegrass cv. Barlet with a higher α-linolenic acid (C18:3) content than of cv. Magella) (Elgersma *et al*., 2003b). Cows fed with cv. Barlet had a lower fat percentage in their milk. The milk contained more polyunsaturated fatty acids (PUFA) and had higher contents of healthy omega-7 FA (vaccenic and rumenic acid, C18:1 t11 and C18:2 c9, t11) (Ellen and Elgersma, 2004) than milk from cows fed cv. Magella (Elgersma *et al*., 2003a). To evaluate if this effect of grass cultivar also occurred in a grazing situation, this experiment was carried out.

Materials and methods

Two diploid perennial ryegrass (*Lolium perenne* L.) cultivars with a comparable chemical composition and a similar heading date were sown in a randomised block design with adjacent strips in Wageningen, The Netherlands.
In 2002, twelve cows stocked from June onwards in a strip grazing system and were milked outdoors, twice daily at 6.00 and 16.00 h. On August 30, 2002, they were transferred to a paddock with adjacent plots (strips of 6.2 × 116 m) of cvs. Barlet and Magella (19 randomized blocks). Each cow was fed 3 kg of concentrate per day in equal portions at milking. The cows were moved daily to fresh plots with an approximate herbage yield of 1850 kg DM ha^{-1}. The 12 cows had access to a 1:1 mixture of both cultivars, consisting of 4 randomized plots during one week. The high herbage allowance (44 kg DM cow^{-1}) enabled *ad libitum* herbage intake (Smit *et al*., 2003).
On September 6, 2 groups of 6 cows were formed and grass plots were individually fenced. As 6 cows now had access to one plot per day, herbage allowance was reduced by 50 %. Cow

groups were moved daily to new plots. During one week in total, cows grazed pure stands of cvs Barlet and Magella in a cross-over design. The cows were 137 ± 15 days in lactation at the start of the experiment. Milk production (MP) was recorded at each milking. Groups changed diet after 3.5 days. At day 0 (the last day of the previous experiment with the high herbage allowance) and after 3.5 and 7 days, the FA contents were determined as fatty acid methyl esters (FAME) in milk samples (1:1 mixtures of evening milk and morning milk), pooled per cow group. Milk sampling procedures and analyses were carried out as reported earlier (Elgersma *et al*., 2003a).
For milk FA composition data, the cow group was the experimental unit. Contents of FA on days 3.5 and 7 were expressed relative to the content on day 0. One-way analysis of variance was used. Effects of time (day) were analysed using cow or cow group as a block factor and *vice versa*. A similar procedure was carried out to test for cultivar differences.

Results and discussion

As expected, fresh herbage of perennial ryegrass cv. Barlet had a higher proportion of α-linolenic acid (0.62 of total FA) than cv. Magella (0.60), albeit at a lower level than in 2000 (0.75 and 0.71, respectively) (Elgersma *et al*., 2003b). The herbage yield > 4 cm height was similar for both cultivars (1833 ± 109 kg DM ha^{-1}) at a sward surface height of 18.1 cm (Smit *et al*., 2003). The residual DM yield after 24 h grazing was 1126 ± 135 kg DM ha^{-1} and average daily intake was estimated at 17 ± 3 kg DM. During this experiment, herbage allowance was reduced to 22 kg DM > 4 cm sward height, which theoretically would have been enough to enable a similar intake as during the previous period. However, visual observations revealed that during this experiment herbage allowance seemed to be restricted, as the swards were grazed down deeper than normal. Despite this observation, MP did not decline during the experiment. Daily MP averaged 24.1 ± 2.2 l for group 1 and 23.6 ± 2.1 l for cow group 2.
There were no effects of grass cultivar on milk FA contents (not shown), but there were changes with time for some FA. The content of rumenic acid declined from 30.8 g kg^{-1} FAME on day 0 to 17.4 g kg^{-1} FAME on day 7 in one cow group; for the other group it declined from 19.6 to 14.8 g kg^{-1} FAME within a week. Despite the low number of replicates, a clear trend was found for the effect of time (P = 0.09) (Figure 1A). Similarly, a non-significant but consistent decline in the vaccenic acid content was found, on average from 51.1 to 35.1 g kg^{-1} FAME within a week (Figure 1B).

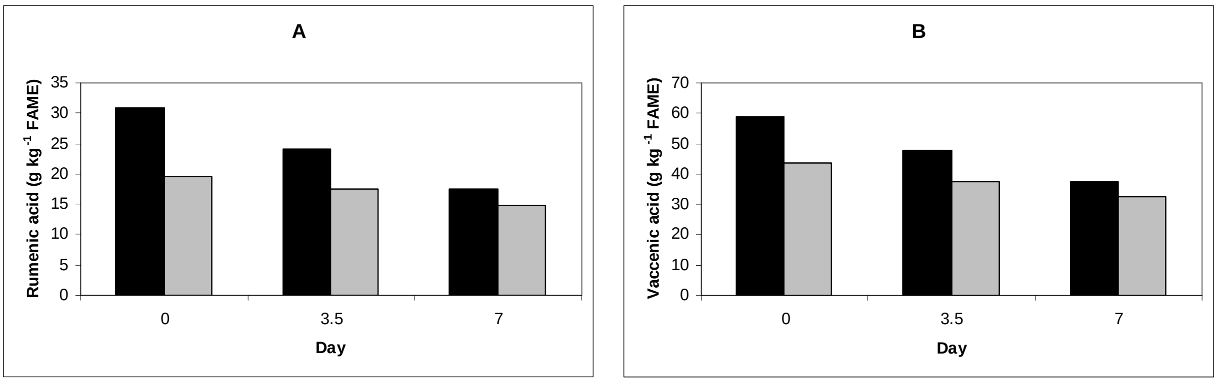

Figure 1. Change in contents (g kg^{-1} FAME) of rumenic acid (A) and vaccenic acid (B) in milk fat during 7 days of two groups (1: black bars, 2: shaded bars) of six cows each, grazing perennial ryegrass swards with a 50 % lower herbage allowance from day 1 onward.

In an earlier indoor feeding experiment with herbage cut at 5 cm sward height from the same experimental field (Elgersma *et al*., 2003a), milk fat from cows fed cv. Barlet contained more rumenic acid than the milk fat from cv. Magella. As then the cultivars were fed to two different groups of six cows, cow-effects may have played a role. However, for both cow groups an overall linear relation between the daily rumenic acid production in milk and the α-linolenic acid intake during the season was found (Elgersma *et al*., 2003a). The experimental design of this experiment was suitable to analyse effects of grass cultivar, but the fact that no effects were found was perhaps due to the short duration of the grazing periods and the smaller difference in the proportion of α-linolenic acid. Therefore, the initial hypothesis could not be verified and further research is needed at this point. However, the experiment did reveal interesting and new results. Firstly, the high initial level of rumenic acid under high herbage allowance under *ad libitum* grazing (19.6 to 30.8 g kg^{-1} FAME) compared to the earlier results found with stall-feeding (11 to 17 g kg^{-1} FAME) (Elgersma *et al*., 2003a) supports our hypothesis (Elgersma *et al*., 2003c) that grazed grass results in higher contents of rumenic acid than found in milk from cows stall-fed grass. Clearly, further research is needed to confirm this hypothesis. Secondly, the very quick changes in milk FA composition in this experiment were unexpected and most probably due to the decline in herbage allowance. The leaf blade proportion of herbage dry matter declines in lower sward horizons, which affects the composition of the ingested herbage as green leaf blades have a higher fat content than leaf sheaths.
Besides, herbage quality changes with grazing horizon, e.g., the content of protein declines with canopy depth, whereas especially in autumn the water-soluble carbohydrate content in the stubble was much lower than in higher canopy layers (Smit and Elgersma, 2004). In this experiment, intake was probably not or hardly reduced because MP levels remained stable. However, the quality of the ingested herbage and the limited possibilities for selection of leafy plant parts most probably lowered the daily intake of α-linolenic acid. More research is needed to unravel underlying processes related to herbage composition, grazing, intake and milk quality. The novel information on the rate and magnitude of changes in milk composition found in this experiment could help to develop grazing management guidelines aiming at the production of milk from grazing cows with a healthier FA profile.

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Dietetically relevant polyunsaturated fatty acids in the milk of cows grazing pastures at different altitudes

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Abstract

Twelve Brown Swiss dairy cows were fed during one summer with fresh forages only, in barns or on pasture. During spring and early summer, the cows were kept in the lowlands and received ryegrass dominated forage. During June and July, the cows were at an alpine site with highly diverse, extensive pasture. Another six cows received a mixed diet of grass and maize silage plus concentrates at the lowland site during the whole summer. Conjugated linoleic acid and total C18-*trans* fatty acids in the milk were clearly increased by feeding of green forage, but no significant difference between lowland and highland occurred, whereas α-linolenic acid and the other C18-*cis* fatty acids exclusively increased at the alpine site. The long-chain n-3 fatty acids increased with feeding of green forage during the whole experiment.

Keywords: milk, fatty acids, CLA, pasture, alpine

Introduction

Milk of cows grazing high alpine pastures, as well as the cheese produced from this milk, are described to contain more of the dietetically beneficial conjugated linoleic acid (CLA), α-linolenic acid (α-LA) and long-chain omega-3 (n-3) fatty acids than milk and cheese derived from lowland production (Collomb *et al*., 2001; Innocente *et al*., 2002). On alpine dairy farms, grazing, often without any supplementation, is common. There is evidence (Dhiman *et al*., 1999), that such a diet, compared to a grain and corn supplemented diet, may cause these shifts in the fatty acid composition of cow's milk. If this would be the main cause, 'alpine milk' would have no advantage over pasture-based extensively produced milk. However, no experimental comparison of lowland and alpine pasture quality with respect to the resulting milk fatty acid composition is described in the literature until now. The aim of our study was to compare the fatty acid composition of milk produced without any dietary supplementation at typical Swiss lowland and highland pastures. This was further compared to a control diet of silages, including maize, and concentrates.

Materials and methods

Eighteen Brown Swiss cows in second lactation and on average at the 82nd lactation day were allocated to three treatment groups of six cows each. During an initial period (P0) all cows received a mixed diet (MD) containing on average 40 % grass silage, 21 % maize silage, 7 % hay and 32 % concentrates, as required for the individual milk yield. In the following periods, group I was kept at 400 m asl and fed the MD throughout the whole experiment. Groups II and III were kept at 400 m during April and May (periods P1 and P2) and then moved to 2000 m asl during June and July (periods P3 and P4). These two groups received similar fresh herbage either on pasture (II) or indoors (III). Group II and III cows did not receive any concentrate during P1-P4. In P5 all cows again were kept at 400 m asl and fed the MD. In each period one intensive sampling and recording week was carried out. Periods P1 and P3 were performed with the herbage being in its intensive growth phase, P2 and P4 at the flowering stage. Measurements were carried out after 10 to 14 days of adaptation to altitude and feeding conditions. Fatty acid analysis was carried out for feed after accelerated solvent extraction and gas chomatography of fatty acid methylesters on a supelcowax-10 column. Milk fatty acids were transesterified and then analysed with gas chromatography on a CP-sil-88 column.

Results and discussion

Herbage quality in the four measurement weeks was as follows: 6.5, 6.1, 6.0, and 5.7 MJ NEL kg^{-1} DM and 408, 490, 562 and 583 g NDF kg^{-1} DM, respectively. Herbage diversity was about three times higher, and the ratio of monocotyledones to dicotyledones was much lower in the alpine pastures. The fatty acid composition of the diets is shown in figure 1.

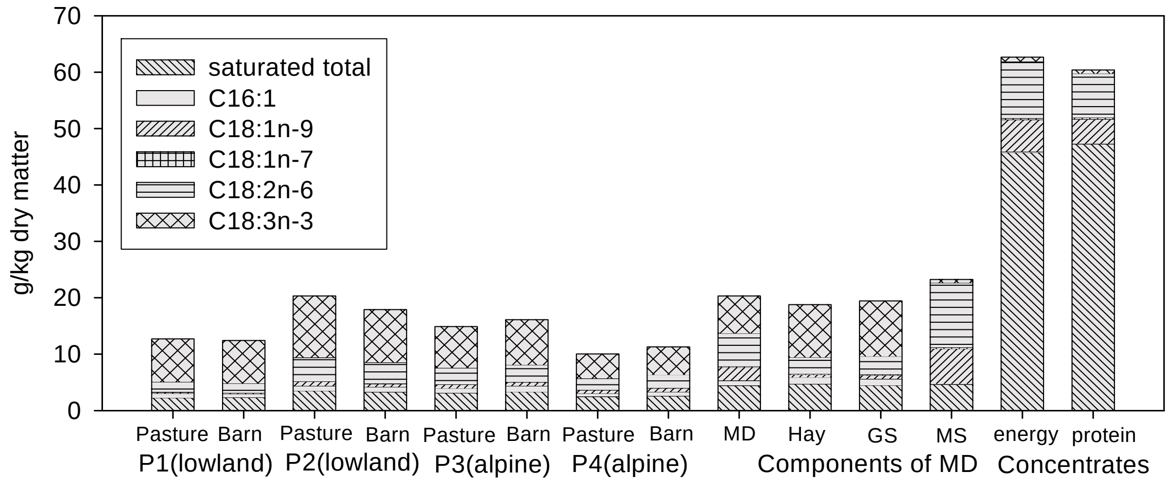

Figure 1. Fatty acid contents of the feeds. MD: mixed diet; GS: grass silage; MS: maize silage.

The shift from MD to grazing caused an increase of milk CLA content from 0.31 up to 0.79 g kg^{-1} milk ($P < 0.001$; Figure 2), but there was no significant difference between lowland and alpine forage. In P5 the CLA contents decreased to the initial level, where those of group I had remained the whole time. The other C18:1- and C18:2-*trans* fatty acids followed exactly the same pattern. The magnitude of the effect on CLA observed in this study was very similar to the effect of a change from a 30 % pasture diet to a 100 % pasture diet (Dhiman *et al*., 1999) and also to the difference reported by Collomb *et al*. (2001) between milk of lowland and alpine origin. In contrast, both, mono- and polyunsaturated C18-*cis* fatty acids slightly decreased, when cows received green forage in the lowlands and significantly increased when the cows were moved to the alpine site. The α-linolenic acid developed as the other C18-*cis* acids: although there was a very weak increase already at the lowland pastures, the main increase happened at the alpine site, resulting in significantly higher α-LA contents at alpine (0.53 g kg^{-1} milk) compared to lowland pastures (0.31 g kg^{-1} milk; $P < 0.01$; Figure 2). The long chain n-3 fatty acids (C20:5n-3 (Figure 2), C22:5n-3 and C22:6n-3) increased in groups II and III with a time lag. Their content in milk was significantly higher than in group I from period P2 on, but there was no significant alpine influence on these fatty acids. In contrast, C20:4n-6 significantly decreased with feeding of the green forages (Figure 2).
Concentrates and maize silage, making up more than 50 % of the MD dry matter, contained a high amount of saturated fatty acids and C18:2n-6 while α-LA was not detectable (Figure 1). In agreement with Dhiman *et al*. (1999) this explains the difference between the MD and the green forage treatments in terms of the milk C18-*trans* fatty acids and CLA. In contrast, the increase of the sum of C18-*cis* fatty acids, including α-LA, in the milk during the alpine sojourn of the cows was obviously not directly caused by differences in the fatty acid

composition of the forages, since the herbage generally had a similar fatty acid profile and in P4 the content of total fatty acids and particularly of α-LA even decreased. Consequently, it is unlikely that fatty acids from the alpine forage have contributed to the alpine effect on the C18-*cis* acids. As assumed by Agenäs *et al*. (2002) the α-LA in milk might have been rather derived from body stores. In our experiment plasma insulin significantly decreased and β-hydroxybutyrate (BHB) increased during the alpine sojourn, indicating impaired energy balance and increased fat mobilisation in the cows. This, and also the increase in C18-*cis*, were even more pronounced on pasture, probably due to energy expenditure while walking in steep areas under hypoxic air conditions. The correlations between milk α-LA and plasma insulin resp. BHB were r = -0.50 and r = 0.54. Thus an alpine sojourn could contribute through the pathway of increased energy requirements, triggering body fat mobilisation, to the increased α-LA-levels in milk. Other possible reasons could be changes in the ruminal microflora because of increased fibre, and decreased net energy contents of the diet and/or a decreased biohydrogenation in the rumen and increased absorption of rumen by-pass α-LA.
In conclusion, these results confirm the advantageous fatty acid profiles of milk from alpine production. However, the CLA content of milk increases generally under pure pasture conditions, and the same level can be expected in alpine milk production as also in extensive systems in the lowlands. This also applies to the long chain n-3 fatty acids. In contrast, α-LA increases particularly during an alpine sojourn of the cows, but this seems to be related to energy deficiency rather than to specific fatty acid profiles of the alpine forage.

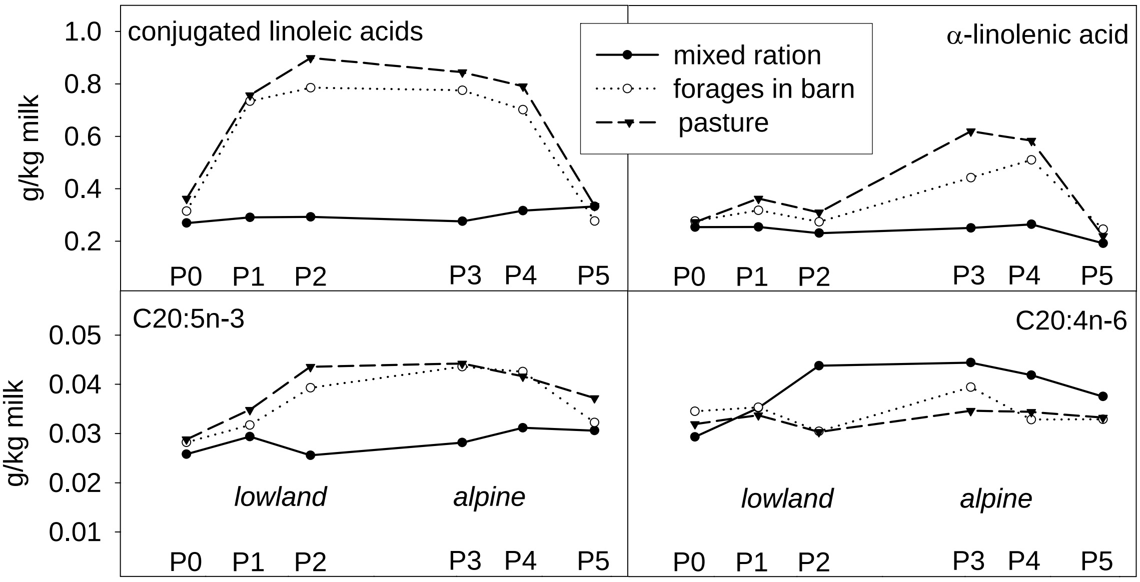

Figure 2. Evolution of selected fatty acids in milk during the experiment. P0 and P5: all cows with mixed ration. P1 and P2 lowland periods; P3 and P4 alpine periods for grazed groups.

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Effect of haylage or maize silage based diets with or without energy restriction on milk fat properties

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Abstract

Forage type and energy level effects on milk yield, milk composition and milk fat globule properties were investigated in two experiments on 4 dairy cows at the beginning of lactation. In the first experiment, a haylage based diet (BBH) was compared to a maize silage diet (MS) in a cross-over design. Concentrate (soya bean and cereals) was added in order to cover the energy and protein requirements. In the second experiment, the same two treatments were applied, with or without a 30 % restriction of the energy supply in a three-period design.
In the first experiment, the BBH diet compared to MS diet did not affect milk production or milk composition, but it significantly reduced milk fat globule diameter and increased the proportion of polyunsaturated fatty acids. Forage type did not modify the (C16:0+C18:0)/C18:1 ratio, an indicator of butter spreadability. In the second experiment, no interaction was observed between forage type and diet energy level. These results confirm the effect of big bale haylage on milk fat globule diameter whatever the diet energy level. Restricting energy implied a decrease of milk yield and milk protein content. Energy restriction did not modify milk fat globule diameter, despite a significant increase in mono- and polyunsaturated fatty acid percentages.

Keywords: dairy cow, maize silage, big bale haylage, energy restriction, milk fat, milk fat globule

Introduction

The milk fat included in the globules is the major native form of milk fat. The milk fat globule is a triglyceride droplet (solid in the centre, liquid at the periphery) surrounded by a membrane of complicated structure and composition. Physicochemical properties of the milk fat globule influence the technological and organoleptic qualities of butter. For example, disrupting milk fat globules during churning is easier when the globules are big or when their membrane is fragile. It implies that butter yields are influenced by milk fat globule diameter and milk fat globule membrane composition. Furthermore, milk fatty acid composition influences milk fat crystallization and consequently butter spreadability.
Feeding system may modify the physicochemical properties of the milk fat globule. For example, conserved grass based diets, compared to maize silage based diets, decrease milk fat globule size (Hurtaud *et al.*, 2002). Nevertheless, the use of conserved grass is often associated with an energy deficit because of a decrease in feed intake, and the effects of this deficit could add to the direct effects of the forage.
The objectives of this experiment were to study forage type effects (big bale haylage vs. maize silage) on milk composition and milk fat globule properties and to separate forage type effects from those caused by a dietary energy restriction of 30 %.

Materials and methods

Two trials were conducted successively with 4 multiparous Holstein cows at the beginning of lactation (87 days of lactation). The experiment began in January 2003 and finished in March 2003.

Trial 1: A big bale haylage (BBH, n = 4) based diet was compared to a maize silage diet (MS, n = 4) in a cross-over design. There was a three weeks transition period between the two experimental periods. Concentrate (soya bean and cereals) was added in order to cover the energy and protein requirements. The proportions of soya bean and cereals were 15 and 35 % of total DMI for BBH diet and 25 and 5 % of total DMI for MS diet, respectively.
Trial 2: The same two treatments were applied with or without a 30 % restriction of energy supply in a three-period design (100BBH, 70BBH, 100MS and 70MS, n = 3 for each treatment). There was a two weeks transition period between the experimental periods.
Milk yields were recorded at each milking. Fat and protein contents of individual milk were analysed six times a week. A milk sample representative of a one-day milking (proportionate mixtures of morning and afternoon milks) was taken in each experimental week. Those samples were analysed for milk fat globule size, zeta potential (a membrane composition indicator), and milk fatty acid composition. Data were analysed with a GLM procedure.

Results

Trial 1: Feed intakes for MS and BBH diets were 17 and 11 kg d^{-1} DM for the forages and 7 and 10 kg d^{-1} DM for the concentrate, respectively. The BBH diet induced a decrease in energy intake compared to the MS diet (Table 1). BBH diet did not modify either milk production or protein and fat contents, but it significantly reduced milk fat globule size (-0.29 µm, P = 0.005) without modifying zeta potential. Polyunsaturated fatty acid levels were higher with the BBH diet (+0.80 points, P < 0.01). Forage type did not have any effect on (C16:0+C18:0)/C18:1 ratio, which is an indicator of butter spreadability.

Table 1. Milk composition, milk fat globule and milk fatty acid levels – Trial 1.

	BBH	MS	RSD	Effect (P)
Energy balance, UFL d^{-1}	-1.3	1.4	1.24	0.090
Milk yield, kg d^{-1}	35.3	36.4	1.73	0.482
Fat content, g kg^{-1}	35.0	37.7	2.16	0.217
Protein content, g kg^{-1}	31.1	32.0	1.16	0.377
Milk fat globule, µm	3.60	3.88	0.03	0.005
Zeta potential, mV	-12.4	-13.0	1.15	0.552
Milk fatty acids percentages				
Saturated, %	75.1	75.5	0.55	0.390
Monounsatured, %	21.6	21.9	0.48	0.382
Polyunsaturated, %	3.37	2.57	0.12	0.008
(C16:0+C18:0)/C18:1 ratio	3.05	3.03	0.20	0.907

Trial 2: We observed a decrease of 28 % of energy intake between 100 % and 70 % diets for the two studied treatments (P = 0.001). No significant interaction between forage type and diet energy level was observed. Trial 2 confirmed the effect of BBH forage on milk fat globule diameter (-0.69 µm, P = 0.05) whatever the diet energy level of the diet (Table 2). The forage type did not affect zeta potential. As expected, restricting energy seemed to reduce milk yield and milk protein content (respectively -2.0 kg d^{-1} and -1.8 g kg^{-1}, P = 0.1).

Table 2. Milk composition, milk fat globule and milk fatty acid levels – Trial 2.

	BBH		MS		RSD	Effect (P)	
	100	70	100	70		forage type	energy restriction
Energy balance, UFL d^{-1}	-0.8	-4.5	2.7	-1,9	0.41	0.220	0.002
Energy intake, UFL d^{-1}	18.1	13.7	22.1	16.4	0.42	0.118	0.001
Milk yield, kg d^{-1}	33.2	31.0	30.8	29.1	1.12	0.644	0.106
Fat content, g kg^{-1}	34.4	35.0	41.3	39.7	0.91	0.498	0.470
Protein content, g kg^{-1}	32.7	30.6	32.1	30.7	0.99	0.947	0.099
Milk fat globule, µm	3.16	3.32	4.00	3.90	0.19	0.046	0.809
Zeta potential, mV	-13.5	-13.0	-12.9	-12.9	0.43	0.107	0.507
Milk fatty acids percentages							
Saturated, %	72.7	70.6	75.8	73.4	0.95	0.238	0.055
Monounsatured, %	23.8	26.0	21.5	23.6	1.01	0.204	0.071
Polyunsaturated, %	3.43	3.40	2.65	3.01	0.14	0.380	0.076
(C16:0+C18:0)/C18:1 ratio	2.62	2.29	3.17	2.77	0.21	0.314	0.108

Energy restriction did not modify milk fat globule diameter and zeta potential, and resulted in a significant increase in mono- and polyunsaturated fatty acids levels. Milk fatty acid composition seems to have been modified as in trial 1 by forage type, but differences are not significant.

Discussion

Supplied at a same dietary energy level, haylage reduced milk fat globule diameter compared to a maize silage diet. That situation has already been observed in a comparison between maize silage and hay diets (Hurtaud *et al.*, 2002). An increase of churning time and milk fat losses in buttermilk might be expected when dairy cows are fed with haylage diets (Hurtaud *et al.*, 2001). Furthermore, results for (C16:0+C18:0)/C18:1 ratio indicate that restricting energy might improve butter spreadability independent of forage type. The lack of effects on zeta potential indicates that neither forage type nor diet energy level modify the milk fat globule membrane composition. BBH vs. MS diets comparison confirmed that linolenic acid level increases when animals are fed with grass based diets (pasture, silage, haylage, hay) (Chilliard *et al.*, 2001).

Conclusions

This experiment confirmed that energy deficit and forage effects accumulate when dairy cows are fed haylage diets. Hypotheses concerning consequences of such a feeding system on butter yields and qualities have to be confirmed.

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Winter feeding systems and dairy cows breed have an impact on Camembert and Pont L'Evêque PDO cheeses in Normandy

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Abstract

The effects of 2 feeding systems and 2 dairy cow breeds on milk yield and composition, physical and sensorial properties of Camembert and Pont L'Evêque cheeses were investigated. The experiment was a 2 × 2 factorial arrangement of treatments. A restricted grass diet with only 15 % of concentrate (GLc) was compared to maize silage diet with 30 % of concentrate (MHc). Thirty-four Holstein (Ho) and 34 Normande (No) cows in early lactation were assigned to one of two feeding systems for a six weeks period. Cows on the GLc feeding system had lower milk yield, fat and protein content. In the two feeding systems, No cows had lower milk yields but higher milk protein content than Ho cows. The GLc feeding system altered milk fatty acid composition. GLc feeding system and No breed produced a more yellow cheese colour. Feeding systems had limited effects on the firmness of Camembert. Contrary to this, feeding system GLc and the Ho breed significantly decreased the firmness of Pont L'Evêque.

Keyswords: dairy cow, maize silage, haylage big bale, milk composition, cheese

Introduction

The reduction of costs of production and the research of a larger diversity of PDO dairy products in Normandy (cheeses and butter) is now a realistic objective. There is increased interest in grazing systems with reduced concentrate input. The future objective of the PDO in Normandy is to promote the Normande breed, which is currently outnumbered by the Holstein breed. This promotion would intensify the relationship between product and 'terroir'. The objective of this work was to study the effects of feeding systems and test the interaction with dairy cow breed on the characteristics of two typical cheeses from Normandy: Camembert and Pont L'Evêque.

Materials and methods

The trial was conducted with two groups of dairy cows in early lactation (45 d) in the INRA experimental farm of Le Pin-au-Haras situated in Normandy bocage. The experiment was a 2 × 2 factorial arrangement of treatments with 2 feeding systems and 2 cow breeds. A restricted grass diet (mix of big bale haylage and grass silage) with 15 % of concentrate (GLc) was compared to maize silage diet with 30 % of concentrate (MHc). The objective of MHc was to maximise individual cow performance in comparison with GLc which was to optimally use conserved grass even if the potential of the dairy cows was not achieved. Thirty-four Holstein (Ho) and 34 Normande (No) cows were assigned to one of the two feeding systems for a six weeks period (from 10 February to 30 March): Ho-MHc, Ho-GLc, No-MHc, No-GLc. The amount of feed offered and refused were weighed daily. Milk yield was recorded at each milking. Milk fat and protein contents were analysed for each cow individually six times a week. Once a week, the nitrogen composition, calcium and milk fatty acid composition were determined on a mix of evening and morning milkings of two of the 4 groups of cows. Coagulation properties and laboratory cheese yield (centrifugation of a curd after 1 hour at 35 °C after rennet addition) were also measured. Camembert and Pont L'Evêque cheeses were produced in 2 Normande factories (Laiterie Vallée, Bernières d'Ailly and Atelier Fromager, Pont L'Evêque). Compression measurements were performed on slices of cheeses after 6 weeks of storage with an universal Instron equipped with a strip of metal. Cheeses colour was measured by reflectance method. Trained panellists of the PDO committee assessed the cheeses for flavour, odour and texture in conformity with the properties of PDO cheeses.

Results

There was no interaction between dairy cow breed and feeding system except for milk fatty acids. GLc treatment decreased milk yield (-4.3 kg d^{-1}), fat (-3.8 g kg^{-1}) and protein contents (-3.0 g kg^{-1}). The No breed recorded a lower milk yield (-5.0 kg d^{-1}), but higher protein content (2.4 g kg^{-1}), and no effect in fat content. With the GLc treatment, the No breed had a good protein content (30 g kg^{-1}) when protein content of Ho was very low. The GLc treatment and No breed significantly increased the ratio of casein to protein (respectively +1.5 and 0.9 percent units) but the GLc treatment decreased milk urea content (-122 mg L^{-1}). The GLc feeding system decreased the proportion of short chain fatty acids but increased unsaturated fatty acids. Both GLc and No breed increased C18:3 fatty acid (0.56 % and 0.22 % respectively). The C16:0 + C18:0 / C18:1 ratio, an indicator of butter spreadability significantly decreased with GLc treatment. Normande breed increased the size of fat globules (Table 1).

Table 1. Milk yield and composition and cheese yielding properties.

Breed (B)	Holstein		Normande		SE	Effect		
Feeding system (FS)	MHc	GLc	MHc	GLc		B	FS	B * FS
Milk yield, kg d^{-1}	33.8	29.2	28.5	24.4	3.8	< 0.001	< 0.001	0.798
Fat content, g kg^{-1}	40.9	37.4	41.2	37.0	3.3	0.959	< 0.001	0.667
Protein content, g kg^{-1}	30.6	27.7	33.1	30.0	1.6	< 0.001	< 0.001	0.828
C16:0 + C18:0 / C18:1	2.49	2.37	2.60	2.21	0.02	0.265	< 0.001	0.003
Fat globule size, µm	4.12	4.05	4.44	4.26	0.13	0.067	0.291	0.638
Curd firmness, mm	35.1	27.9	42.5	37.8	1.18	0.007	0.025	0.367
Cheese yield (centrifugation), %	30.2	25.2	29.3	26.6	0.92	0.819	0.052	0.338

Table 2. Physical and sensorial properties of Camembert cheese.

Camembert	Holstein		Normande		SE	Effect		
	MHc	GLc	MHc	GLc		B	FS	B * FS
Yellowness index	16.7	22.5	19.3	24.0	0.88	0.042	0.003	0.424
Firmness under rind, N	2.3	1.5	2.1	1.9	0.30	0.677	0.081	0.276
Sensory analysis (mark from 0 to 5)								
Aspect of entire cheese	3.3	3.2	3.5	3.6	0.05	0.005	0.932	0.131
Aspect of cut cheese	3.8	3.4	3.8	3.5	0.04	0.246	< 0.001	0.707
Melting	2.7	3.1	2.8	3.1	0.06	0.774	0.004	0.356
Pasting texture	2.5	3.0	2.4	2.6	0.07	0.088	0.019	0.417
Taste (mark from 1 to 20)	11.6	10.0	11.1	11.9	0.15	0.011	0.212	< 0.001

At a standardized pH, curd firmness was decreased with GLc treatment and increased with the No breed. GLc treatment decreased laboratory cheese yield (Table 1). Breed and feeding system had small effects on Camembert and Pont L'Evêque cheeses properties and taste. Cheeses were more yellow with GLc treatment and No breed. GLc treatment induced less firm cheeses, especially on the Pont L'Evêque cheeses. The GLc feeding system had no effect on Camembert conformity (form, colour, aspect). The marks of PDO committee were higher for the No breed Camembert. Only GLc treatment improved cut cheese aspect (flowing aspect, number and growth of the holes) and decreased the cheese firmness. The better-appreciated Camembert cheeses were those of the Ho-MHc and No-GLc treatments but the differences remained small. Sensorial characteristics of the Pont L'Evêque cheeses were less affected than those of Camembert cheeses by type of feeding system and breed. In fact, only the aspect of the cut Pont L'Evêque cheese and the firmness under the rind seemed to have been modified by the breed (Tables 2 and 3).

Table 3. Physical and sensorial properties of Pont L'Evêque cheese.

Pont L'Evêque	Holstein		Normande		SE	Effect		
	MHc	GLc	MHc	GLc		B	FS	B * FS
Yellowness index	16.5	23.2	18.3	24.7	0.55	0.023	< 0.001	0.778
Firmness under rind, N	5.1	3.6	6.2	4.9	0.40	0.022	0.014	0.815
Sensory analysis (mark from 0 to 5)								
Aspect of entire cheese	3.9	3.8	3.8	3.8	0.05	0.741	0.908	0.819
Aspect of cut cheese	3.9	3.7	3.5	3.7	0.04	0.019	0.667	0.044
Firmness	2.6	2.4	2.9	2.8	0.06	0.013	0.238	0.763
Taste (mark from 1 to 20)	13.1	12.8	12.3	12.8	0.13	0.130	0.768	0.105

Discussion

Dairy cow breed and feeding systems had small effects on milk composition and cheeses properties. A reduced milk yield and protein content with the GLc feeding system is classically observed with such a low energy diet (Coulon and Rémond, 1991). In the GLc feeding system, the combination of reduced energy intake and conserved grass was not conclusive because it resulted in a combined effect of grass and adipose tissue fatty acids. The No breed effect is classical but limited for fat content compared to results from the literature, however this maybe due to the early stage of lactation of the cows. The breed and feeding systems effect on milk coagulation properties is a consequence of the protein content that increased with No breed and MHc feeding system (Froc *et al.*, 1988). The yellow colour of the cheeses with GLc feeding system is due to the high carotenes content in grass (Prache *et al.*, 2002). In the No breed, the yellow colour may be due to the size of fat globules (Michalski *et al.*, 2003) combined or not with different carotenoids metabolism. The effects of GLc feeding system on firmness are a consequence of a lower spreadability index. There was an interaction between cheese technology and experimental treatments. The effects of feeding systems were more important on Camembert than on Pont L'Evêque cheeses maybe due to the different cheese making (milk fat standardization, milk acidification), types and times of maturation of cheeses.

Conclusions

In view of these preliminary results, the effects of feeding systems and breed on PDO cheeses seem to be relatively small, especially on taste. In this kind of experiment, the role of cheese technology seems to be an important factor and there is a need for further studies on the interactions between the cheese technology and feeding systems or dairy cows breed.

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Rumen fermentation and milk fat composition of dairy cows fed linseed and hay or fresh grass

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Abstract

The linolenic acid (18:3*n*-3) content of dairy milk is generally rather low because dietary polyunsaturated fatty acids are biohydrogenated in the rumen to a large extent. However, it was suggested that biohydrogenation of 18:3*n*-3 could be lower when it is derived from forage compared to oilseeds. Therefore, the aim of the present study was to investigate the effects of dietary 18:3*n*-3 on rumen fermentation and milk fat composition when six ruminally canulated cows were fed either a linseed supplemented diet (L) or a grass diet (G). While dry matter intake did not differ between treatments, daily uptake of oleic (18:1*n*-9), linoleic acid (18:2*n*-6) and 18:3*n*-3 was higher ($P < 0.01$) in treatment L. Compared to treatment G, ruminal pH, ammonia concentration and bacterial counts were decreased ($P < 0.05$) in treatment L. The 18:3(*n*-3) concentration in blood plasma and milk was higher ($P < 0.01$) in treatment L compared to G and resulted in a higher apparent transfer rate of 18:3*n*-3 into the milk fat. Concentrations of CLA and 18:1*t*10/11 were increased ($P < 0.01$) in the milk fat of cows fed the diet G compared to cows fed the diet L. No significant differences occurred between the treatments concerning the calculated desaturase activity in the mammary gland.

Keywords: CLA, dairy cow, grass, linseed, linolenic acid, milk fat

Introduction

In general, dietary unsaturated fatty acids are biohydrogenated in the rumen by micro-organisms to a large extent thereby decreasing their availability for being absorbed as such in the small intestine. This is one reason for the high concentration of saturated fatty acids in milk fat and its consumption has been associated with higher risk of cardiovascular diseases. In order to decrease ruminal biohydrogenation different feeding strategies were suggested with the aim of increasing the content of linolenic acid (18:3*n*-3), in particular, which is known to exert various beneficial physiological effects (Williams, 2000).
Although linseed and fresh grass both contain a high proportion of 18:3*n*-3, Wachira *et al*. (2000) speculated that the biohydrogenation rate of 18:3*n*-3 differs depending on the source. Linolenic acid in linseed is predominantly bound to triacylglycerols, whereas in grass the predominant form is glycolipids. The latter could be less susceptible to rumen lipolysis and biohydrogenation due to their location in the cell structure (Wachira *et al.*, 2000). Therefore, the aim of the present study was to compare the influence of linseed and fresh grass on rumen fermentation and milk fat composition when fed to dairy cows.

Materials and methods

The study was carried out according to a cross-over design with six multiparous ruminally canulated Brown Swiss cows, averaging 19.1 kg d^{-1} milk yield and 150 d in milk. The cows were either fed a diet of ground linseed and hay (L) or fresh grass (G). The cows were adapted to the respective diets for 16 d followed by a 5 d experimental period. The diets were offered twice a day at 07:00 and 16:30 h. Two cows refused to eat the linseed and hence feed was directly introduced through the canula into the rumen. During the experimental period, feed intake was recorded daily and milk yield and milk constituents were quantified over three consecutive days at each milking. On day three of the experimental period, rumen fluid was sampled at 06:00, 08:00, 10:00 and 16:00 h in order to determine ruminal pH, ammonia and numbers of rumen protozoa and bacteria. The following day blood samples were collected by jugular vein puncture at the same time points. The diets were analysed for nutrient content using standard procedures. The fatty acid composition of feed, milk and plasma were determined by gas chromatography.

The statistical evaluation was carried out by ANOVA techniques for a cross-over design using PROC MIXED (SAS, Version 8.00, SAS Institute Inc., Cary, NC, USA). Rumen fluid properties and fatty acid composition of the plasma were analysed as repeated measurements.

Results and discussion

Total daily dry matter (DM) intake did not ($P > 0.05$) differ between treatments (16.9 kg). However, the intake of total fatty acids, stearic (18:0), oleic (18:1*n*-9), linoleic acids (18:2*n*-6), and 18:3*n*-3 were respectively 267, 15, 92, 57 and 95 g d^{-1} higher ($P < 0.001$) in treatment L compared to treatment G. The 18:3*n*-3 proportion expressed as the percentage of the total C16 and C18 fatty acids was higher in treatment G (Figure 1).

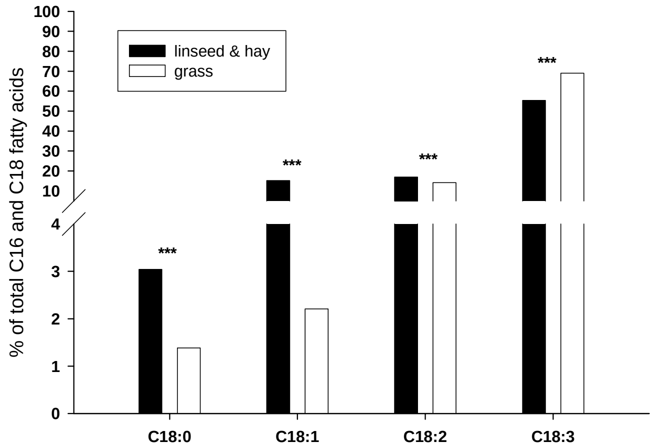

Figure 1. Proportion of C18 fatty acids in the feed consumed expressed as the percentage of total C16 and C18 fatty acids. ***, $P < 0.001$.

The milk yield (17.8 kg d^{-1}), fat (4.1 %), protein (3.5 %) and lactose (4.8 %) content were not influenced by the dietary treatments. As expected, the milk of cows in treatment G had a higher ($P < 0.001$) urea content (G: 336 mg L^{-1} and L: 250 mg L^{-1}). This was in line with the higher ($P < 0.05$) ammonia concentration in the rumen fluid (G: 6.9 mmol L^{-1} and L: 5.3 mmol L^{-1}). Ruminal pH was lower ($P < 0.01$) in treatment L (6.3) compared to treatment G (6.7) but were above values which could have negatively influenced lipolysis and biohydrogenation (Van Nevel and Demeyer, 1996). Compared to treatment G, total bacterial count was decreased ($P < 0.001$) in treatment L (L: 1.8×10^{10} mL^{-1} and G: 2.7×10^{10} mL^{-1}) supporting the hypothesis that fatty acid release rate from triaclyglycerols is higher than from glycolipids (Wachira *et al.*, 2000). However, ciliate count was not affected by treatments (1.6×10^5 mL^{-1}) although these microbes should be even more susceptible to the antimicrobial effect of unsaturated fatty acids than bacteria (Harfoot and Hazelwood, 1997).

When discussing the results of the blood plasma fatty acid profile it should be considered that the fatty acid concentration is not only affected by the diet, but also by ruminal biohydrogenation, absorption as well as tissue turn over rate. The proportion of 18:3*n*-3 in the blood plasma was lower in treatment G compared to treatment L (Figure 2). Concomitantly, the increase of the 18:1*t*10/11 concentration in the plasma was greater in group G than in group L suggesting a higher biohydrogenation of 18:3*n*-3 to 18:1*t*11 in the rumen. Furthermore, the CLA proportion was higher in treatment G compared to treatment L which could indicate a higher isomerisation of 18:2*n*-6 to CLA or, a higher endogenous desaturation of 18:1*t*11 to CLA.

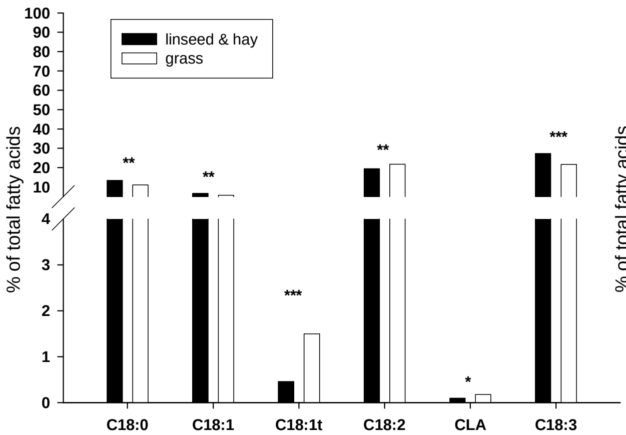

Figure 2. Fatty acid profile of the blood plasma. ***, $P < 0.001$; **, $P < 0.01$; *, $P < 0.05$.

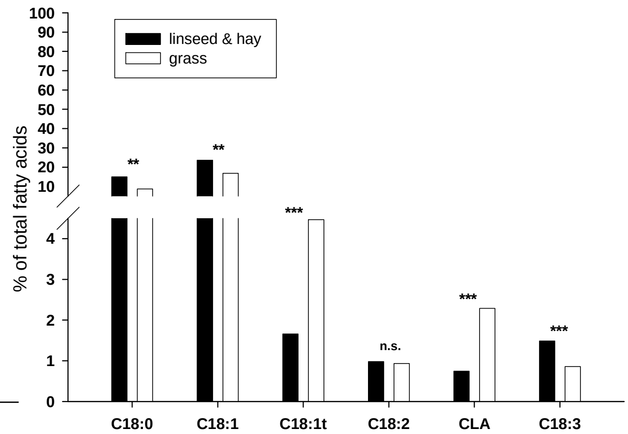

Figure 3. Fatty acid profile of the milk fat. ***, $P < 0.001$; **, $P < 0.01$; *, $P < 0.05$.

In both treatments the proportions of 18:3*n*-3 and 18:2*n*-6 were much lower in the milk fat than in plasma lipids (Figure 3). The differences regarding 18:3*n*-3, 18:1*n*-9 and 18:0 shifted in favour of treatment L while the opposite occurred regarding 18:1*t*10/11 and CLA. The ratio of the desaturase pairs (18:1*n*-9/18:0, $P = 0.12$ and CLA/18:1*t*10/11, $P = 0.29$) suggested that desaturase activity in the mammary gland was not affected by the diet. Because of the endogenous metabolism the present data does not allow determination of the true transfer rate of fatty acids into the milk fat. However, when comparing dietary intake and excretion into the milk, the apparent transfer rate of 18:3*n*-3 was higher ($P < 0.05$) in treatment L and the apparent transfer of 18:2*n*-6 was higher ($P < 0.001$) in treatment G.

Conclusions

No clear conclusion can be drawn about differences in biohydrogenation of this fatty acid deriving either form linseed or grass because of the different intake of 18:3*n*-3 as well as total fatty acids. Despite the lower dietary 18:2*n*-6 and 18:3*n*-3 intake with the grass diet, the relative and absolute amount of CLA was significantly higher in treatment G compared to treatment L.

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Quality of beef from grass-based production systems compared with beef from intensive production systems

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Abstract

The quality of beef from grass-based production systems was compared with beef originating from intensive fattening systems. A total of 70 striploins (*m. longissimus dorsi*) were purchased in various retail markets in north-eastern Switzerland and are designated as beef from cattle grazed in organic farming systems (G1), beef from grazed weaners (G2), one label with conventional intensive fattening (CL), from butcher shops (CB) or from supermarkets (CS). Beef with the lightest colour was CL, while G1 beef showed the most intensive red colour and G2 beef the least intensive red colour. Shear force, reflecting toughness, was relatively high in CB and CS meat and also showed a higher variability than in G1 beef. Beef from G1 and G2 was significantly richer in n-3 fatty acids and the n-6 / n-3 ratio was noticeably lower than in beef from CL and CS origin. CB showed intermediate values. The n-6 / n-3 ratio of CB and CS was considerably higher in spring compared to values in samples purchased in autumn, while in G1, G2, and CL no seasonal effect was observed. It may be concluded that beef from extensive grass-based production is a valuable source of n-3 fatty acids and can be as tender as beef from intensive production.

Keywords: beef, n-3 fatty acids, production systems, grazing, meat colour, tenderness

Introduction

Major components of meat quality are physico-chemical properties (including visual appearance and tenderness), dietetic properties (i.e., fat content and fatty acid composition) and properties which are not directly measurable such as the type of production. The latter includes organic beef production which generally prescribes summer-grazing. However, from the consumer's point of view, the visual presentation of meat is still the most important trait for purchase decisions. Tenderness is probably the most relevant organoleptic characteristic of red meat (Koohmaraie, 1992) influencing recurrent purchase decisions. As grass-based fattening is often accompanied by less intensive growth of the animals, these are older at slaughter, which could be associated with less tender meat. The low fattening intensity may also cause a lower intramuscular fat content (less pronounced marbling). Concerning the health aspect of beef, there might be an advantage of grass-based systems, since grass is known to contain a high proportion of α-linolenic acid (ALA), the basic omega-3 (n-3) fatty acid. It was shown that ALA can be endogenously desaturated and elongated to long-chain n-3 fatty acids, i.e., eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). In various studies, n-3 fatty acids and conjugated linoleic acids (CLA) were found to exert beneficial health effects. Therefore, an improved supply of n-3 fatty acids and CLA in human nutrition is desirable and could be enhanced through the introduction of pasture-based production systems (Nürnberg *et al*., 2002). The objective of the present investigation was to analyse retail beef with stated origin from pasture-based systems as purchased at the point of sale not only in autumn but also in spring, several months after the end of the pasture season.

Materials and methods

The comparison performed in the present study was based on 70 striploins (*m. longissimus dorsi*) of about 1.2 kg from five different categories of production origin. Two of these origins related to grazed animals (G1, n = 20; G2 n = 10). G1 beef was from organic production of steers and heifers, G2 beef came from weaners of a suckler beef label with slaughter of the calves at approximately 10 months of age. The other three origins were from another beef label (CL, n = 20) where intensive fattening is common, from unlabeled heifer beef from butcher shops (CB, n = 10), or from conventional beef from supermarkets (CS, n = 10). In order to examine potential seasonal effects, half of the striploins of each origin were obtained in autumn 2002, the other half in early spring 2003. All samples were purchased in retail stores in north-eastern Switzerland. After transport to the lab, samples were cut into 2.5 cm thick slices and one slice each was grilled in an electrical contact grill (model TURMIX 246, Beer Grill, Zurich) to a final core temperature of 72 °C (controlled by thermocouples inserted into the centre of the slices and attached to a datalogger ALMEMO model 3290-8, Ahlborn, Holzkirchen, Germany). After cooling for 30 min., cooking loss was determined by weighing and seven cores (cylinders of 1.27 cm diameter) as well as seven stripes (1 × 1 cm^2 cross section) were prepared from each grilled slice parallel to the muscle fibre direction. The cores were sheared by a Warner-Bratzler-Shear blade and the stripes by a Volodkevich device, both mounted on a TA-XT2 Textur Analyser (Stable Micro System, Surrey, UK). Colour measurements were made using a Minolta Chroma Meter (model 300-CR, Dietikon, Switzerland) in three replicates. Beef was analysed for its intramuscular fat content along with the determination of fatty acid composition of the intramuscular lipids. For this purpose, fatty acids were extracted with Hexane Isopropanol; (3:2 with Triundecanoin as internal standard) and converted to methylesters. The determination was done with a gas chromatograph (HP 6890, Hewlett-Packard, USA) equipped with a split injector, an FID detector and a 100 m CP-Sil88 column. The amounts of fatty acids were calculated as percentages of the total area of identified methylesters. Analysis of variance was performed using the SAS (version 8.0).

Results and discussion

Beef from CL origin was lightest, while G1 was of the most intensive and G2 the least intensive red colour. The colour difference can partly be attributed to age differences (Branscheid *et al.*, 1998). Both shear force traits, Warner-Bratzler and Volodkevich, indicated a greater toughness and a higher variability in CB and CS beef compared to G2 and, particularly, to G1 beef. G1 Warner-Bratzler values were on average (35 N) below the threshold of 40 N suggested by Branscheid *et al.* (1998) for tough meat. The means of G2 (40) and CL (39) beef were exactly at this borderline while CB (51) and CS (52) exceeded this value. Age effects on the connective tissue component of texture (Nishimura *et al.*, 1999) were not obvious and thus presumably overridden by differences in slaughter process and meat aging. There was no significant group difference in cooking loss (34 % on average) and intramuscular fat content (1.6, 1.2, 1.6, 1.7 and 1.3 % on average for G1, G2, CL, CB and CS respectively). Beef from G1 and G2 was richer in n-3 fatty acids than all other origins ($P < 0.05$ for G1; Figure 1A) and both pasture-based origins showed similarly high values of n-3 fatty acids in autumn and in spring (41.8 and 54.3 mg 100 g^{-1}, respectively). The n-6 / n-3 ratio was noticeably lower in samples from G1 and G2 than from CL and CS (Figure 1B). CB beef showed intermediate values. Additionally, the n-6 / n-3 ratio of CB and CS was considerably higher in spring than in autumn suggesting that in these production systems summer diets supplied higher amounts of n-3 fatty acids. In G1, G2 and CL no seasonal effects were observed.

It has been assumed that human beings evolved consuming a diet that contained about equal amounts of n-3 and n-6 polyunsaturated fatty acids. Over the past 150 years this balance changed and today, most humans consume cereal grain products rich in n-6 fatty acids (Simopoulos, 1999). Beef from grass-based production systems had a n-6 / n-3 ratio which was near this level and was considerably lower than that recommended for dietary intake of man (5:1), while beef from conventional production was sometimes slightly above that level (Figure 1B). Both pasture-based beef origins showed not only elevated ALA contents (data not shown) but also, relative to the origins from intensive fattening, higher contents of EPA (10.9 vs. 5.2 mg / 100 g) and DHA (1.8 vs. 1.3 mg / 100 g). Contents of CLA were higher in G1 and G2 (6.7 and 6.6 mg 100 g^{-1} beef) than in CB and CS (5.60 and 4.34 mg / 100g beef), with intermediate contents in CL (5.8 mg 100 g^{-1} beef). Accordingly, the consumption of beef from grass-fed animals could contribute to better meet human requirements for these fatty acids as was also suggested by Nürnberg *et al.* (2002).

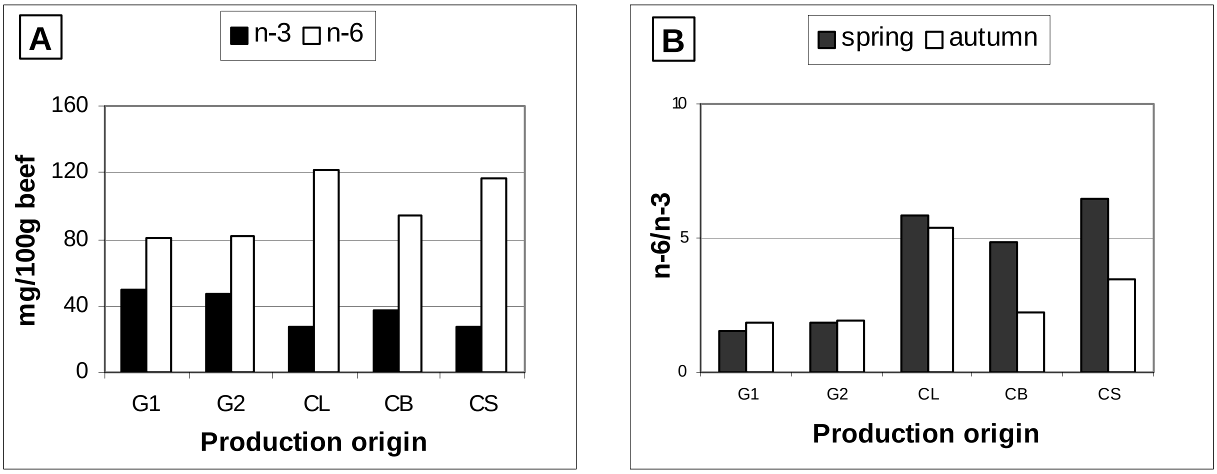

Figure 1. Contents of n-3 and n-6 fatty acids of beef of different origin (A) and seasonal effects on the ratio of n-6 / n-3 fatty acids (B).

Conclusions

For people not eating sea fish, meat is an important source of long-chain n-3 fatty acids. This study demonstrated that pasture-derived beef can be helpful in that respect. In addition, retail beef from pasture-based systems proved to be not inferior in physical properties to beef from intensive fattening systems. Finally, in the grass-based systems similarly high contents of the desired fatty acids as in autumn were found at the end of the winter feeding period, presumably because winter diets in these systems were still heavily relying on grass-derived products, such as hay and grass silage.

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The potential and limitations of integrated grassland research

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Abstract

Integrated research approaches are currently very popular and generally considered more likely than disciplinary studies to solve management problems, in multifunctional agricultural landscapes. This paper explores the nature of inter- and transdisciplinary research and the potential and limitations of such research approaches. Our focus is on the policy expectations and the products of integrative research approaches. Stakeholder participation is seen as the critical factor in the growth of transdisciplinary approaches where academic and non-academic participants work together to solve complex land management problems. However, as a result of the rapid growth of transdisciplinary approaches, the line between research and application is becoming blurred. As a framework for discussing integrated projects and their products, we present data gathered from interviews with funding bodies, project leaders and participants involved in integrated projects on European agricultural landscapes, as well as contact with more than 100 journal editors and the results from an international web-based survey of researchers. Based on this information we develop a code of good practice for integrated research. Finally, we look ahead at the challenges arising from the widespread adoption of integrated research, what we can realistically expect from it and its limitations.

Keywords: interdisciplinarity, research modes, transdisciplinarity, grasslands, integration, multiple-use

1 Introduction

There are many tensions in the management of grasslands at all scales from the individual farmer to European and global markets (Dalgaard *et al.*, 2003). Farmers are under increasing pressure to produce non-food products including recreational opportunities, attractive landscapes and habitats for wildlife. The many different forms of agri-environmental payment schemes are witness to these pressures. Agricultural research has also responded to these pressures and moved its focus away from studying measures in support of increasing food production to the integration of social and environmental aims on agricultural land (Primdahl *et al*., 2003).

One of the trends in the funding of grassland research over the last 20 years has been the rapid growth of large-scale integrative projects. These have had a focus on two contrasting and equally important processes affecting grasslands; (1) the intensification of agricultural production on the best soils, and (2) the abandonment of farming practices in marginal farming areas. The grasslands involved are high yield fodder crops and grazing on the better soils, and more extensive pasture and meadows in marginal areas. In research on intensive crop production, we find many examples of large-scale integrated projects related to environmental protection. These include issues such as the management of nutrient salts and particulates in run-off and the protection of biodiversity. In contrast, the research on marginal grasslands has a focus on the grasslands themselves as possessing a high environmental value. Here, semi-natural grasslands (pastures and cut meadows) are the main interest, and the main issue is how one keeps this land in production (under traditional management regimes) when there is no longer a demand for its agricultural products. A major demographic problem in most parts of the western world is the depopulation of marginal agricultural areas and migration into cities.

Against this background of environmental concerns we have experienced greater demands on the way grasslands are managed and the widening range of objectives they should fulfil. This has fuelled the demand for new research tools to address these problems. Since the problems are complex and span several disciplines, it was natural to consider integrative forms of research as the way forward (Balsiger, 2004). In this paper we explore several of the major concepts associated with integrative research modes, what funding bodies and researchers expect from such research and what is being delivered. This paper is based on the preliminary results of the INTELS study investigating interdisciplinarity and transdisciplinarity in European landscape studies (*http://www.intels.cc*). To provide a framework for discussing integrated projects and their products, we present data gathered from interviews with funding bodies, project leaders and participants involved in integrated projects on European agricultural landscapes, as well as contact with more than 100 journal editors and results from an international web-based survey of researchers. We use this information to review the challenges arising from the rapidly changing field of integrated research with a focus on what we can realistically expect it to achieve. An important project objective is to develop a code of good practice for integrated research. (Tress *et al.*, 2003; Tress *et al.*, 2004).

2 Defining integrative research approaches

Integrative research approaches, especially interdisciplinarity and transdisciplinarity, are widely used in grassland research. This is true for many fields of research related to resource management, especially at larger scales e.g., from landscape to region. The perspective of this paper is biased towards whole farm and landscape studies. At these scales, we see a tendency to move away from specialist research disciplines and a greater emphasis on integrating several, often conflicting, interests, values and goals. Within landscape research, there has been increasing demands for integrative research approaches (Naveh and Lieberman, 1994; Nassauer, 1995; Zonneveld, 1995; Hobbs, 1997; Brandt, 2000; Décamps, 2000; Klijn and Vos, 2000; Palang *et al*., 2000; Naveh, 2001; Tress *et al*., 2001; Bastian, 2002; Wu and Hobbs, 2002). A major driving force behind the increasing number of integrative research projects has been the emphasis given to integrative research in national and international research funding programs (Tress *et al*., 2004).

Nevertheless, there is much confusion regarding the terminology describing integrative research approaches. This not only complicates communication of the core concepts, such as interdisciplinarity, but can also make it difficult to match funding body expectations with research achievements. We stress the need to clarify concepts in the field of integrative research and make definitions explicit. Therefore, we start with descriptions of the main concepts as used in this paper; not as an attempt to provide an authoritative set of definitions but as an aid to communication in order to further the debate (Figure 1).

Disciplinarity: Projects that take place within the bounds of a single, currently recognized academic discipline. We fully appreciate the artificial nature of subject boundaries and that they are dynamic.

Multidisciplinarity: Projects that involve several different academic disciplines researching one theme or problem but with multiple disciplinary goals. Participants exchange knowledge, but do not aim to cross subject boundaries to create new knowledge and theory. The research process progresses as parallel disciplinary efforts without integration but usually with the aim to compare results.

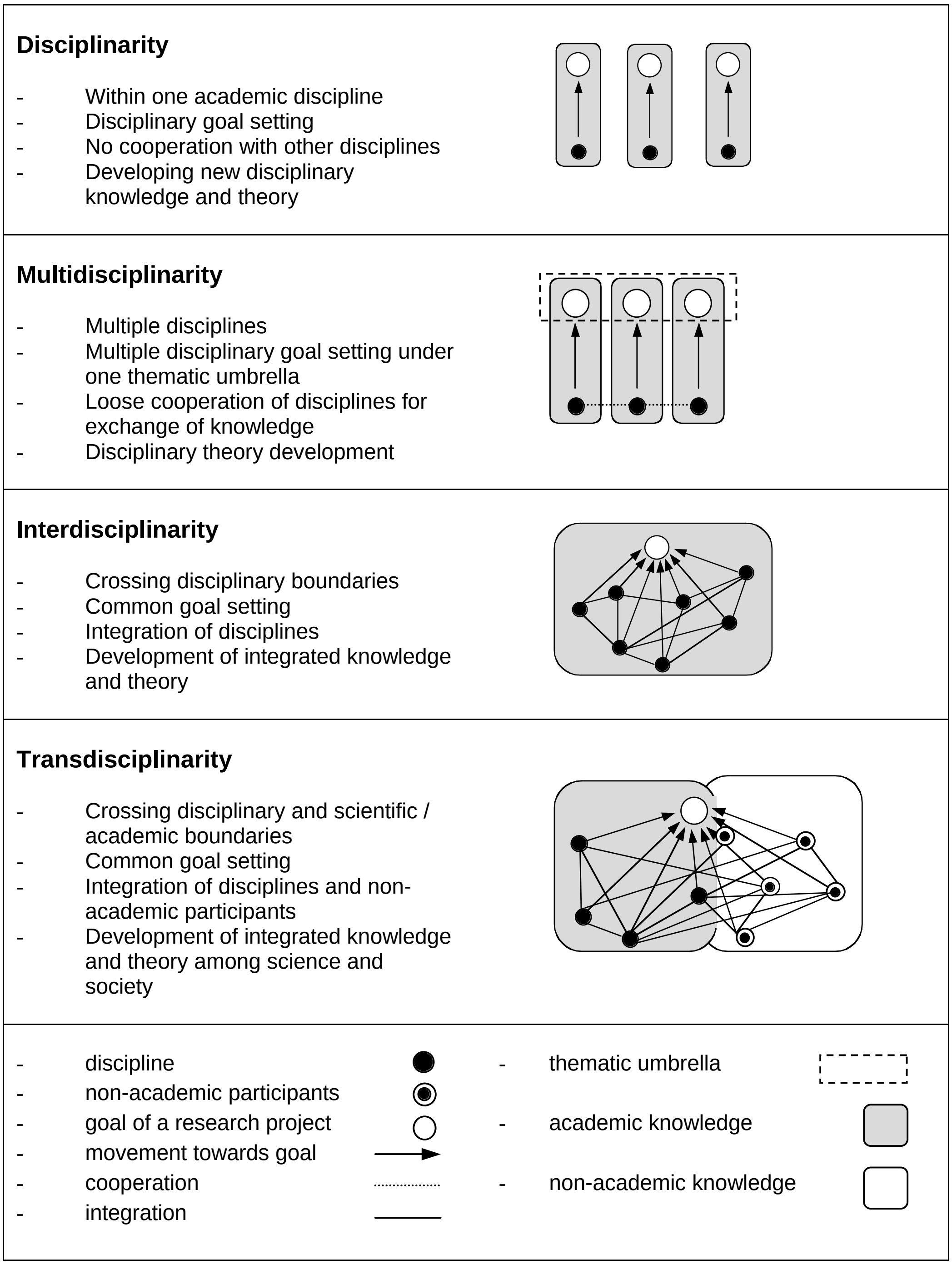

Figure 1. Disciplinary, multidisciplinary, interdisciplinary, and transdisciplinary research concepts.

Participatory studies: Projects that involve academic researchers and non-academic participants working together to solve a problem. Academic researchers and non-academic participants exchange knowledge, but the focus is not on the integration of the different knowledge cultures to create new knowledge. Both disciplinary and multidisciplinary studies may include non-academic participants. Participatory studies are not necessarily research.

Interdisciplinarity: Projects that involve several unrelated academic disciplines in a way that forces them to cross subject boundaries to create new knowledge and theory and solve a common research goal. By unrelated, we mean that they have contrasting research paradigms.

We might consider the differences between qualitative and quantitative approaches or between analytical and interpretative approaches that bring together disciplines from the humanities and the natural sciences.

Transdisciplinarity: Projects that both integrate academic researchers from different unrelated disciplines and non-academic participants, such as land managers and the public, to research a common goal and create new knowledge. Transdisciplinarity combines interdisciplinarity with a participatory approach.

Integrated Studies: Projects that either work interdisciplinary or transdisciplinary, in that new knowledge and theory emerges from the *integration* of disciplinary knowledge.

3 The policy perspective: high expectations for integrative research

The motivation for participating in integrated studies has rarely arisen from academic needs. Individual scientists, project leaders, and research institutes claim that participation in integrative studies is most often a response to the priorities of policy-makers and funding bodies. Researchers also claim that their project applications must be integrated to have any chance of winning large research grants in the field of natural resource management. Funding bodies claim that current societal and environmental problems cross policy sectors and disciplinary boundaries and thus call for a common effort. Many of the problems facing grassland management are complex and may involve aspects of animal husbandry, economy, soil science, rural sociology, ecology, and culture etc. Researchers are expected to contribute to problem solving through examining natural resource management issues from several perspectives. On the other hand, research institutes claim this has made it difficult to fund pure research, even when this is to advance knowledge in fields essential to our understanding of sustainable agricultural systems. Disciplinary research approaches are considered less able to meet current policy needs, whereas integrated studies are expected to produce a greater proportion of operational solutions (Ewel, 2001; Gibbons *et al*., 1994). Researchers have little choice but to follow research policies, and these currently have high expectations of integrated studies. But how realistic are these expectations? The results of our own surveys suggest that these expectations are unrealistically high, placing considerable pressure on researchers and their institutes (Tress, *et al*., 2003; 2004).

The academic integration of disciplines is both very difficult and can take longer than a single disciplinary research project or programme. We require, therefore, a more realistic understanding concerning the nature of integrative research and especially of the limitations of any form of research to solve management problems (Asselt and Rikjens-Klomp, 2002). We believe that integrated studies cannot be a substitute for disciplinary or multidisciplinary efforts. We further reject the idea that interdisciplinary and transdisciplinary research approaches are intrinsically 'better' than disciplinary and multidisciplinary research. The different approaches are all useful and each is suitable to specific research questions. High-quality disciplinary research is a precondition for achieving good integrated research. It has been argued that the relationship between disciplinary and interdisciplinary approaches is parasitic, such that progress in integrative approaches is dependent on the constant supply of high quality new disciplinary knowledge (Hansson, 1999). If one financially favours integrative approaches to the exclusion of disciplinary studies, we risk that progress in certain scientific fields will slow down or stop and there will no longer be new disciplinary knowledge to integrate. Balsiger (2004) goes further, and claims that transdisciplinary research is mainly requested by policy makers, but there is no real need for it.

4 What are we trying to integrate?

When conducting integrated research, it is necessary to understand the meaning of disciplines and their boundaries (Thomson Klein, 1990; Lattuca, 2001) and to critically reflect on their current state and direction (Thomson Klein, 2004). Disciplines are not static and are increasingly evolving into sub-disciplines with their own language and identity. New disciplines appear and old ones disappear, reflecting developments in knowledge cultures and academic institutions. From an epistemological perspective, some boundaries are harder to cross than others. Integrating humanities and natural science perspectives is especially challenging. For many agricultural research projects, combining economic and ecological perspectives has been difficult, with areas of disagreement related to underlying model assumptions, time scales and what should and should not be taken into account. When undertaking integrative research, such boundaries have to be identified and their nature understood before significant degrees of integration are possible.

Integration requires special efforts to bridge academic disciplines and create knew knowledge. Most often what we achieve with large projects that span several disciplines and institutes is multidisciplinary research. There is nothing wrong in doing multidisciplinary studies. We are convinced that for many research purposes and for meeting the demands of funding bodies, it is often the most appropriate research mode. Funding bodies have informed us that they see the process of forcing researchers from different fields to communicate with each other as the main goal of large-scale projects, not necessarily the more difficult task of integrating disciplinary knowledge. They believe that steering researchers to work together, in the same study area or through studying the same problem will result in formal and informal interactions that will make valuable contributions to solving land use management problems.

5 Project management

Achieving a high level of integration between disciplines is difficult and most projects fail to realize this aim. Project organisation, project design and the day-to-day working environment of people working in large-scale projects can determine success or failure (Jacobsen *et al.*, 2004). If institutional frameworks are unsupportive of the integration process as expressed through low resource allocation or cultural isolation, the barriers will be insurmountable. Coordinating the staff of large research teams in space and time is a major challenge of project organisation. Spatial separation and infrequent or formal meetings will not help the process of integration. Supportive leadership and management styles combined with frequent and goal-oriented meetings are important factors. Projects that have no clear strategy on how to deal with integration issues often had difficulties in getting started or reaching successful outcomes. We have often observed that projects, that set out to be integrated, had neither integration goals nor a common problem definition. As a result, many projects end as constellations of small independent (disciplinary) groups. During the course of a project, these groups work more or less independently from each other, only coming together at the end to integrate results. But this is seldom realized when it comes so late in the project process (Fry, 2001). The design of integrated research should include measures that span the whole project period. The integration process should start at the beginning – at the stage of project formulation and application. At this stage we need to ask why we are integrating interests and what integration is expected to achieve. If we are unable to formulate answers to these questions, how are we going to know when we have been successful?

Good personal chemistry between researchers is also a key to success. Mutual trust, motivation and pleasure in working together are important in any research team. However, the common ground is much smaller when contrasting disciplines are involved than when researchers all come from the same or closely related disciplines. Overcoming cultural barriers places high demands on the interpersonal relationships between members of interdisciplinary projects. As a result, smaller research teams are often better suited to crossing disciplinary boundaries than larger ones.

6 Training needs

All research requires a working knowledge of the accepted tools and methods that are integral to specific disciplines and knowledge cultures. Yet, we still observe that interdisciplinary and transdisciplinary studies often start without either participants or project leaders having a firm understanding of integrative research approaches. With no background training or experience in these approaches, researchers often have enormous problems in making the integration work and may return to the relative security of their disciplinary modes of research. Whilst on topic of training, it is worth mentioning the special situation of PhD students. Many large-scale integrated projects involve several PhD students. Often these PhD students are given the task of achieving integration between the disciplines. Our surveys also show that the PhD students engaged in integrative research take longer than average to complete their studies. This may be an especially acute problem for research students in transdisciplinary projects where the solving of a particular practical problem may not involve sufficient research to qualify for a PhD. Training research students in the epistemological background to integrative research and in the social and psychological processes involved in working across subject and knowledge culture boundaries should be part of the formal course work. It will be very important for students to understand the dominant theoretical approaches of the different disciplines involved in the project if they are to play a major role in the integration process (Thomson Klein, 2004). Our belief is that integrated research is less suited to PhD students and that if they are to tackle this work they will need significantly greater levels of support than is current practice.

The integration process may take longer especially in defining common research goals, and thus need more support in the early project phase. Participants should, as far as possible, have opportunity for regular contact and spontaneous discussion to build the mutual trust and understanding needed to reach high levels of integration. To achieve this, it might be necessary to create temporary environments that physically bring interdisciplinary teams together across institutional boundaries. Research management can do much to foster inter- and transdisciplinary studies. But this requires research managers to be sensitive to the needs of integrated research and how to create the special conditions and supportive environments needed by integrative research teams. To increase the success of integrated research, training is requires at three levels: for participants, project leaders and research managers.

7 Improving the theory base

As well as their expected practical applicability and problem solving potential, interdisciplinarity and transdisciplinarity are just alternative research approaches. This implies that they have an underlying epistemological support, including integrated theories and concepts. However, these are weak points in integrated studies. So far, little coherent interdisciplinary or transdisciplinary theory has emerged from landscape research (Tress and Tress, 2002). The same is true for the development of inter- and transdisciplinary concepts and methodologies. One suggestion is to increase efforts in support of a systematic collection of results and experiences of integrated studies in order to identify new generalizable knowledge and improve methods and tools (Fry, 2003; Smoliner *et al*., 2001). The implicit knowledge gained from practical experiences in integrated studies is only rarely made explicit and is, therefore, not available to the scientific community (Nonaka and Takeuchi, 1995). This violates a basic academic tradition: to build on existing knowledge. Instead, most integrated studies start from scratch and thus progress is slow.

8 The products of integrated research

A merit system gives scientists rewards for certain activities that institutes, universities or the wider scientific community regard as important achievements. Current academic merit systems are tailored for disciplinary approaches and rely heavily on peer-reviewed publications in international journals as the main criteria of success. Likewise, the career advancement of scientists is still mainly based on disciplinary efforts. This is seen by some as a limitation to the development of integrated approaches. If scientists are to work with integrated approaches, their involvement should have equal chances of being rewarded as disciplinary efforts. A merit system for integrated approaches may require academia to acknowledge a wider range of research products. Assessment of these products, however, will need the development of extensive, systematic, transparent and fair systems of peer-reviewed achievement.

There exists confusion over what integrated research can deliver. There is a wide belief among researchers that it is difficult to publish the results of inter- and trans-disciplinary research. To test this, we contacted more than 155 journals in agriculture, forestry or ecology. Almost all have published papers from grasslands research. We asked the editors of these journals whether they would publish the results of integrated studies. Of the 95 that replied 94 said that they would welcome such papers. Similarly, the instructions to authors of scientific journals show that more than 50 % actively seek papers from interdisciplinary research and a further 40 % are neutral. There may be discrepancies between the declared publishing policy of journals and the responses of reviewers to integrated papers, or there may be other reasons for finding the results of integrated research difficult to publish. The following factors were mentioned by researchers in our survey:

- The work does not make a significant or novel contribution to the relevant bodies of knowledge,
- The work is too descriptive,
- It is difficult to write joint papers when co-authors belong to different research cultures:
- Different styles
- Different concepts of data
- Different strategies for analysing data
- Lack of a common theory base,
- The work is the application of existing knowledge, not original enough to be published.

An equally important product of integrated research is the ability to solve environmental problems. However, we have found little evidence to suggest that integrated projects are more or less likely than single disciplinary research to provide solutions to environmental problems. Applied research is more likely to focus on specific problems and their solutions, but whether integrated approaches result in more or better solutions is difficult to assess. There is little empirical evidence either way. The long-term benefits of increasing communication between disciplines are also difficult to assess.

At an abstract level, integrative or participatory research projects contain elements of knowledge creation, application, and reflection, as well as feedback to science. These processes go hand in hand and mutually influence each other. We analyse the process of knowledge creation in two steps to clarify the boundary between research and consultancy / outreach activities (Figure 2):

(1) Existing knowledge is used to develop a solution to a specific problem. This knowledge may be derived from the collective expertise of the project team (which may include non-academics as well as academics) or from the results of earlier research studies – part of the body of scientific knowledge. For a project to be considered as research demands that new knowledge has to be generated by the project team in order to solve the problem. This debate is very relevant to the increased consultancy and outreach activities of European research institutes.

(2) The second part of the process of knowledge creation occurs when the focus is on the generation of generic knowledge. We also acknowledge that the systematic application of existing knowledge can be a form of hypothesis testing – leading to the production of generic knowledge. As science is interested in the nature and behaviour of observable phenomena (Feynman, 1998), it seeks knowledge that has relevance and validity beyond a specific context. This generic knowledge is fed back to science usually through the publication of a peer reviewed scientific paper or book and is the main process through which progress in science takes place.

It would appear that many applied integrative projects only focus on the goal of gaining the knowledge needed for solving the specific problem defined by the funding agency. Once this has been achieved, there may be neither time nor money for more basic reflection on the knowledge created or how it relates to the wider scientific context. The focus of consultancy work is more on the application of existing knowledge than on the creation of generic knowledge and hence scientific advancement. Consultancy relies on the application of existing knowledge for the solution to a problem – the work is not usually considered as research even when that solution is contextual and unique.

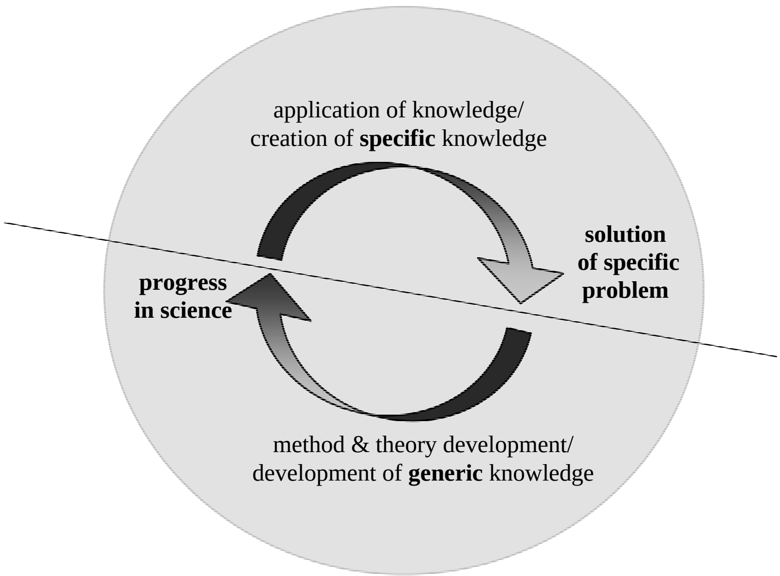

Figure 2. The process of knowledge creation – the development of generic knowledge.

9 Identifying good interdisciplinary practice

What is a good interdisciplinary or transdisciplinary study? Attempts have been made, to develop sets of evaluation criteria for integrated projects (Defila and Di Giulio, 1998; Spaapen and Wamelink, 1999; Balsiger, 2004). There are, however, no widely recognized quality standards that could be used to evaluate projects through their various stages. Quality standards would have two main advantages: They would make it easier for funding bodies to distinguish real interdisciplinary projects from those that only play with the name to improve their chance for getting support and they would serve as guidelines for researchers by setting the standards their projects should achieve. Development of integrated research standards would contribute significantly to improving interdisciplinary and transdisciplinary projects. One criterion would be the degree of integration reached in a project and how this contributes to the add-on value of end products.

One characteristic of the large-scale research projects studied by the INTELS project was that most had no specific plan to reach integration. Yet, many of the other aims of these projects had clear objectives linked to specific methods and milestones to assess planned progress. We firmly believe that achieving integration should also be seen as a specific project aim with a full description of the planned progress of integration and how this will be achieved. Only in a few recently started initiatives have we identified specific aims for improving knowledge and skills in integrated research among the aims of research programs.

The following is a summary list of the measures / advice based on research the INTELS project (Tress *et al*., 2003; 2004)

- develop a specific plan for the integration process with clear aims
- start integration early in the project process
- give participants opportunity for frequent formal and informal contact
- organize seminars specifically to communicate different research modes and approaches
- include a plan for integrated products showing add-on value
- in general small groups work better than large
- the power of personal chemistry cannot be overestimated
- good project leadership and management are essential to the success of large projects
- supportive institutional structures are required, these provide reward and identity
- training is required at the researcher, project leader and institutional management level
- integrative projects may not always be suitable for PhD studies

10 Discussion

The growth in integrated approaches is currently driven more by funding agencies and research policy, than the needs of researchers. Yet, our surveys also found that many academics enjoyed the challenges of integration and fully expected the merit system to adapt in response to changes in research modes. When asked if they would participate in an integrated project again, 67 % said they already were, and a further 30 % said they would like to. However, this popularity can easily be jeopardized if integrated approaches fail to live up to their promise of added value compared with disciplinary approaches.

Having stressed all the difficulties facing integrative research, we would like to balance this by stating that it is possible to find successful interdisciplinary and transdisciplinary projects and that they are getting better at publishing their results. In addition, participants from integrated studies report that their involvement gave them unexpected new insights not only into other fields of research, but also into their own subjects (Kinzig, 2001). These insights fundamentally changed the way they perceived their own discipline and, sometimes, their methodological approach. To all those involved in integrated research the challenge is to demonstrate that their efforts provide added value to both academia and society.

To improve the success rate of integrated studies, the expectations of scientists and funding bodies need to reach a better balance and need to be made explicit. This would include greater reflection and a more realistic appraisal of what integrated research approaches can achieve and what they cannot (see Futures volume 36, 2004). We need to acknowledge – against the tide of opinion – that integrated studies are not the solution to each and every land management problem nor will they always result in win-win resource management situations. Interdisciplinary or transdisciplinary approaches will not prevent power struggles between interest groups and will not tell policy makers what should to be done. Integrated research approaches will, however, increasingly inform policy of the consequences of different land use scenarios and hence provide a better basis for decision-making. Integrated approaches will also help identify barriers to problem solution. Finally, integrated research may provide new insights into old problems.

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Knowledge Exchange – Searching for Impact

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Abstract

Important scientific insights do not always trickle down automatically to farmers or decision makers. Since problems cannot be solved by the way of thinking that has caused these problems, as Einstein once said, we might have to reconsider the way we look upon knowledge. Dominant concepts of knowledge influence the course of development, as is illustrated by examples from Polish and Dutch agriculture. The paper concludes with an alternative: the ecological concept of knowledge, referring to the ecological challenge mankind is facing.

1 Knowledge and the Ecological Challenge

Scientists and technicians are extending the borderlines of what is known about eco-systems, about the vulnerability of areas in relation to agricultural production and other land-uses, and about technologies that could help to bring behaviour of humans in line again with the requirements of their ecological environment. However: does it matter?

Potential users of these insights and technologies are prone to many pressures. Farmers have to survive in competitive markets that are being liberalized further and further. Consumers depend on what is being offered by retailers, making their choices between low prices or environment-friendly products. And policy makers seem to have their own rationality that does not always match well with what experts see as rational. As an international trend government spending on research, extension and education is shrinking, while at the same time financiers tend to leave less free space to knowledge workers for doing what they themselves think is important. Sound and urgent scientific insights do not automatically trickle down to those who are supposed to change things in practice. What can be done to improve the impact of knowledge about ecological imperatives?

We take the view that implicit concepts of knowledge often hamper the social learning processes that are needed to create impact. It is a pitfall to think that impact means that in the end people must behave as technicians think they should. What counts is that networks of people are capable of responding adequately to the requirements of their environment and to the challenges they meet. In this contribution we offer an alternative that is in line with what can be called: an 'Ecological Rationality'[1]. Basic principles behind all forms of life apply to human networks as well. This perspective sheds new light on the role of knowledge and science in society.

The following sections present a short history of the agricultural extension systems in Poland and The Netherlands. These two case studies illustrate the changing role of knowledge in agricultural development under quite different circumstances. Farmers in both countries have difficulties in finding appropriate answers to the major changes they are facing, but in different manners. These cases do not necessarily show the best way to organise knowledge systems, but rather provide examples of dilemmas to cope with and pitfalls to avoid. In the second part of this presentation we will work out an ecological view on knowledge that puts

[1] The term 'ecological rationality' is borrowed from Röling and Jiggins (2000), who called for a new way of thinking that would enable mankind to respond to the enormous ecological challenges that are being caused by human activity in recent times. Wielinga (2001) explored such a rationality in his PhD thesis.

these illustrations in a different perspective. We conclude with statements that scientists might want to use in the quest of improving the impact of their knowledge.

2 Polish extension services in transition

Poland counts 1,881,000 farm holdings. 500,000–700,000 farms are market-oriented enterprises. Around 57 % of the holdings is smaller than 5 ha. Only 8.5 % of the enterprises is larger than 15 ha, but they represent 36 % of the total agricultural area. The average size is 7.2 ha (compare the EU average: 13.0 ha).

2.1 Major changes

Polish agriculture is in transition. In fact it is experiencing the second major transition within little more than a decade. After the turn-around from government-controlled agricultural production to private entrepreneurship, presently the adjustment to the European common market requires major changes again. Farmers, as well as the processing industry have to abide to strict rules in order to ensure the higher quality standards in the EU and to reduce the risk of spreading pests and diseases, before free trade of food products, vegetable production, and livestock will be allowed. Not only high yields but also quality and cost reduction are important for competing effectively in the EU market. Meanwhile the high number of small farmers having little chances, neither at the international market for agricultural products, nor at the local labour market, is a major problem that needs to be addressed, just as does the quality of life in rural areas (Kania and Drygas, 1996). How does the agricultural knowledge and information system respond to these changes?

Nowadays farmers can make use of many sources of information. The Polish government provides extension services at the national and the provincial level. Information and advice can also be obtained from private extension organisations, firms trading in agricultural inputs or purchasing farm products, Chambers of Agriculture and branch unions, agencies and foundations dealing with specific subjects, banks, agricultural schools, universities and research institutes. Last but not least the internet gives access to practically all information that is being made available anywhere in the world.

2.2 The state-owned agricultural extension system

At the national level the National Advisory Centre for Agriculture and Rural Development supervises 2 national and 7 regional centres. Their main task is to support the necessary adjustments of Polish agriculture according to the scenario of the EU integration. This includes amongst others:

- wide popularisation of all endeavours related to the adjustment process
- cooperation in the implementation of modern technology and dissemination of research results in practice
- the establishment of a national agricultural information system, such as the publication of magazines on different subject matter for extension staff, farmers and rural circles
- the organisation of training courses, seminars and conferences

At the provincial level there are Provincial Agricultural Advisory Centres in 16 provinces with 26 branches, operating under the responsibility of the provincial governor’s office. Their main task is to provide services to farmers and rural dwellers in the field of production, economics, organisation, production quality and marketing of agricultural products. Also home economics, youth clubs and local organisations are being attended to. These provincial extension services are well embedded in the social structure by social agricultural councils at the national, provincial, regional and communal level. These councils are composed of farmers (75 %) and representatives of professional organisations, including researchers. They monitor, advise, comment on and inspire the activities of the extension centres. The extension system has functioned this way since 1999 and employs 5,680 people, out of which 4,694 technicians (field staff and managers). As strong points of the Polish agricultural extension system, the following can be mentioned (Kania, 2000a, b):

- rural extension is wider than agricultural production and addresses the needs of rural communities
- well experienced and well trained extension personnel
- very good technical facilities
- a broad scope of services freely available: agricultural information is a public property;
- formalized ties with research, cooperation in the transfer of agricultural information and dissemination of innovations
- systemized extension forms, verified methods and system approaches
- dissemination of knowledge for balanced farming and the protection of the natural environment, and for the improvement of ecological awareness amongst farmers and other rural inhabitants
- development of local leadership stimulating various forms of enterprise in the country
- extension for the benefit of rural women (home economics) and children (4 H Clubs)
- education for farmers and rural inhabitants not having had access to formal education

Weaknesses should be mentioned as well:

- the system is relatively expensive for the tax payers
- services are often subject to political decisions
- bureaucracy, and a reactive attitude on matters that arise, instead of a pro-active approach based on strategic planning and programmes to be attended by farmers and local leaders
- duplication of services by the national and provincial extension system
- improper distribution of regional centres for agricultural extension and rural development

2.3 The environment is changing

In this transition period many things are changing simultaneously for the rural communities. Rural extension services need to find answers to the following developments:

- the access to the European Union requires a reorientation from production increase to production quality, to cost effectiveness and to high sanitary standards
- environmental protection has become an important issue for agricultural production
- farmers and their supporting agencies have to learn how to deal with the administrative procedures of the EU, i.e., for obtaining subsidies and projects
- farmers have to choose whether to specialise in order to have chances at the international market, or to seek other employment, i.e., in off-farm activities
- not only farm production but the quality of the entire production chain (including input supply, processing and marketing) is becoming crucial
- information technology provides access to many sources of information, changing the information shortage for farmers into an information overflow
- government is seeking ways of reducing the costs of the extension services

- although information from research and extension is still being regarded as a public property, it is questionable how long this will remain, since private consultants are already active in specialised branches of production, and government is interested in a ‘marketing mix’ of public and commercial information.

2.4 The extension system needs to respond

The extension system needs to find appropriate answers to these changes, at the level of skills and services, as well as at the level of the organisational structure. Technicians are required to reorient themselves in order to provide the services needed today (Kania, 2002):

- from advice in production techniques to cost effectiveness requires training in farm economies
- from the focus on transfer of the best techniques to helping farmers in their own decision making process, which is very demanding in communication skills
- assisting clients in selecting valuable information from an overflow, which is quite different from teaching them the best way to do things
- the improvement of production chains requires not only technology in the different aspects (primary production, post-harvest technology, processing, marketing), but also organisational skills
- farm administration according to the EU rules, the application for subsidies and the submission of project proposals are constituting new fields for extension services

The extension system will not escape from a new reorientation, facing the political pressure to reduce costs. The question is how to find an optimal mix between state-owned services, services provided by farmers organisations, and private agencies offering commercial advice. Each type of services has its own advantages and disadvantages (Kania, 2003). The strength and weaknesses of *state owned extension services* have already been mentioned. For *farmer-owned extension services* we could list the following:

\+ can respond directly to farmers’ needs and expectations;
\+ less costly for government;
\+ specialisation in order to address the needs of commercial farms;
\- high costs for farmers;
\- less coverage of rural inhabitants;
\- less capable of supporting painful measures in order to implement necessary changes;
\- when information has to be paid for, it is no longer a public property, causing unequal access to information and difficulties in maintaining information lines between extension and research.

The same strengths and weaknesses apply even stronger to a system based on commercial advice. Farmers organisations still can choose to pay part of the services from general contributions by their members. Commercial advice always has to be fully paid by the client.

It is not yet fully clear which arguments will prevail in the discussion that is ongoing in Poland. Certainly knowledge experts will have a hard time to defend the importance of the wide coverage of extension services in the rural areas, the necessary influence from farmers and other rural stakeholders on the extension activities, and the essential role of the institutionalised linkages between research, practice and policy that to a large extent are being maintained by the state-owned extension system. The Dutch case shows what might happen when these aspects become underestimated.

3 Dutch agriculture in crisis

The number of farm holdings has declined from 350,000 in 1951 to 89,580 in 2002. Farming still occupies 70 % of the total land area in the country. An average farm size of 33 ha does not tell much, because more than 25,000 farm holdings are not soil dependent (horticulture under glass, intensive animal production).

3.1 Changes, but not for the better

In the period 1960–1990 the Dutch agricultural sector achieved a strong position in the world market as the third largest exporter of agricultural products. This is remarkable for such a small, densely populated and industrialized country. Today, many farmers struggle with low or negative incomes and poor market perspectives, in spite of high investments in the latest technology for efficient and environment-friendly production. They lost their once so strong political influence. The market is no longer dominated by farmers' cooperatives but by supermarket chains that feel no loyalty to farmers. As if this is not yet bad enough, farmers are plagued by one disaster after another: swine fever, phytophtera in potato's, foot and mouth disease, and recently (2003) bird pest for which more than 20 million chickens (one fifth of the total population) had to be destroyed. These disease outbreaks are not only painful and costly to farmers, but also damage their image in the public opinion. Meanwhile the public does not understand anymore why such a large proportion of their tax money goes to farmers subsidies while poor farmers outside of the European market are getting no changes because of unfair EU trade practices.

Most people realize that the agricultural sector cannot continue on the current track. The costs of labour, agricultural land, and the expenses for a clean environment in the densely populated country are too high for bulk production such as grains, milk, eggs and meat. The capital- and knowledge-intensive agricultural system should turn to specialities, niche markets and high quality genetic material, whereas another part of the farming community should re-integrate with its natural environment in order to maintain the landscape and to satisfy the needs of regional consumers. Although this was already the outcome of a national debate in 1994-1995, serious reforms have not yet surpassed the stage of discussion rooms and negotiation tables. Is it not strange that this strong network, that once was so successful in penetrating the world market, is now unable to respond adequately to the changed macro-environment, even though so much is at stake?

3.2 The Agricultural Knowledge and Information System (AKIS) until 1990

The efficient agricultural knowledge system, that was built in the fifties and sixties, is generally seen as one of the driving forces behind the success of the highly innovative Dutch agriculture. The government extension service was the linking pin between research and farmers, policy makers and teachers (Wielinga, 1999; 2000). After the second world war the service was upgraded to 1,219 staff members in 1951, and that number remained more or less steady until 1990. The number of farming units decreased in this period from around 350,000 to 124,903. In the early days community development including home economics were part of the services, while later on these issues were taken over by the farmers' organisations. Gradually a task division developed between government extension agents (technology, farm economics), socio-economic extension workers from the farmers' organisations (home economics, bookkeeping, legal advice) and private consultants that came up in the eighties (specialised technology, accountancy).

The strong points of the system were:

- short and institutionalised information lines between research, farmers and policy makers
- strong influence from users (i.e., farmers' organisations, branch organisations, study clubs)
- information as public good, free of charge

Farmers were well aware of their mutual interdependency in their ambition to conquer the world market. A strong network developed, including farmers' leaders, captains of the agricultural industry, researchers and politicians, all sharing the same goal: growth. They managed to get control over markets and politics, and they created conducive conditions like subsidies on investments and guaranteed bottom prices. First they did so in The Netherlands, and later on in the European Economic Community as well. And successful they were – a bit too much actually. The high level of control made the network deaf and blind to the signals of trouble. When finally the public no longer accepted the negative side effects of the intensive agricultural production system, notably pollution and subsidized overproduction, the unpaid bill for cleaning up was very high.

3.3 Driving forces for change

In 1984 the Dutch government changed its policy from stimulating production growth to containing the damage. This endangered the position of trust that extension agents from the public service had build up with farmers, since they now had to convey unpopular messages. They were having a hard time already because they lost clientele to private agents offering more frequent and specialised services. Progressive farmers were prepared to pay the price for good and timely advice. This coincided with the ongoing specialisation in farm production, making it impossible for a state-controlled service to cover the ever widening range of information needs. When the extension service was privatised in 1989, a friendly financial regime was being agreed on with the farmers' organisations that would gradually take over control. Meanwhile, the linkage function (or 'second line extension' as it was called) was considered so important that new government agencies were formed (IKC[2]) employing many of the subject matter specialists and networkers of the former system. The 1,215 employees were divided over the privatised service (DLV[3]: 700) and the IKC's (515).

3.4 Effects of the knowledge market

It turned out differently from expected. Once the central management of the knowledge system had come to an end, all actors struggled for new positions on their own. DLV started competing with private agencies and agricultural schools, extension workers from the farmers organisations jumped into the more lucrative market of specialised technical advice as well, and the applied research stations established their own linkages with advanced farmers and DLV. The IKC's were unable to maintain their function as spider in the knowledge web, and could not prevent the demise of the open public information system.

In the nineties the knowledge policy changed. Instead of financing institutes for research and extension for example, the Ministry of Agriculture turned to financing output, and acted as a client on the knowledge market. Since then knowledge institutions have had to compete for

[2] IKC: Information and Knowledge Centres
[3] DLV: De Landbouw Voorlichting (The Agricultural Extension)

public money in project schemes, while the themes are supposed to be determined at the policy level (although things are a bit more complicated behind the screen).

Today it cannot be said that the market for extension services is flourishing. After a promising start in the early nineties, DLV is now struggling to survive, taking draconic measures such as practically dissolving its head office, hoping that the best regional business units still will find a niche in the market. Other major players at the information market have a hard time as well, while the former IKC's (presently called Expertise Centres) kept on shrinking, their role being limited to technical advice to the policy makers of the Ministry of Agriculture. In summary, little is left of the once so famous Dutch AKIS. Still there are networks of specialised farmers doing well in the international market. There still are research institutes of world class as well. However, the system has lost its coherence. Nowadays politicians are blaming research for not being effective enough in solving the problems of society. We are not surprised.

4 Changing concepts of knowledge

Although the features are quite different in the Polish and the Dutch case, there are similarities in the concepts of knowledge that have been guiding major decisions over time. Such concepts hold until too many problems are piling up that cannot be solved anymore. Then new concepts get a chance to break through.

4.1 The expert oriented concept of knowledge

The period 1950–1970 was characterised by great optimism. Progress in science and technology opened up new perspectives to eradicate hunger and poverty, and to bring prosperity for all. Investments in research and knowledge dissemination would have a high rate of economic return. Society had confidence in their scientists and technicians, leaving them plenty of room to do what they believed was necessary. The more mankind would know about nature and the way the world functions, the better it would be possible to determine the best way to go. Knowledge was similar to the truth or the best way, objectively validated by science. Development was technology driven. The role of scientists was to expand the worldwide body of scientific knowledge, and extension workers should transfer this knowledge to users such as farmers. Basically this belief was dominant both in the capitalist and the communist world.

4.2 Problems

When in The Netherlands the problems of pollution and overproduction could no longer be neglected, it was believed that science and technology could solve them all. However, government and farmers, organisations could not agree on acceptable norms for fertilising soil with organic waste. Both contestants mobilised their own scientists advancing opposite views. Diverging interests often entail that information with value for one party is not necessarily valuable or trustworthy for others. In competition, knowledge can even become a weapon. An open knowledge system is only possible as long as the actors share the same interests.

In sum, the expert oriented concept of knowledge reaches its limits if the following occurs:

- When problems become too complex, the capacity of science to provide solid foundations for policy decisions appears to be limited.
- Actors having diverging interests usually have different perceptions of the truth. This can come to the point that science looses its role as the impartial referee.

- When competition or power struggle are at stake, information becomes a weapon. Then scientific quality is only one factor amongst others determining the value of information.

4.3 The market oriented concept of knowledge

In the market orientation knowledge is a product with a price. There are producers (i.e., research) and consumers (i.e., farmers, but also policy makers). Extension workers are salesmen of knowledge products. Whereas joint responsibility is being stressed in the technology oriented approaches, the market orientation promotes the opposite: actors are responsible for themselves and only the best will survive. Knowledge management fits in this view, treating knowledge as a production factor just like land, labour and capital.

Competition challenges those who offer information services to bring out the best of themselves, to develop their specific qualities, and to be alert on changing demands in the market. In the rural sector, where specialisation and diversification goes further, the shift from technology orientation to market orientation is a necessity at a certain stage of development.

In the Netherlands the conceptual shift was made only after privatising the extension service. Once the short lines had been broken up, it was easier to give up the idea of joint responsibility and establish client–producer relationships. The reduction of costs was not a major argument for privatisation, in contrast to the Polish situation.

4.4 Problems

There are negative side effects as well. When actors are forced to survive a competitive market, they will put their own interests first, to the detriment of the common good. Commercial parties tend to go for the easiest profit, leaving the more complicated matters to others. Investments that pay off in the long run, such as the maintenance of good information networks, usually get lower priority.

When government tries to repair the ‘market imperfections’ by subsidising programmes for research, extension and education, another problem will surface. By lack of direct information lines, policy makers, farmers and researchers tend to create their own version of reality. These images are not corrected by direct contacts, since communication is largely reduced to paperwork. When this occurs, we see financiers trying to gain control by setting strict targets and criteria, while clever consultants use their creativity to get access to funds. In spite of the restrictive structure, they keep on doing what they find necessary, at least for their own survival. In The Netherlands this escalating pattern partly explains the limited effect of all efforts to revive the innovative capacity for the agricultural sector.

The market oriented concept of knowledge reaches its limits if:

- common goods are at stake;
- commercial parties manage to monopolise essential information lines;
- insufficient communication between stakeholders leads to self-referential networks;
- the struggle for survival gets to the point that no actors are left in a position in which they can do what is necessary for the quality of the network.

4.5 The network oriented concept of knowledge

Communicative thinkers oppose to the idea of survival of the fittest. They argue that rural development is a multi-stakeholder process, whereas the market does not necessarily lead to desirable outcomes. Where communication between stakeholders like farmers, consumers, policy makers, researchers, nature protectionists and others fail, people get locked up in self-referential circles. Good solutions can only emerge if people engage in networks where social learning processes take place. These processes require skilful facilitation.

In the network orientation knowledge is a construct (Derrida, 1978). Every individual develops his own constructs, and in a successful social learning process these constructs converge towards shared images of reality that might serve as a basis for collective action. Problems in society can only be solved if actors take their own responsibility. A wide range of participatory techniques have been developed in order to facilitate multi-stakeholder communication, and many successful applications have been reported as well. However, the network approach is not yet mainstream amongst policy makers and managers. This has its reasons.

4.6 Problems

Social learning processes are open ended: one can never predict what new knowledge will emerge and how people are going to use it. This does not match well with the urge financiers feel in gaining control over developments and the pressure they feel for justifying expenses. Another serious drawback is the fact that such learning processes depend on the awareness of mutual dependency and voluntary participation. It is still hard to see how to handle cases in which actors refuse to cooperate or hold hidden agendas. The ecological challenge is too serious to depend of uncertain communicative methods alone. How can we deal with the dilemma between urgent scientific insights about risky collective behaviour on the one hand and the fact that people will only behave differently if they acquire their own knowledge in uncertain social learning processes?

5 An ecological concept of knowledge

5.1 Living networks

Let us take a wider view and look as human networks *as part of* their living environment, instead of humans *managing* nature that is, human networks as living organisms (Wielinga, 2001; 2002a; 2002b). What is the role of knowledge in living creatures? Living systems consist of components that are coupled to each other by interaction patterns. Feedback mechanisms regulate the processes of life. Every organism can be seen as a network in which the components reproduce the organism, and the organism reproduces the components. These networks are coupled to their environment through the capacity of perceiving signals and generating a response. These principles apply to simple forms of life such as bacteria cells, as well as higher levels of aggregation such as plants, animals, and ecosystems. Even the worldwide biosphere can be seen as a huge living network (Lovelock, 1979). In the evolutionary process living systems develop into higher degrees of specialisation and task division, requiring more subtle feedback mechanisms in order to maintain the structural couplings (Capra, 1996).

In networks of humans the same principles can be seen. In healthy networks people are willing to give their input and to attune to others. Interaction patterns develop, in which task division and specialisation can grow as long as people trust that others will perform their role within the order of the network as well. Knowledge enables individuals to perceive signals, to interpret them, and to take action. Humans have developed the capability of forming abstract images they can communicate about. Therefore they can learn faster than any other creature.

Scientific knowledge covers only those images of reality that have been validated according to accepted rules. The biological function of knowledge in humans is social coordination

(Maturana and Varela, 1987). This includes all explicit and implicit constructs of reality, convictions, intuition, capabilities, and more or less standardised patterns of behaviour. In fact, it includes the entire mechanism from perception of signals to response. Maturana and Varela define knowledge as 'effective action in the domain of existence'. If we want to understand the role of scientific knowledge in the responsive capacity of a human network, we have to search for other major components of knowledge that influence the effectiveness of its actions as well.

5.2 The Circle of Coherence

The Circle of Coherence (Wielinga, 2001) shows how knowledge develops in a network (Figure 1). Both individual actors and the collectivity of a network build up knowledge that determines their ability to respond to the circumstances. The model displays two dimensions:

The knowledge dimension refers to the images of reality (that what commonly is called 'knowledge'), capabilities and behavioural patterns. Learning (knowledge development) takes place between two poles:

Similarities: There must be sufficient recognition in order to interpret new signals.

Differences. There must be a certain degree of confusion in order to be interested to learn.

Between the poles people can be *curious* and develop new knowledge. Upon too much confusion people limit their perception, whereas upon too many similarities healthy people respond by looking for new differences that can always be found.

The position dimension refers to the relations between actors in a network. There must be a certain degree of trust for allowing others to get involved in individual learning processes. Again collective learning can take place between two poles:

Individual. There must be room for authentic individual input.

Collectivity. There must be attuning to the needs of the collectivity of the network.

Too little room for individual expression and safety drives aggressiveness. Too little attuning leads to loss of collective protection and added value. This causes fear. Aggression stimulates to an enlarged individual space, whereas fear stimulates to more attuning. The borderlines of trust are constantly shifting and need to be probed all the time. This probing is the natural drive behind *game*, and playing provides satisfaction.

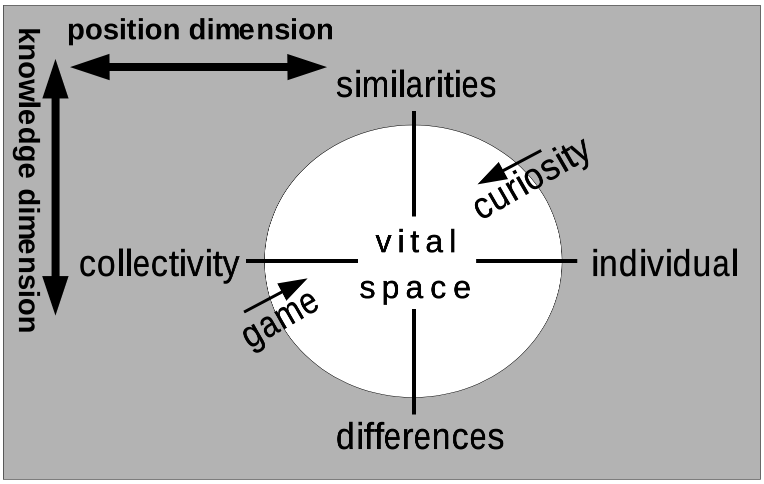

Figure 1. The Circle of Coherence.

These two dimensions are similar to the well known phenomenon that every communication contains messages at two levels: the level of contents (communication) and the level of relations (metacommunication). The added insight is that healthy systems are self-regulatory, just like healthy eco-systems are. Children are curious and like to play. The mechanisms to return to the middle are built-in. This central part of the circle is called the *'vital space'*.

5.3 Leadership

Scientific knowledge and technical know-how will be taken seriously in a healthy network where actors are interconnected and take their responsibility. This will not be the case if: [1] there is insufficient recognition; [2] messages are too disturbing; or [3] there is lack of trust. Cases 1 and 2 refer to the knowledge dimension, where as the 3rd case means that there is lack of vital space at the position dimension. If the in-built mechanisms do not work well enough to move towards vital space, it means that somewhere the process is blocked. Then leadership is required to remove blockages and restore the space where living process flow.

It is important to notice that the living process cannot be controlled as such. One can hope that vital space will grow, but the harder one tries to achieve it, the less likely it is that one will. This is true for most things in life that really matter: creativity, authority, trust and love, to mention just a few. Elster (1983) speaks of by-products because they cannot be manufactured in a direct way. The good news is that life works autonomously towards more task division, specialisation, complexity and beauty, as long as the feedback mechanisms grow along and people stay connected to their social and ecological environment. We don’t have to create life (fortunately) because the seeds are everywhere. What needs to be done is creating the proper biotope where life can flourish. The bad news is that this becomes more difficult when complexity increases. When feedback mechanisms fail, unbalances will be felt painfully. The tendency is to increase efforts to get control over processes rather than to restore connections.

Adequate action follows social learning processes in which stakeholders acquire relevant knowledge. Whether or not scientific information will feed the process depends on the nature of the blockages. Sometimes it helps to reformulate the information, while in other cases position game is needed to ensure that stakeholders and scientists take each other seriously. The ecological concept of knowledge stresses the importance of the connections: the basic task of leadership is to restore structural couplings between people and their environment. When this is overlooked, intervention may become a blockage in itself, e.g., when experts or financiers try to determine the targeted situation unilaterally.

5.4 Consequences

The metaphor of living networks offers a perspective on strategies for change that is not yet common: instead of the well known project approaches, applying strategies and instruments for reaching clearly defined targets that can be accounted for, it advocates the creation of space by removing blockages, requiring tailor-made interventions in order to link people together. In the Dutch situation this calls for a revival of intermediate actors who can deliver tailor-made action to do what is necessary in order to restore relationship and create vital space. In Poland it would suggest to be careful with the intermediate structure that is still in place, and to improve its capacity to facilitate multi stakeholder processes.

6 Statements

In the previous sections we have explored the role of knowledge in human behaviour, in order to find ways for improving the impact of scientific knowledge on ecologically sound practices. As a contribution to the discussion we formulate our conclusions in five statements.

[a] *Dissemination of scientific knowledge and technical know-how is not sufficient to induce ecologically responsible behaviour.*

It is not the access to information that counts, but the question whether actors effectively acquire the knowledge they need and act accordingly. This first statement entails that one should not expect that important messages will be effective as such. People acquire knowledge in social learning processes, in which dissemination of scientific knowledge is just one factor. In most cases more needs to be done in order to induce change.

[b] *The knowledge market does not automatically favour ecologically responsible behaviour.*
If actors are forced to survive in a competitive market, individual interests tend to prevail over collective responsibility. Competition and proper terms of exchange are necessary elements of healthy networks, but additional mechanisms are needed as well for enabling people to take their responsibility for the common good. Fortunately there are always conscious individuals and networks of people who do so, but when the market climate becomes too rough, there will be less people left who manage to row upstream. The consequence of this second statement is that governments cannot rely on setting restrictive rules and regulations, and promoting knowledge dissemination by buying services at the knowledge market.

[c] *A network needs at least one actor in the position of taking leadership for doing what is necessary to keep the network healthy.*
In a healthy network there are always actors who perceive signals of unbalance or disconnection and act in order to restore meaningful interaction. Things go wrong if thresholds are getting too high. In the life cycle of networks there are always difficult periods, but they can be overcome as long as at least one actor keeps on feeling responsible and able of doing what is necessary. This statement has consequences for those who wish to create a conducive environment for healthy networks. The institutional structure should place at least one actor in a position to take leadership in the social learning process of the network. In the golden years of Dutch agriculture an entire army of knowledge workers (researchers, extension workers, trainers) was set free to perform this role. At present this role is vacant in many networks that are essential for the objectives of government. In Poland this role is being threatened by a move towards privatisation of extension services.

[d] *Sustainable development requires skilful facilitation*
The facilitation of learning processes in multi-stakeholder networks requires specialists who are trained in skills such as communication, negotiation and mediation. Such skills are needed in the implementation of educational programmes, but also within multi-disciplinary programme teams at the regional, national and international level. There is a need for training in such skills, as well as for further development of methods, e.g., in mediation, conflict solving, but also in evaluation and monitoring of social learning processes.

[e] *Healthy networks develop ecologically responsible behaviour.*
Ecologically responsible behaviour does not just follow scientific insights, but it emerges from interaction between stakeholders within networks on the condition of respect and trust. Respect means that actors are willing to take their ecological and social environment seriously. This requires open information lines. If this is the case, also scientific insights will be weighed in the learning process taking place. Instead of trying to get people where we want them to be, we should trust in the responsive capacity of the network if people are fully interconnected.

This final statement summarises the ecological view on knowledge as explored in this paper. It places scientific knowledge as an important but not decisive element of social learning processes. There is still a lot to learn in mastering ways how to penetrate in regressive interaction patterns and nasty blockages. A promising start can be to create room for a new generation of facilitators, and to learn how scientists, policy makers, and such facilitators can play the game together.

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Farmer’s experiences and scientific on-farm experimentation integrated in an experiential science approach

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Abstract

In this study the methodological aspects of experiential science based on on-farm grassland experimentation are described. The farmer concerned wanted to develop ley mixtures of grass and red and white clover which best suited his farm objectives. Considerable attention was paid to the grass component of the mixtures, instead of the legume composition. Agronomic results have been summarised elsewhere (Baars and Veltman, 2000).
The integration and evaluation of both natural science and farmer’s experience can be described as experiential science (Baars, 2002). In terms of experiential science, the important methodological elements were: the evaluation and integration of several unexpected farmer’s actions in relation to his grassland observations and the casuistic outcome evaluation of observations based on the recognition of patterns in the fields, in relation to earlier farmer’s actions. In terms of formal science, important elements were: measurement of yields, statistical evaluation and modelling of results (Baars and Veltman, 2000). The integration of qualitative and quantitative findings were important to develop practical ‘systems that work’.

Keywords: experiential science, participatory, transdisciplinary, leys, grass / clover mixtures

Introduction

On organic farms, the observations and experiences of the herdsman are important in the development of new knowledge and insight (Baars, 2002). This is due to the type of management on organic farms, which can be characterised as preventive, strategic and holistic, with a focus on the agro-ecological context of the local system (Verhoog *et al*., 2003). As a strategy to develop new insight, one can focus on pioneering farmers. Pioneers in organic farming are defined as people who act according to organic concepts instead of reacting to (negative) regulations. These pioneers pay specific and personal attention to a certain farm area and deal with questions with regard to the specific constraints of their own farm’s limitations.
The farm manager of Warmonderhofstede was such a pioneer, when he adapted new ley mixtures for organic crop rotations. His constraint was in short term leys, in particular the balance of grass and clover in a mixed system, the complete dependence of the animal’s diet on grass-clover and the very low input of manure. The interesting and progressive aspect was that his system relied completely on soil mineralisation, legumes and atmospheric deposition for its N supply, with no additional N being added from external N sources. The goal of the study was to develop ley mixtures which best suited the farm objectives. Leys should produce a high amount of fodder with sufficient protein and with low inputs of animal manure. In this research, considerable attention was paid to the grass component of the mixtures, whereas previously the main attention was on the effects of the legumes.

Methodology

To enable co-operation with a pioneering farmer it is important to be clear about his goals in life, his ethical background and the constraints that he imposes on himself. These farm backgrounds and principles were described at the start of the project (Baars, 2002). From the first year onwards, there were monthly farm visits during the growing season. Researcher and farmer together evaluated all grassland fields. The main focus was on the growth of red and white clover in all fields. The farmer's contribution was to describe pasture management between two successive visits and to relate specific observations of growth since the previous visit. The researcher contributed general knowledge and information on clover from other experiments and from the literature, and in addition undertook measurements and analysis from several farm fields. Thus, in these talks general information plus qualitative information from the farmer's side were brought together with the analytical data from the researcher's side.

Results and discussion

With regards to the context description, two levels of context are important. Firstly the agro-ecological context of the farm in terms of landscape, soil quality and level of intensity, and secondly, the social context, namely the farmer's goals and personal perspective. Experimental trials were embedded in the context of a specific farming system ecology and a farmer's style and biography, which were clear limitations for appropriate answers and were steering the search process. In this case, the limitations were that all manure was put on arable crops in the rotation, no additional manure (only straw) was bought into the farm, dairy cows were only fed with roughage (grass / clover, silage and whole plant silage), no concentrates were fed and the leys were in a difficult part of the crop rotation (sown in late summer after potatoes).

With regards to mutual learning, the experiences and observations of the farmer were as important as the on-farm experiments. Mutual observations were made on several fields at the farm, both experimental as practical fields. Two elements were important in the evaluation of experiential science, that of 'pattern recognition' and 'intuitive actions'.

Pattern recognition reflected the relation of a specific farmer's action and later on the patterns in the fields (Kiene, 1998). Pattern recognition took place in numerous places. Several examples were present with regard to sowing date and the survival and success of white clover development in early spring. Most of these observations were unique, dealing with a specific field or with specific years.

The awareness of such on-farm actions, which were likely to be successful (intuitive or unplanned actions) were the guide for the development of new knowledge. In 1997, due to the extremely mild autumn weather after sowing of the grass / clover mixtures, there was too much herbage left in the field. The farmer decided to cut the trial areas in the first frost period of November, which was a year specific challenge. The frost protected the soil structure and the herbage could be harvested. However, a part of the field was not cut and so an unplanned experiment was created. In the next year we measured the herbage yield and clover growth in this uncut part of the field as well as in the other, although this part was not replicated like the other treatments. From the November cut area, a well-balanced sward was harvested in the next spring. Annual weeds had disappeared. The uncut area only had a very high first cut yield, but later on an almost cloverless crop was harvested. This type of new and intuitive acting was integrated into new steps of investigations, with new ideas developed and new insights reached.

Scientific measurements and statistical evaluation of experiments are combined with the process of action, observation and reflection. The on-farm experimentation in large-scale field trials started in August 1996. Until March 1999 measurements were made in replicated trials. Open planning was part of the research approach. The annual reflection on the scientific on-farm results and the personal experiences of the farmer inside and outside the experimental fields led to regular adjustment of the question. The development of the experimentation was

gradual, with a yearly change of mixtures. Replicated field trials and modelling were used as scientific methods (Baars and Veltman, 2000).
The search process stops once the farmer has developed a comprehensive, new way of management. The on-going process of experimenting and experiencing went on until a new adequate set of actions were reached, which was described in terms of management: ‘a system that works’. For the farmer, this management was relevant to understand the system in terms of processes and extremities. For the farmer, the process stopped, once a set of new action became part of the system.

Conclusions

The way of learning by the pioneering farmer was not just a process of random trial and error. Personal interest and involvement in a certain part of the farm reduced the farmer’s focus. Although the whole farm was present as a system and acted as the context for his explorations, this personal focus limited his fields of interest in a positive way. Reflection on positive and negative experiences, sometimes the result of coincidence, was an important element of this process. New ideas about factors affecting the outcome of the problem in which the farmer was currently involved, were integrated into the next step of research and development. From that point of view the farmer could be regarded as an ‘experiential researcher’, where collaboration, mutual learning and collegial interactions were inter-mixed (Waters-Bayer and Bayer, 2000). In this co-operation between researcher and pioneering farmer, it was necessary to maintain an open mind and to adapt the on-farm experiments if possible. It was also important to make these additional on-farm measurements, in order to support newly emerging insights. Characteristically this approach lead to a yearly development and adaptation of experiments instead of a repetition of the same trial over a longer period. It did, however, often conflict with the demand for statistics. In this casuistic outcome research, a causal relationship was demonstrated by establishing the correspondence between the unique pattern in the intervention and the subsequent effect.

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Schools can be valuable partners to promote interest and knowledge of grassland management.

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Abstract

Overgrowth is one of the main threats to remaining semi-natural grasslands in Norway today. Preservation of valuable habitats requires both professional knowledge, and keen, practical initiatives. To promote local interest in, and understanding of, management and conservation, schools were invited to participate. An educational programme was developed to include both theory and practice and to associate different subjects. The pupils studied ecological conditions, land-use and biodiversity. Management activities included clearing of scrub and bushes, controlled burning and mowing, to ensure the maintenance of an open landscape and biodiversity.

In this transdisciplinary project knowledge is exchanged between agricultural, botanical, zoological, historical and educational experts, as well as between experts and the local community. Schools get help and ideas to use the semi-natural grasslands as a learning area, and contribute with data collections and management. For the farmer it is favourable to focus on the multifunctionality of the grasslands i.e., production of fodder, maintaining an open landscape and biodiversity. The project created interests for semi-natural grassland management and inspired the municipalities to maintain biodiversity. It also seemed to contribute to children's and youths' identity, and to make the municipality more attractive for future establishment.

Keywords: biodiversity, educational programme, land-use

Introduction

Overgrowth is one of the main threats to remaining semi-natural grasslands in Norway today (Norderhaug *et al.*, 1999). Traditional utilisation of outfields by grazing, haymaking and fuel wood felling are drastically reduced, and trees and bushes invade the grasslands. These land-use changes result in a gradual reduction of open habitats and loss of biodiversity. Restoration and management are necessary to maintain the biodiversity of semi-natural grasslands. Conservation of remaining valuable habitats, however, requires both professional knowledge, and practical action.

To promote local interest and understanding of management and conservation of remaining semi-natural grasslands, a transdisciplinary project was initiated in 2000. The project connected subject professions as agriculture, botany, zoology, local history and pedagogy. A close collaboration between farmers, schools and the research institutes was also established to ensure good exchange of knowledge and to develop the best possible educational programme on management of semi-natural grasslands. The aim with the project is in accordance with the curriculum for the 10-year compulsory school and for the Upper Secondary education where the need for local environmental activities is underlined.

Materials and methods

The project started in the counties of Sør- and Nord-Trøndelag, Central Norway, and today includes about ten schools. A written agreement has been signed between each school and farmer concerning utilising the grassland area for educational purpose for at least three years. The utilisation of the grasslands as a learning area should not be in conflict with the ordinary fodder production or grazing. The pupils are mostly from nine to twelve years old, but there is no age-limit.

Several activities have been developed within the project and relevant educational material has been prepared (Bele *et al.*, 2003). This material includes background, methods and registration forms. Management activities in the field include clearing, controlled burning, mowing and grazing. The effects of the management are also studied. Three quadrants (100 m^2) with three different management regimes were investigated. One quadrant is a control-area without any management, the second is cleared of scrub and bushes and the third is cleared and burned, mowed or grazed. The effects of the different management regimes are documented by yearly registration of grassland species and by photos. Pupils record ecological conditions and land-use (local history) in their study area. For this work they have to use maps and different historical documents. Interviews of the farmer and old people usually give good knowledge about local traditional land-use.

During field- and laboratory work the pupils learn about the biodiversity of semi-natural grasslands. The project focused on plant and spider species as indicators for the semi-natural grasslands. The pupils recorded some selected plants species by counting flowering individuals in small quadrants. Some schools recorded red-listed grassland plant species. Spiders and insects were caught by traps on the ground. For identification of plant and spider species, schools receive professional assistance by sending the field-material to the research institute. During the project pupils also learn about traditional use of plants (medicine, food) and local (dialect) names.

To exchange the knowledge about grasslands and biodiversity, pupils take part in different seminars. They also publicise their project on information boards in their study area, in local newspapers and on the World Wide Web.

A project evaluation was done at two schools.

Results and discussion

The evaluation of the project showed that the fieldwork was very popular among the pupils (Bele and Almendingen, 2000). Practical management activities and digging traps seemed to be the most popular. Studying grassland species was also underlined as enjoyable, but the pupils sometimes found it difficult to identify them. The pupils also said that they learned to work together during the field work. Tests before the project started and after one year showed that the pupils had learned a lot about plants and insects. The knowledge of management and former land-use in the actual landscape types also grew during the project.

Most of the teachers thought the project worked well, but to be able to run the programme they needed better knowledge about grassland ecology, biodiversity and management. Today the Norwegian Crop Research Institute contributes with instructions and courses to increase both the teachers' and the farmers' competence regarding grassland ecology.

Fieldwork and demonstrations gave both teachers and pupils experiences of traditional management in practise. In this way they became a resource for their local community regarding knowledge about traditional land-use methods and the best way to manage semi-natural grasslands.

Collected data are stored for use in future research projects, and will be used for monitoring effects of management methods on grassland and grassland species. The Norwegian Crop Research Institute has as an example received flowering data on *Primula vulgaris* from one of the managed areas. This species is rare in the counties of Sør- and Nord-Trøndelag. We have also received data concerning management effects of controlled burning. In addition, the pupils found new spider species for the region. The two spider collections give valuable contributions to the spider catalogue of Trøndelag (Aakra, in prep.).

Conclusions

Transdisciplinary projects like this will probably be advantageous for all participants involved and for the whole municipality. Knowledge is exchanged both transdisciplinarily (between agricultural, botanical, zoological, historical and educational experts) and between experts and the local community. Schools get help and ideas to use the semi-natural grasslands as a learning area, and contribute with data collections and management. For the farmer it is favourable to focus on the multifunctionality of the grasslands i.e., production of fodder, maintaining an open landscape and biodiversity. In addition, the project created interests for semi-natural grassland management and inspired the municipalities to maintain biodiversity. The project also seemed to contribute to children’s and youths’ identity, and to make the municipality more attractive for future establishment.

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Network of extension service and Grassland Society toward an effective grassland management in Estonia

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Abstract

The key feature of the Estonian extension scheme is building private advisory services directly through the open competition of advisors, giving the responsibility for quality control of the services to farmers themselves from the very beginning of the process. The system of certification of advisors has been introduced, and a registry of advisors has been created, as well as the eligibility criteria have been developed.
The most serious problem for the agricultural knowledge and information complex is the fact that the system is not oriented enough to the changing needs of the society, and often it cannot provide adequate solutions for emerging problems. The relationship between the organisations, producing the information (research institutions, incl. Universities), and those applying it (advisors and producers), is still weak. The research projects, which are focused on farmers and rural society needs, are usually not financed at the Agricultural University where the fundamental research projects are preferred.
The Estonian Grassland Society belongs to the extension complex with the aim to combine research, advisors, rural people and decision-makers from the Ministries. The mechanism for adequate response to the feedback, coming from the farmers, has also been established. The EGS activities should engage not only dairy farmers, but also the whole rural environment, and its role should be increased in influencing the agricultural policy.

Keywords: advisors, Estonian Grassland Society, extension service

Introduction

As Estonia was passing through the period of restoration and regaining its independence during the late 1980s and early 1990s, many reforms were introduced, and several among them such as Law of Peasant Farming, Property Reform, Land Reform, Agricultural Reform, and Currency Reform, were related to agriculture. The case in Estonia is a good example of a country in transition that has been trying to build up its private agricultural advisory services, experiencing need identification, problems, achievements and shortcomings in the process, that could be valuable lessons for other countries of the region (Kreen *et al.*, 1999).
Together with the development of the advisory services, the need to develop the necessary support structure for advisors was also recognised. The Estonian Grassland Society (EGS) is one part of the extension service complex in Estonia. EGS activities are focused on grassland environment, and its main mission is to develop the exchange of knowledge and information between the interdisciplinary research and the society.

History and development of the Estonian Grassland Society
The Estonian Grassland Society has a rather long history. The idea of founding the Estonian Meadow and Pasture Development Society was initiated by the forward-looking dairy farmers and cattle breeders of that time, Th. Pool and E. Harpe, as well as by the breeder of forage legume and grasses, J. Mets. The foundation meeting of the society was held on January 31, 1930 in Tallinn. Although the activities of the Society were stopped in 1940 by the Soviet authorities, in ten years of its operation a strong basis had been laid for the development of

grassland culture even in the conditions of occupation lasting for the next fifty years. The activities of the Estonian Meadow and Pasture Development Society were started again in Tartu on April 16, 1993 under the name of the Estonian Grassland Society. At present, more than 100 interdisciplinary researchers, advisors, plant breeders and active farmers are engaged in the work of the society.

The role of the Estonian Grassland Society in the Agricultural Knowledge System

The general concepts of the advisory services in Estonia were completed in 1996 and after that the structure of extension complex has been in constant development. The national rural advisory programme has been financed increasingly from the state budget. A system for certification of advisors has been introduced. A registry for advisors has been created and eligibility criteria have been developed. The Estonian Association of Rural Consultants and Advisors as the umbrella organisation for advisors has been established. Several support systems and information services are available both for farmers and advisors, mostly provided by state-owned institutions.

So, the restructuring of the extension system had its influence, to smaller or larger extent, on all the institutions, participating in the process of agricultural policy, research, training and education, advisory service and information flow. Much has been done, but there is no reason to be satisfied. It is a permanent process of development of the exchange of knowledge.

One of the most important shortcomings is the fact that the information flow from the research to extension is still not sufficient. One of the reasons is that although the advisers have the umbrella organisation of their own (the Estonian Association of Rural Consultants), they still have not been able to make the researchers appreciate their needs. The agricultural research institutions publish the results of their studies mainly in scientific journals, seldom in newspapers, practical magazines and newsletters. However, they also organise training days and seminars for interested advisors and farmers. Unfortunately, the written and oral information, they provide, is not always ready to be used by the advisors and needs to be adapted to the real situations. Especially the researchers from Universities are not very keen on conducting applied studies, as their most donor organisations (the Ministry of Education and Science, the Estonian Science Foundation) do not show any interest in supporting such research. This means that the advisors need to spend quite a lot of their valuable time in search of the information they need for their everyday work.

In the above-mentioned situation, the role of the Estonian Grassland Society, and of other non-profitable organisations, is very important. Interdisciplinary researchers from different research institutions, advisors, farmers and people from the rural environment make up the membership of the society. The society acts as the meeting point for the different parties of the society. From one hand, different interests, goals and needs cross there, but on the other hand it is a proper place for finding solutions to problems and integration. All together it is possible to shape a striking message, which will influence also the political agenda.

The role and activities of the Estonian Grassland Society in transferring knowledge, interdisciplinary research and influencing policy

The activities of the EGS are not changed a lot in the period after Estonia regained its independence in 1991. The changes, caused by the restructuring extension service in Estonia, have had a positive influence on the operation of the society, and created a wide multi-functional range of activities. The mission of the EGS is to develop the flow of grassland-based knowledge and information between the multidisciplinary research, advisors and the society. The EGS works in close co-operation with the different research institutions, as well as with advisory and farmers organisations. The EGS joins the professionals of different fields, and has a steady position among cattle farmers and the growers of grass seeds.

The board of EGS is planning, leading and supporting the regular activities as the seminars, workshops, field-trials days, visiting advanced farms etc. The frequency of activities depends about the target group needs. The results of farmers' feedback, obtained by the EGS, form the base for evaluating and planning the activities of the EGS. The target group needs are changing constantly and the key point for success is to follow them. Nowadays the novel topic for Estonian producers is integration with EU and the special activities are focused to adaptation with EU rules and supporting system for farmers. Also the interdisciplinary activities of producers, advisors and researchers become more and more attractive for all interest groups / stakeholders.

The activities organised by EGS are popular because the issues of current interest are discussed and farmers are involved into solutions finding process together with the best experts (mainly researchers and advisors). Every producer should have a solution for own question or problem(s).

As the Ministry of Agriculture supports group and mass activities, a number of the EGS grassland advisory projects were subsidised through the open competition. The feedback from the monitoring, organised by the EGS, is a useful tool for decision-makers. Several grassland applied research topics, financed by the Ministry of Agriculture, are being previously discussed and accepted by farmers during the workshops organised by the EGS.

The future activities of the EGS should engage not only dairy farmers, but also the whole rural environment, for developing the multi-functionality of grassland systems. The research groups and Societies who are engaged to management and restoration of semi-natural and natural grasslands (coastal meadows, wetlands, wooded meadows and pastures etc) should be involved to EGS activities as well. The quality and beauty of a landscape is not reserved for farmers only. Other people living in the area or visiting the area for pleasure or recreation benefit from this landscape. The binding together of researchers from different fields, advisors and farmers, should increase the role of the EGS, and its influence, through the Ministry of Agriculture, on the agricultural policy.

Conclusions

1. Despite of relatively short history, the Estonian advisory service has been considerably successful. The demand for advises is increasing very rapidly.
2. The main mission of the Estonian Grassland Society is to develop the exchange of knowledge and information between the interdisciplinary research and the society. The EGS initiates interdisciplinary activities between researchers, advisors and producers.
3. The feedback obtained from farmers forms the main base for evaluating the EGS activities. The farmers are involved into solutions finding process together with the best experts.
4. The feedback from producers, advisors and researchers is a valuable tool for the decision-makers from the Ministry of Agriculture.
5. The EGS future activities should engage not only dairy farmers, but also the whole rural environment, for developing the multi-functionality of grassland systems.

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Forage and grasslands production and utilisation in France: a CD-ROM presenting a systemic analysis

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Abstract

Grasslands and forage crops are part of a larger system. On one hand, they are both an intermediate consumption without a market value, used to feed ruminants and which can be replaced, depending on feed prices, production system and the motivations of the farmers. On the other hand, they are valuable *per se* in terms of environmental benefits. The systemic analysis run for France made it possible to identify the flow of matter and their changes over time and regions, the constraints within the network and the motivations of the various stakeholders involved into this network.
An interactive CD-ROM was developed that presents all the data and analyses in order to be used as an educational and research tool. It does not include any prospective scenario.

Keywords: systemic analysis, grasslands, forages, stakeholders, CD-ROM

Introduction

Grasslands and forage production have to be considered as part of a larger system including the inputs required for their cultivation and their valorization through animal production. Changes occurring in such a complex network are the consequences of stakeholder decisions. A systemic analysis of grasslands and forage production network was undertaken in order to establish the structure (flows of matters), the stakeholders and their motivations and the regulations within the network. This approach was developed by a group of INRA scientists and based upon meetings with groups of professionals and data mining in various databases. In order to disseminate the documented description of the network, a CD-ROM was developed, targeting professionals, students and teachers.

Description of the network «Grasslands and forage crops»
The structure of the network to be analysed and documented is shown on figure 1. In such a network, forage clearly appears as an intermediate consumption without any market value (except for some dehydrated products or hay). This structure did not change over the last decades but flows of matters and distribution among regions, stakeholders and regulations strongly changed over years. Grasslands and forage crops are at the crossroads of two logics: the logic of production and the logic of environmental stakes. In the logic of production, forage harvested or grazed from grasslands and forage crops are in direct competition with other products that could be fed to ruminants.

The competition is mainly based upon:
i) quality of the feed and how it meets animal requirements. The proportion of forage in the diet of ruminants tends to decline for high producing animals, especially dairy cows,

ii) cost / quality ratio. Here, grasslands and grazing appear highly competitive,
iii) work load with concerns to farmers,
iv) image of crops, practices and animal products for the consumers.

The area of grasslands and forage crops required to feed ruminants has logically declined during the last two decades for several reasons. The most important ones are the previously described competition, the productivity gains in forage production, the declining number of ruminants resulting from constraint in the milk and meat markets and EU policy. Those markets depend upon internal human consumption where food quality and security, price and image influence consumer's behavior and upon export and import, this latter aspect being strongly regulated through European and WTO regulations.
The area of grasslands and forage crops and their specific composition affect upstream activities of the network, mainly seed production, both in terms of volume and in terms of the characteristics of varieties to be marketed.

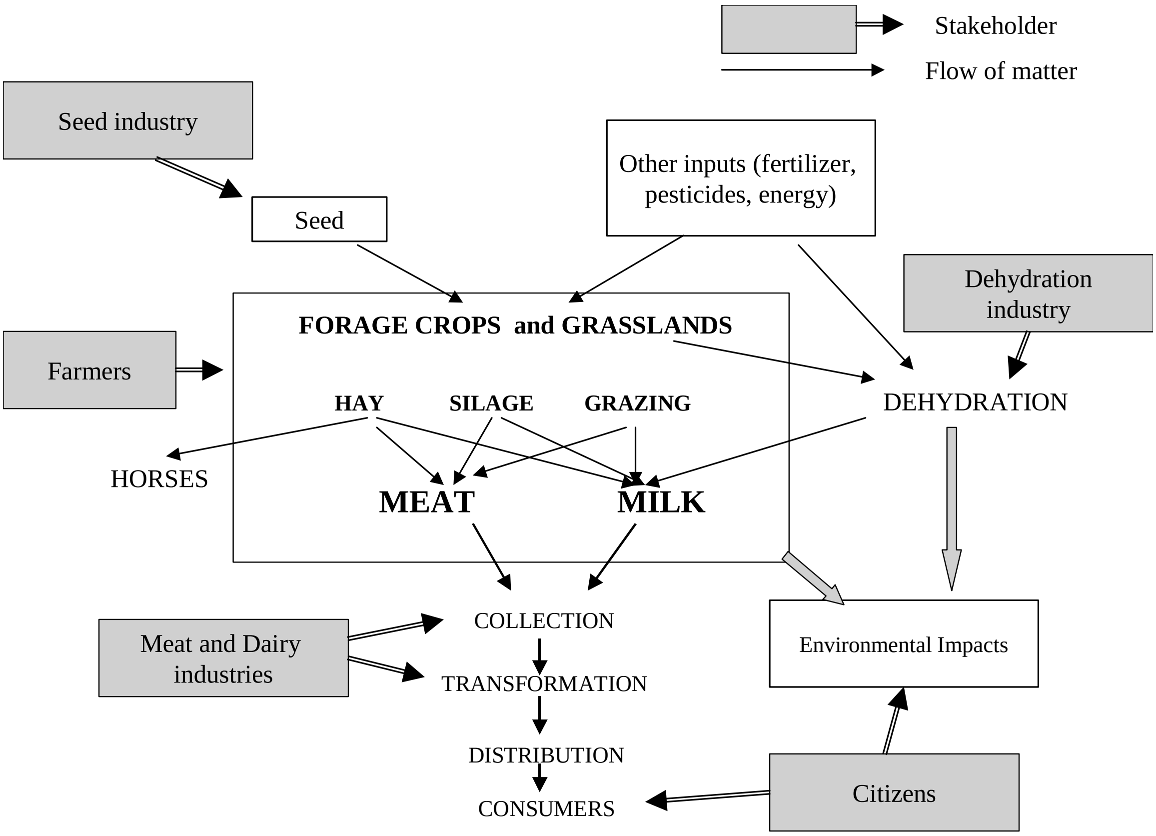

Figure 1. Schematic presentation of the Grasslands and forage crops network.

When considering environmental stakes, sown forage crops and above all permanent grasslands have a value *per se*, provided that agronomic practices are adequate. These environmental stakes include outputs such as nitrate leachate or pesticides residues, inputs such as non renewable energy and internal features such as biodiversity, permanent soil cover and landscape. As forage crops and grasslands cover more than 40 % of the agricultural area in most European countries and 45 % in France, the logic of environmental stakes is very strong and must be precisely investigated when production objectives and environment preservation have to be reconciled.

On both logics, consideration of the stakeholders, their numbers and locations as well as their motivations is very important. Indeed, they are the forces inducing changes.

A CD-ROM: an educational tool
This tool was developed to promote the dissemination of the results of this analysis.
It includes:

- Documented data from the various elements of the network, (seeds and varieties including registration aspects, forage crops and grasslands (area and production), animals (number and animal products), consumption). It includes time data over several years (up to 25 years for some aspects) and, when relevant, shows the differences among regions. These data were collected from various databases and cross-checked.
- Regulations. Particular attention was paid to the World Trade Organisation and their impact on dairy and meat products, the Common Agricultural Policy (quotas, price policies, supports to area and animal, environmental regulations) and French policies (Agri-environmental measures).
- Data on economic stakeholders, especially farmers and industries (seeds and downstream industries).

At present, this approach was only developed for the French case, and as a consequence the CD-ROM was developed in the French language.

This tool was designed to be adaptable.
It is based upon a Flash interface which leads to many short PowerPoint presentations that are all connected to each other in a relevant tree diagram through hypertext links. Thanks to the small size of each file, loading times are short. This structure is highly upgradeable. In upper versions, more files can be added to the tree diagram. Above all, it is envisaged to develop a corresponding website where presentations with time data will be regularly updated. This interactive tool can be used to teach or to establish the context and stakes of research and development activities related to grasslands and forage production and utilisation. It does not include any prospective scenarios. The wide range of information and data available and the ease of access are real benefits. The time-based databases will have to be updated either through later releases or thanks to a corresponding website.

Conclusions and prospects

- Systemic analysis proved to be highly valuable to identify more precisely the position and role of grasslands and forage crops in the complex network that determines their changes. It highlighted the key role of the stakeholders motivations for their decision making, these motivations being not only technical or financial.
- This systemic analysis was a first step of a broader project aiming at drawing prospective scenarios of changes likely to occur on this network.
- The CD-ROM is a deliverable tool aiming at disseminating this original approach and the massive amount of information and data collected during this work. It was designed to be upgradeable and to meet requirements of various end-users.

It would be very fruitful to develop such an systemic approach at the European level as the final database would be outstanding and could be of benefit to policy makers to support their decisions regarding grasslands and forage crops.

Nutrient balancing at the farm level: The Swiss experience

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Abstract

Between 1990 and 2003 the Swiss centres for agricultural extension LBL and SRVA have developed the 'Nährstoffbilanz' (from 2002: 'Suisse-Bilanz'), an instrument for the enforcement of the guidelines for integrated and organic production in Switzerland. This was done in close co-operation with experts from research, agricultural extension, administration and practice. The instrument permits the quantification and evaluation of nutrient fluxes at the farm level on the basis of supply and demand. Today, the 'Suisse-Bilanz' is widely accepted in Switzerland due to consistent interdisciplinary co-operation. It is applied on nearly all farms supported by national direct payments or with private label contracts (> 90 %). It also serves as a basis for manure and recycling-fertiliser contracts.

Keywords: nutrient balance, manure, equilibrum, fertiliser, Suisse-Bilanz, interdisciplinary cooperation

Introduction

Before 1990 simple methods to quantify nutrient balances at farm level were used in Swiss agricultural extension and education, such as: supply / demand-methods, farm-gate-methods, simple stocking-rate-calculations.
In 1993 a new direct payment programme was introduced in Swiss agricultural policy which aimed to provide incentives to farmers for ecologically orientated production systems. One of the central criteria is the equilibrum of nitrogen (N) and phosphorus (P) balance at farm level.
When is a nutrient balance actually in equilibrium? A technically accurate instrument was needed to be used for the enforcement of the guidelines for integrated and organic production in Switzerland. For that reason the two Swiss centres for agricultural extension LBL and SRVA (service romand de vulgarisation agricole) developed the 'Nährstoffbilanz' (from 2002: 'Suisse-Bilanz'; Amaudruz *et al*., 2003) following the supply / demand approach. In 2002 'Suisse-Bilanz' was declared the reference method by the Swiss government.
The criterion 'equilibrum of the nutrient balance' became decisive for the reduction of water pollution with N and P. In 2002, 15 years experience resulted in the 'Suisse-Bilanz'- a widely accepted nutrient-balancing method which is being applied on over 90 % of Swiss farms. It is an example of a successful transdisciplinary collaboration between research, agricultural extension, administration and practice and it will be presented in this paper.

Methods of approach and technical basis

Throughout the development of the method the supply / demand-approach was strictly followed: within the 'whole farm' system nutrient supply from animal production is compared with the nutrient demand for plant production. A deficit is balanced by importing fertilisers and a surplus by exporting manure (Figure 1). The scientific basis for crop nutrient demand form the 'guidelines for fertilisation in crops and grassland production' which also include detailed standard values for nutrient excretion by livestock (Flisch *et al*., 2001). Between 1990 and 1995 the 'Nährstoffbilanz' was tested under practical conditions on 200 farms with either integrated or organic production.

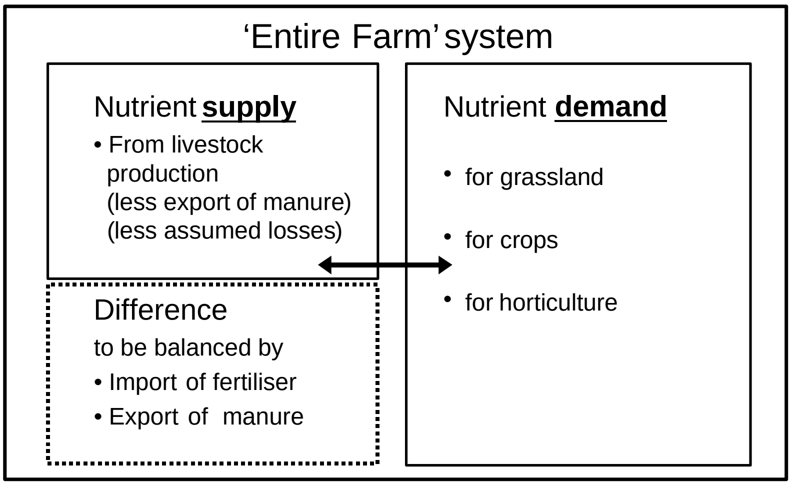

Figure 1. Principle of the supply / demand-method.

Several improvements of the method resulted from this study. In 1993 LBL examined different balancing methods (two supply / demand methods, three input / output-methods, one including the criterion of location potential) on behalf of the Swiss federal office for agriculture (Bloechlinger and Schuepbach, 1993). Between 1994 and 1999 the 'Nährstoffbilanz' was modified several times to account for changes in farm management (e.g., to the use of pig feed with reduced protein and P content). In 2002 a major revision of the 'Nährstoffbilanz' was carried out to take into account the new scientific basis (Flisch *et al.*, 2001) and to fully harmonise the methods in the German and French speaking parts of Switzerland.

Results and experiences

Testing of the 'Nährstoffbilanz' on 200 Swiss farms proved the suitability of the instrument for practical application under real conditions. It was concluded that the method had achieved its major objective: to be able to decide comprehensibly and clearly for each farm whether the criterion 'equilibrum of nutrient balance' was fulfilled or not. Some additional insights were:

- The method can be successfully applied on different types of farms. Sporadic weaknesses were observed on farms with vegetable cultivation, beef-cattle, sheep and horses. The reasons mostly were uncertain standard values.
- The awareness and know-how of all farmers, extension services and fertiliser companies about correct manure management improved considerably.
- The instrument is particularly suitable for rapidly obtaining an overview of nutrient reasonable stocking rate and to decide whether and, if yes, how much fertiliser can be imported. Fluxes on the farm, to detect serious fertilisation errors, to determine optimum stocking ratesand to decide how much fertiliser can be imported.

The comparative study of Bloechlinger and Schuepbach (1993) stated that the method of supply / demand balance from LBL should be given preference over the farmgate method in the enforcement policy demands of integrated and organic production. This is in contrast to its use for scientific purposes, where the farmgate method is more suitable. Reasons for this recommendation and the further strengths of the 'Nährstoffbilanz' are:

- Only easily available data concerning farm management are needed, such as areas, number of animals, yields.
- The method is based exclusively on widely accepted standard values from research institutes leading to high acceptance and transparency and uniformity in Switzerland.

- It is uniformly applicable on all farm types, thereby avoiding discrimination.
- Integrated plausibility tests for the prevention of system errors are effective; e.g., there is only as much grassland yield available as animal feeding demands.
- Both the N- and P-balance can be accurately quantified and assessed.

A wide acceptance of the instrument in practice is crucial to the ecological orientation of Swiss agriculture. This is achieved if each farm is assessed individually and according to its current code of agricultural practice. For this reason the ‘Nährstoffbilanz’ was modified several times to encompass basic changes in agricultural practice, for example in the use of pig feed with reduced protein and P content. To reduce the nutrient supply assumed in the ‘Nährstoffbilanz’, pig-farmers started to use protein- and / or P-reduced pig feed. They demanded to be allowed to substitute the standard values used in the ‘Nährstoffbilanz’ with their farm-specific values. A group of experts from research, agricultural extension, administration and practice elaborated a reliable solution for the ‘Nährstoffbilanz’ (Barmettler *et al.*, 2002). A similar approach was taken when it came to innovations ingrazing, housing systems, etc.

The main reasons for the wide acceptance of the ‘Suisse-Bilanz’ are:

- In addition to the most abundant farm-types in Switzerland, specialised farms (grazing beef-cattle, sheep, goats, horses, fruit, ‘exotic’ plant and animal species) can also be balanced accurately, because researchers elaborated standard values for these as well.
- Consequent transdisciplinary development with integration of all concerned parties: Research, administration, extension, animal-feed-industry, surveillance organisations.
- The central theme: a technically correct and transparent procedure, optimised within the triangle:‘scientific precision – practicability on the farm – simplicity’.
- The formation of a mixed group of experts (‘Groupe technique’) to elaborate and discuss further amendments and modifications to the method.

Conclusions: What has been achieved by nutrient balancing in Switzerland to date?

i) A conmmon instrument for agricultural extension, planning, enforcement of direct payment criteria and water protection legislation, basis for contracts concerning the interfarm movements of manure, etc.

ii) A wide acceptance of the instrument, application on over 90 % of all Swiss farms.

iii) Appreciation by all parties concerned regarding nutrient fluxes at farm level. This triggered off discussions, promoted critical thinking, improved nutrient management and motivated farmers to handle manure efficiently with minimum losses. It also led to a substantial drop in the use of mineral fertiliser.

iv) A reduced reluctance to deal with different disciplines, promoting a common language and common terms. An improved collaboration within agricultural technology circles and is a model for seeking solutions in other fields with conflicting technical goals.

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The ecological knowledge of farmers located in National and Landscape Parks in Poland

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Abstract

The aim of this study was to estimate farmers' ecological knowledge and its effect on environmental conservation. 328 farms from 28 villages located within the protected areas of one National and one Landscape Park in North East Poland were evaluated by a special questionnaire method. Permanent grasslands are important in the region (about 30 % of agricultural land) but they are used in a very extensive way and a lot of errors in management were observed. Although farmers were interested in nature conservation more than 60 % thought that agricultural activity was not harmful to the environment. It was proved that there was a significant correlation between farmers' education level and their relation to nature. The positive conclusion was that the majority of farmers were interested in increasing their ecological knowledge and they were able to convert their farms to ecological or sustainable systems. However, there was a clear need for some support from the state.

Keywords: ecological knowledge, farmers awareness, nature conservation, national park, protected area

Introduction

The system of nature conservation in Poland is rather well developed. 32.5 % of the total area of Poland (about 10 million hectares) is fully or partly protected by law. However, the majority of protected land is still used for agricultural purposes and agriculture has an important effect on the environment (both positive and negative). Good agricultural practice and respect for ecological rules and special regulations by farmers are very important for nature conservation. However, this activity also needs some financial support to farmers from the state (Majewski, 2001). The aim of this study was to estimate the level of ecological knowledge of farmers whose land is located in the environmentally sensitive areas. The previous study (Majewski *et al.*, 2002) showed that farmers very often did not realise that their activity could be harmful for environment.

Materials and methods

The special questionnaire (40 questions) was sent to 360 farms located in 38 villages within the 'Narwiański Park' area of the National Park (A) and the 'Przełom Bugu' Landscape Park (B) in North East Poland. The farmers and villages were chosen at random. The study was carried out in the years 1999-2001. We received 328 answers to the survey and the data were statistically analysed by correlation and chi-quadrate tests.

This paper presents only a part of the wider study which has been presented as a doctoral thesis at Warsaw Agricultural University (Czarnocka, 2003). We were particularly interested in the extent of farmers' ecological knowledge and the effect that this had on practical grassland management.

Results and discussion

The majority of the total number of farms surveyed (85-93 %) had grassland. However, in the 'Narwiański' National Park area, 30 % of the grassland had not been cut because of flooding or low efficiency of animal production (according to the farmers' opinion). A different situation was observed in the 'Przelom Bugu' Landscape Park. Here, only 2 % of total grassland area had not been utilised. A very interesting finding of the survey concerned the ecological awareness of tested farmers. The majority of farmers clearly thought that degradation of the environment only took place in urban areas (cities) and that this was not a concern in rural (country) areas (Table 1).

Table 1. The farmers' opinion about environmental risk (in % of tested farms).
A = National Park 'Narwiański', B = Landscape Park 'Przelom Bugu'

Question	YES		NO		I do not know	
Is the environment at risk?	A	B	A	B	A	B
In Poland	52	72	20	8	29	7
In country areas	28	25	56	68	16	7
Caused by agriculture	13	34	68	55	19	11

More than 60 % of farmers answered that they considered that their activity was not harmful to the environment. It was clear that farmers did not know that some of their agricultural practices caused soil and water contamination and could be a reason for grassland degradation (Table 2). However, in response to another question farmers indicated that they were interested in nature conservation (74 % of farmers in National Park and 86 % in Landscape Park). Although they were interested, it was apparent that they made a lot of mistakes in normal practise (Table 2). For example, they thought that organic fertilisation was not a problem for the environment and about 25 % of farmers did not think that mineral fertilisation could be dangerous. Our studies also confirmed that although farmers knew what they should do or what was forbidden by law, generally they did not obey these rules in practice. An example of this was that most farmers' knew that grassland burning was forbidden but, according to the observations made by advisors from both tested areas, this practice was widespread. More optimistic conclusions can be made concerning farmers' opinion about ecological agriculture. Depending on the area 70-90 % of farmers had heard about the scheme and 30-35 % wanted to convert their farms, although they expected some financial and educational support from the state. It was also shown that there was a significant correlation between farmers education levels and their response to nature conservation problems: individuals with a higher level of education were more interested in environmental conservation than others. Age of farmers also influenced their relation to nature with younger farmers being much more open to the ideas of the ecological rules of agriculture than older ones (more than 55 years old).

Table 2. The farmers' opinion on the risk of some agricultural practices for the environment (% of tested farms). A = National Park 'Narwiański', B = Landscape Park 'Przelom Bugu'.

Kind of practice	Risky		Not risky		I do not know	
	A	B	A	B	A	B
Organic fertilisation	10	7	74	86	16	8
Mineral fertilisation	56	64	24	25	20	11
Chemical crop protection	67	81	11	10	21	9
Burning of grasslands	65	77	9	9	26	14
Pouring out sewer to the rivers or ditches	74	85	2	3	25	12
Grazing near the roads	68	83	12	5	20	12

Conclusions

It can be concluded from the questionnaire that farmers' ecological knowledge is still not sufficient and agricultural practice was poor in this respect within the protected areas. Farmers made a lot of mistakes and often did not realise that their activity could be dangerous and harmful to the environment. Farmers were interested in converting their farms into ecological or sustainable systems and they understood that it could be a challenge for them. However, they expected more support from the state and advisory service.

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Tools for supporting grassland management changes through livestock farmers' groups

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Abstract

In mountainous regions, the quality labels approach involves modifications and technical changes to production systems, particularly concerning pasture use. To support these changes new tools for managing pasturelands have been created and tested in a 'research / intervention' context. The use of sets of tables to characterise grazed and mowed areas based on forage schedules collected by agricultural advisors have been proposed. Within the framework of research aimed at Pyrenean dairy farms, the benefits and limitations of, and the adaptations required by these new tools have been analysed. It emerges from this research procedure, in partnership with farmers and advisors, that it is essential to begin by providing simple tools to analyse and compare the differences between various livestock farming systems.

Keywords: technical change, advising tool, grassland management, farmers' practices

Introduction

Faced with changes in the CAP, there is great uncertainty as to how dairy farming systems on mountainous zones should evolve. A number of approaches have been implemented, based on the European regulations defining the Protected Designation of Origin (PDO) and Protected Geographical Indication (PGI) labels (Sylvander, 1994). The challenge is to define more clearly the specifications of the conditions of milk and cheese production. This may require farmers to modify their production systems. These modifications involve technical changes, particularly with regard to greater pasture use. This paper describes work undertaken to construct management tools for pasture areas to provide support for these changes including (i) the choice of methodology, (ii) new management tools for grassland areas and (iii) the use and limitations of these tools, together with modifications for the situation under study.

Conditions of the study and choice of methodology

In the French Pyrenees, a new PGI for cheese made using raw milk is to be established. The specifications require a grazing period (3 months) and the use of hay (at least 25 %) for winter forage. Presently just a third of the farmers in the region conform to these specifications (Thénard *et al.*, 2004). Groups have been formed with farmers, advisors and researchers to propose new grassland management. INRA have chosen to support this technical change by providing new tools, based both on the technical sciences (agronomy, animal husbandry) and on the management sciences, to describe management practices in the forage system. From the methodological point of view, 'research intervention' (David, 2000) has been implemented which, in this case, consists of offering tools suited to the conditions of the PGI approach and of formalising existing knowledge and earlier work. This approach is based on research development groups. The farmers met several times with advisors and researchers to assemble their experience and problems with running their forage systems. The starting point for the work reported here was to make use of forage schedules (Figure 1), one of the most common ways used by advisors to describe the farmer's land use. There are tables of all the grass fields on the farm and the operations carried out on these fields. These forage schedules are descriptive, but provide no information about the state of the herbage, efficiency of utilisation, and do not permit a judgement of the appropriateness of the farming methods to the production objectives. They are also characteristic of the farm under study, which means that any comparison with other farms regarding field management is difficult. As a result there are certain limitations to using them to support technical change. These limitations required new tools / approaches to be proposed.

New tools for better management of grassland fields

Four objectives for these new grassland management tools were established. The objectives were (i) to characterise the farmers' grazing and mowing practices, (ii) to allow comparisons between farms, (iii) to provide the information needed to plan a choice of forage management for PGI label, and (iv) to encourage communication between farmers and advisors to help establish recommendations for pasture management. Using this information about forage scheduling, and based on grassland management (Duru *et al.*, 2000, Theau *et al.*, 1998), the tools developed are hopefully comprehensible to both farmers and advisors. The aim of the work was to move from descriptive information to explanatory information (Figure 1). Two kinds of data collected by the advisors from the farms were used (i) defoliation events as recorded in feeding schedules, expressed in degree-day for comparing different weather situations, and (ii) herbage height in the grazed fields. These tools were formalised as a table characterising grazed and mown fields and based on the characteristics of the dominant species (Theau *et al.*, 2001).

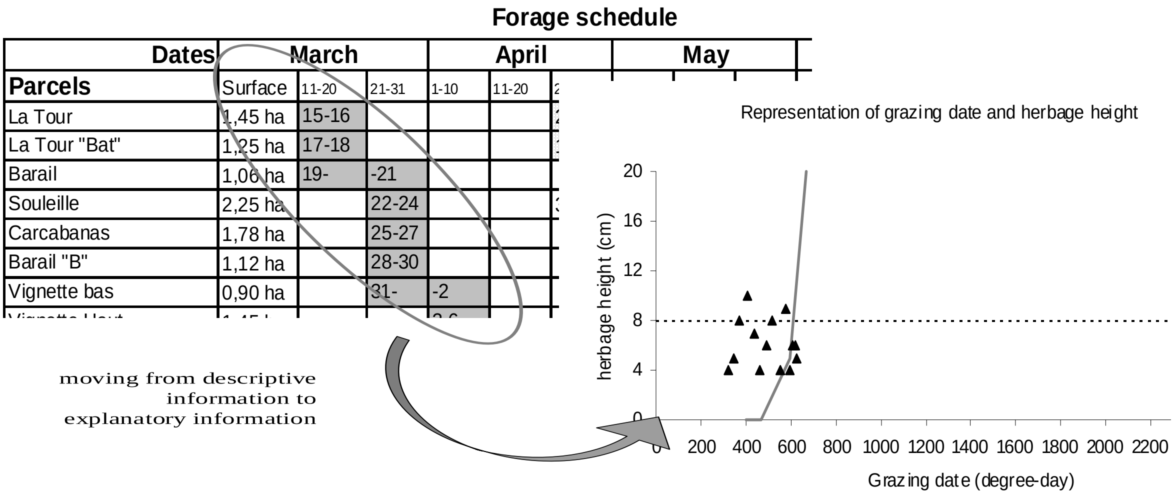
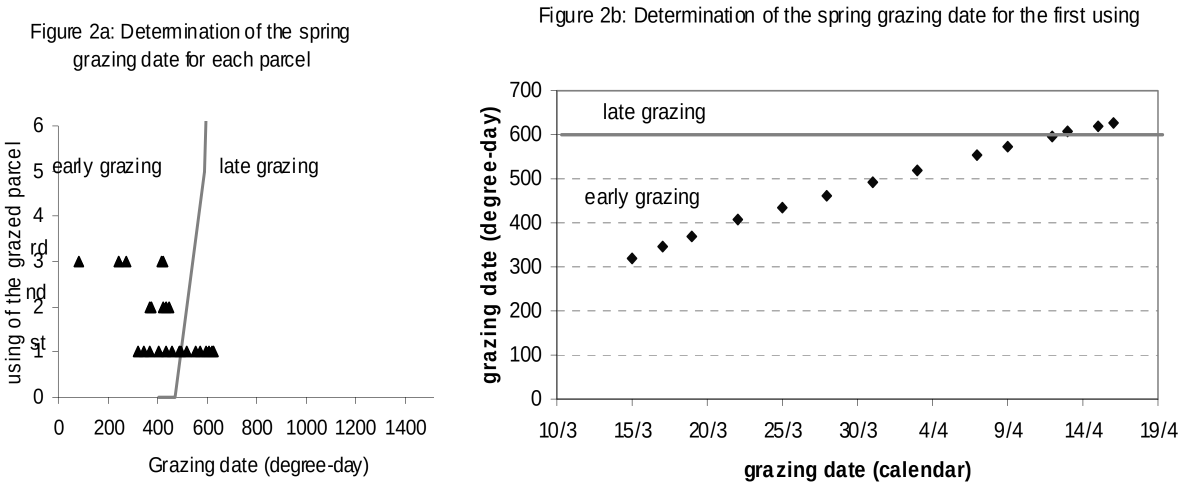


Figure 1. Transition from a forage schedule (left) to a table of grazing practices (right).

Use of these tools, their limitations and adaptation to the studied situation.

Studies were carried out with approximately twenty farmers by agricultural advisors to collect the information needed to characterise mowing and grazing practices. This information gathering gave rise to several difficulties: (i) the forage schedules were sometimes incomplete, especially towards the end of the season, and (ii) herbage heights were either not recorded, or not very carefully recorded. This led to the suggestion of using simplified tables, which do not include herbage height, and only take account of the spring grazing period (Figure 2a). Although these tools enabled a diagnosis of the grassland management, it appeared that the farmers had difficulties in representing their farming methods in terms of temperature sums, as they usually work with calendar dates. This difficulty limited the farmers' justification of their land use. A simpler table (Figure 2b) was therefore proposed, which showed each field using the calendar scale and the degree-day scale (Theau *et al.*, 2004). Taking a few cases as examples, all the farmers were shown the results of forage practices using the tables described above. The results showed that certain farmers experienced difficulties in planning their grazing and mowing areas. The differences in land use between farmers were more clearly described and comparison between forage strategies was facilitated. This method also helped farmers understand the relationships between production objectives, interactions between the management of the grazed and mowed areas (Coleno *et al.*, 2002), and consistency of production systems, in particular the links between the forage system and herd management (Thénard *et al.*, 2004). These meetings with farmers permitted a contribution to the growth of knowledge and change in behaviour of farmers utilising grass.



After early grazing regrowths are reproductive (high biomass amount low quality), after late grazing regrowths are vegetative (low biomass amount high quality)

Figure 2. (a) Table of grazing used during meetings with farmers; (b) a simplified table proposition.

Conclusions

The need for support for farmers' groups led to the modification of the tools for characterising grazed and mowed land in the interest of simplification and the need to compare situations in a method better suited to the conditions of the study. It was found that the management of grassland by farmers varies greatly. Finally this work shows, from these tables and the variety of situations, the importance of customising the support for farmers' technological change according to their rearing systems.

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New opportunities and demands for decision support on eco-technological agricultural practices

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Abstract

Reduction of inputs into farming systems results in a larger dependence on biological processes and resources. Eco-technological management aims to improve utilisation of internal farm resources, but also leads to larger complexity of the farmers management tasks and to changes in demands for knowledge and decision support. An interdisciplinary, socio-technological evaluation of nitrogen fertilisation practice and recommendations for grasslands in the Netherlands was conducted to determine the required changes in decision support.
Farmers applying eco-technological agricultural practices desire support of learning and adaptation, rather than ready-to-use recipes. This alters and increases demands for knowledge and instruments. In particular new indicators that relate to biological processes should be developed and scientifically underpinned. Moreover, the need for long-term explorations for individual farmers increases since not only the societal demands and limitations, but also the possibilities for new choices and coalitions increase.
Various changes in the roles of stakeholders were identified. Local and regional farmer co-operatives play an essential role in knowledge transfer and representation of farmers. Novel recommendation approaches necessitate a reform in the organisational and competence structure of the developers of recommendations. The emphasis in scientific research should shift from development of seemingly accurate solutions and models to supporting the farmer's learning and adjustment process. National, regional and local government and representatives of the agricultural sector should support the dynamics of changes in the rural area.

Keywords: grassland, recommendations, decision support, learning, adaptation

Introduction

Following the wide acknowledgement of the adverse effects of intensive agricultural practices on agro-ecosystem functioning in temperate regions, regulations and restrictions on fertiliser application have been implemented in recent years (Henkens and Van Keulen, 2001). Increased environmental awareness is accompanied by new societal demands for use of rural areas, for instance for nature conservation and recreation. In response, farmers have significantly adapted their farm management to improve nutrient use efficiency, constituting a movement from increasing inputs to increasing utilisation of internal resources in farming systems, denoted as a shift from technological to eco-technological management. Farmers have also explored new possibilities to develop new products and production methods that match the demands posed by policy and society. This has resulted in a debate on the effectiveness of decision support and recommendation systems, in particular for fertiliser utilisation on grassland. In an explorative study of this debate, various methods were used in an interactive and interdisciplinary approach involving all relevant stakeholders. In this paper a synthesis is presented of the more significant trends and components of the required adjustment in the recommendation system and the consequences for various stakeholders.

Methods

The project was carried out in two subsequent phases of inventory of problems and generation of new components for fertiliser recommendations. Various groups of stakeholders were involved: farmers and their interest groups, environment and nature conservation organizations, national and local government, industry, extensionists and researchers. Methods employed during the inventory phase comprised mind mapping to explore opinions and positions of the stakeholder groups in the debate, interviews with eight farmers with a well-articulated vision on farm fertiliser management, and a concluding workshop with extension workers and farmers. The second phase consisted of interviews with policy makers and scientists with knowledge of new functions of the rural area and a second workshop with various stakeholders related to both the existing recommendation system and the new demands.

Results

Operational / tactical management: The increasing attention in society and policy for lowering detrimental emissions from agro-ecosystems and improving their sustainability has generated new requirements for extension, knowledge transfer and decision support. When the artificial inputs decline, agricultural production becomes increasingly dependent on biological processes and resources, such as mineralization and manure, respectively. As a consequence, the sensitivity for variation in the bio-physical environment and the complexity of the farmer's operational and tactical management tasks increase, whereas the effectiveness and acceptance of decision support systems and tools is often limited (McCown, 2002).
The interviewed farmers indicated that for operational and tactical management, the need for ready-to-use advise and recipes is replaced by a desire to learn and to adjust decision processes. Decision support and additional knowledge needs to correspond better with the farmer's daily routine and learning process. On the other hand the farmers need to be aware that the possibilities to influence and manage the system decline, and that they will be faced with larger margins of uncertainty. Scientific research approaches such as those supporting adaptive management can assist farmers in anticipating uncertainty and exploitation of variation (Walters, 1986).

Strategic management: From the farmer's perspective, the demands and limitations imposed by society and governments increase, as is particularly expressed in the growing number of regulations. However, at the same time opportunities for new roles in management of water, air and landscape emerge for farmers as the primary managers of the rural environment. These new services and functions often transcend the farm scale and also imply the involvement of a larger number of stakeholders, such as national, regional and local governments, water boards, energy distributors, recreation entrepreneurs, etc. The negotiations with these stakeholders and the consequent long term choices of farmers can be supported and evaluated by strategic tools, using data collected on the farm or in the farm region.

A framework for decision support: In the recommendation system tactical / operational and strategic support should be distinguished explicitly. Four components can be considered:

1. A simple base recommendation (scheme) that is adjusted to the farm circumstances and learning ability and style of the farmer.
2. A fully automated decision support system that can be fed with farm-specific data and that accounts for prevailing circumstances and changes therein.

3. A set of tools for strategic exploration for longer terms and larger scales.
4. Transfer of knowledge and experience, both from scientific and experimental origin.

Monitoring schemes and the use of indicators that support on-farm use of components 1 and 2 contribute to the farmer's learning process by supplying continuous feedback on the agricultural and environmental effects of the applied management practices. The relevance of the monitored variables and the indicators used changes continuously, due to changes in the scope of the farmer, new insights of other stakeholders in the rural area and developments in legislation. Also the strategic tools (component 3) should be designed in such a way that easy anticipation of such changes in possible.

Social context and the roles of stakeholders: Mastering the new situation requires not only new insights, instruments and indicators for farmers, but also adjustments in the relationships among farmers and between farmers and scientists, commercial advisors and extension workers. A new framework for farmers' decision support requires reconsidering the roles and contributions of existing and new stakeholders. Scientific research has focussed primarily on generating new knowledge and information through research programmes in experimental fields and laboratories. Scientists should reduce the pursuit of ready-to-use answers and seemingly accurate solutions, models, predictions and recommendations. They should support the learning and adjustment processes of farmers in local and regional contexts. Existing knowledge can be recombined. Requirements for new knowledge will emanate, while the farmer is learning and adjusting his farm management.
An active role is necessary for national, regional and local government and representatives of the agricultural sector by anticipating and supporting:
- new social developments, e.g., initiation of regional projects and farmers' co-operatives,
- developing regional solutions to newly imposed regulations and societal demands, and
- financial and institutional incentives for new services delivered by farmers.

For the developers of recommendations the scope of decision support should clearly be broadened, other products have to be delivered and more integration of regional characteristics and organizations is required. This necessitates a reform of the organizational and competence structure. Local and regional farmers co-operatives play important roles in this transition process, as they contribute to: (a) regulation of regional management of landscape and environment, (b) knowledge transfer between farmers, (c) representation of farmers in negotiations, and (d) improvement of relations with the public. Strong co-operatives of farmers are not only highly valued by farmers, but are also considered to be critical success factors in the implementation of sustainable and multifunctional agricultural practices (Pretty and Ward, 2001).

Conclusions

The shift towards eco-technological farm management necessitates adjustments in recommendation systems to meet changes in knowledge requirements. These systems can be developed within a framework that clearly separates tactical/operational from strategic decision support. Changes in roles and contributions of all relevant stakeholders are required.

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The development of a mathematical model to investigate Irish beef production systems

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Abstract

Irish beef production, whilst predominantly grass-based, is highly variable with regard to system specifications. This, allied to a changeable policy environment, creates difficulties in simulating changes to current systems or use of prototype technologies in a repeatable and standardised way. This project involves the development of a mathematical model to fulfil this requirement. The programming model is based on an Irish spring-calving, beef suckler herd and the typical feeding and trading options available to such an enterprise. The optimal system is predicted with optimisation of revenue over costs being the defining criteria. Typical Irish performances and yields are used. The model facilitates the investigation of the effects of modifications to current systems, the impact of application of prototype systems and the consequences of changes in the policy or economic environment. The model was assessed by beef systems researchers in terms of technical and economic predictions and was found to simulate the results of beef systems experiments reasonably satisfactorily.

Keywords: suckler system, beef production, pasture, programming model

Introduction

The suitability of the Irish climate to grow grass at a modest cost results in cattle farmers endeavouring to maximise the contribution of grazed grass to total feed requirements (O'Riordan and O'Kiely, 1996). To achieve this within the range of prevailing environmental and economic circumstances, farmers operate a large number of beef production systems. In the current, continuously changing market and policy conditions, further new beef production systems will need to be considered. A computerised model based on empirical data provides the opportunity to allow rapid, repeatable simulation and assessment of current and prototype Irish beef production systems. The aim of this project is to develop such a model by integrating appropriate component production models. This model would be required to operate at a systems level and be capable of simulating current practices on beef production enterprises. The interaction of technical and policy components is a key element of the model. Teagasc, Grange Research Centre values for performances, responses and yields are used. INRAtion 3.0 (INRA, 2003) is used to obtain values for nutritional specifications. This INRAtion version has been modified for intake capacities, which measures the capacity to consume feed, and energy requirements of Irish growing and finishing cattle and was thus deemed the most appropriate nutritional model to use.

Materials and methods

The model is being developed using a mathematical programming methodology (Dent *et al*., 1986) which encompasses the following characteristics; a range of possible activities, various constraints to prevent free selection from the range of activities and an objective which can be quantified. It is solved using the optimization software 'What's Best!' (Lindo Systems Inc., 2002). The model was designed in Microsoft Excel with the spreadsheet columns corresponding to the model activities and the rows corresponding to the model constraints. The activities included are those typical of spring-calving, suckler beef production systems in

Ireland with the objective being to maximise revenue over costs. The activities can be categorised as feeding, trading and animal activities. Budgets are formulated for the activities using the most recently available Irish data. These budgets assign a cost or revenue to each activity and, based on these, the program identifies the optimal solution. Figure 1 represents a schematic of the system as modelled.

The model framework integrates physical and financial on-farm conditions with appropriate production models to indicate optimal systems. Due to the expected suitability of pasture-based systems, the model is constructed around the grazing options, which are typical of those available to Irish cattle farmers. Grass growth is modelled on historical data from Grange Research Centre and is responsive to nitrogen (N) application rates with yields ranging from 7.9 t ha^{-1} for 0 kg N ha^{-1} to 15 t ha^{-1} for 300 kg N ha^{-1} (McGee, 2002). A number of conservation strategies are included to facilitate winter feeding and feeding in times of temporary grass shortage during the grazing season. Yields and quality of conserved forage are also based on Grange Research Centre data. The date of harvest is used to regulate forage yield and quality (Keating and O'Kiely, 2000). Concentrate feeding, being a crucial element of beef production, is a key activity available to all animal categories. The concentrate ration is a commonly used barley-based ration balanced for protein with soyabean meal and maize gluten feed. The respective feed proportions may be adjusted as required.

The animal production options included are again typical of those used by Irish farmers. Since the model is based on Irish spring-calving, suckler herds, it includes suckler cow, calf, store and finishing activities.

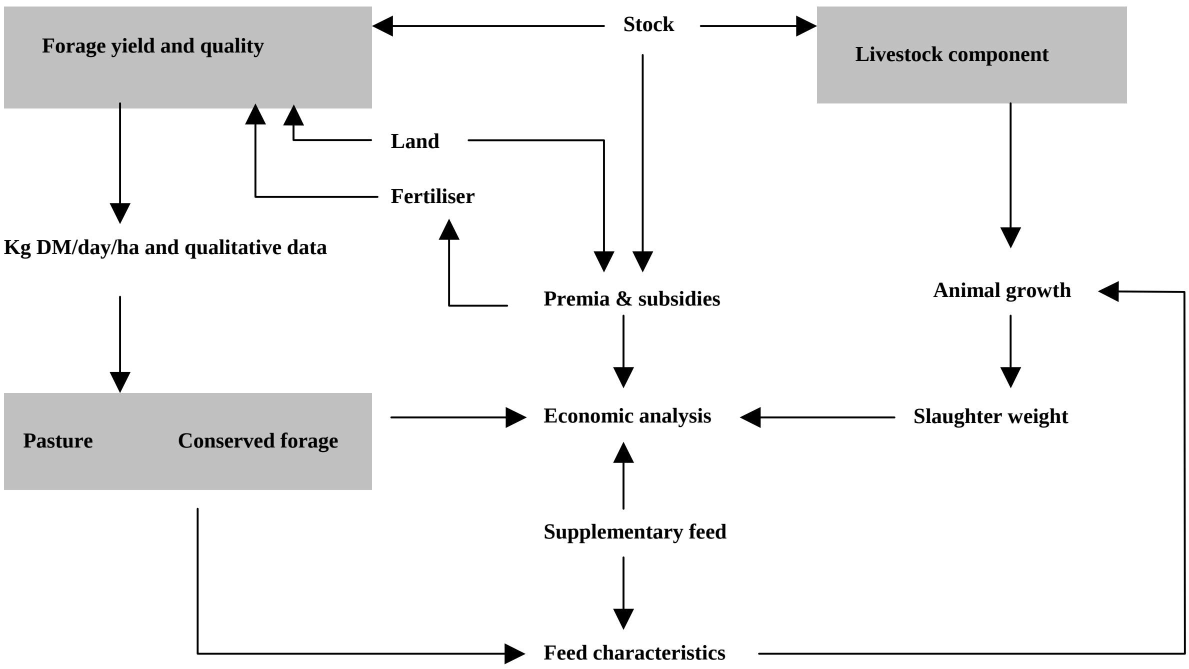

Figure 1. A schematic of the model structure.

Empirical data from Limousin × Friesian cows mated to a Charolais sire, together with their progeny are used. INRAtion 3.0 is used to model energy requirements and intake capacities.

A key consideration was the issue of substitution rate. Substitution rate is the reduction in forage intake caused by the addition of concentrate feedstuffs to the diet. It was addressed using the method outlined by Jarrige (1989). Using the ration energy density (RED) requirement of the animal (which is a function of the live weight and liveweight gain), equations were established to relate RED to an 'apparent fill value' which is a function of the

fill value and energy content of the forage. This apparent fill value regulates the animal intake capacity.
The capability exists within the model to investigate the effects of changes in agricultural policy. By imposing restrictions on the applicable coefficients and by modifying appropriate activity budgets to reflect changes in the value or form of premia payments, an evaluation of hypothetical policy environments may be provided.
In addition to these typical animal and grazing activities, the model includes the opportunity to evaluate prototype production alternatives which, given increased regulations imposed on and accountability demanded of Irish beef producers, may appear attractive. Depending on policy and cost considerations, these may include longer, more extensive production systems or shorter, more intensive production systems. The model indicates how the application of such prototype technologies affects optimal systems. Furthermore, modification of current production systems can be routinely investigated.

Results and conclusion

A phase of validation with beef systems researchers was used to assess the accuracy with which the model made technical and financial predictions. Following from this consultation a number of budgetary and technical modifications were made. It was found that, subject to these amendments, the model simulated experimental beef production systems as operated in Grange Research Centre reasonably well.
Using this model it is possible to analyse current or prospective scenarios of interest. It helps identify optimal systems, indicate the cause of failure in imperfect systems and reveal areas where applied research is lacking, or more basic research is required.
The feeding and animal activities are detailed on a monthly basis, thus enabling the model to demonstrate greater flexibility when solving for the optimal production system. This may include the tactical use of conserved forage or concentrates during the grazing season in response to periods of low grass availability.
Whilst much of the production data is based on performances obtained at Grange Research Centre, the parameters can be modified to reflect other situations.

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Productivity, energy content and species-richness of multi-function grasslands

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Abstract

Multi-function land use is considered as an option to enlarge economic and environmental sustainability and to make the area more attractive for local people and tourism. In 1998 a large programme on sustainable land use started in the Winterswijk area. The area consists of a small-scale landscape with a dominant role for agriculture. Substantial parts of the area are covered by nature, forests, recreation areas and campsites. The programme involves various combinations of land use types and many organisations cooperate in the programme.
For different types of grassland the relationships among grassland management, soil fertility, water management, grassland productivity, forage quality, biodiversity, amenity of the countryside and farm income will be analysed in future years. First preliminary results from on farm research in 2002 on grass productivity, energy content and species-richness are presented.

Keywords: multi-function grasslands, grass production, numbers of plant species, sustainable land use

Introduction

Sustainability and multi-functionality are key components for the development of the rural area in Europe. Multi-function land use systems should integrate food production, safety, nature and landscape conservation, water management and recreation (Paris, 2002). These functions have to be combined at field, farm and regional levels.
To address the possibilities of multi-function land use a large project ('Sustainable Land Use Winterswijk') started in 1998 in the eastern part of the Netherlands near Winterswijk. The final goal of the project is to reconcile economic growth and sustainability in the region. Results of the project must set an example for multi-function land use in other regions. The programme has a strong multi-disciplinary character and involves the interactions between governmental authorities, industry, agriculture, nature and environmental organisations, and research institutes .
In the programme various combinations of land use functions are analysed. In this paper we present the first results of the project 'Multi-function grasslands'. Due to difficulties with subsidies the start of the project was delayed till 2001.

Materials and methods

In 2001 and 2002 a total number of 22 grasslands on nine farms were selected. Five different types of grassland were distinguished: 1) intensive fertilised and utilised grasslands (control), 2) grass-clover swards, 3) grassmixtures (of native grasses), 4) old low-productive, species-rich grasslands and 5) newly seeded grasslands. The latter type of grasslands were created by reseeding with species-rich seed mixtures of herbs, clovers and grasses. Also the grass-clover swards were newly sown. Monitoring started in 2002. In each field four enclosures were harvested every time a field was grazed or cut. Chemical composition, digestibility and other forage components were determined. Species numbers were scored on a permanent quadrate of 100 m^2.

Relationships among grassland management, soil fertility, water management, grassland productivity, roughage quality, biodiversity, amenity of the countryside and farm income will be analysed thoroughly in future years.

Preliminary results and discussion

The grasslands were classed into the five groups (Table 1). Productivity of the grass-clover swards in 2002 was about the same as that of the heavy fertilised grasslands. A slightly higher net energy content per kg DM was observed in the grass-clover mixtures. Both types have a relatively low species-richness. Highest species-richness was observed in the old and the newly seeded grasslands. In spite of the higher species-richness, the species were still common grassland species. Until now no rare species have been found in the permanent quadrats. Productivity in the old grasslands was rather low with a large variation around the average. Productivity of the newly seeded grasslands was intermediate. Also average energy content in these types of grasslands was lower than that in the control and grass-clover systems, but on some fields grass with a good net energy content of about 6.0 MJ kg^{-1} DM was harvested.

Table 1. Preliminary results of 2002 for multi-function grasslands, average and between brackets minimum and maximum value per grassland type.

Grassland type	Intensive (control)	Grass-clover	Grass-mixtures	Old species-rich, low-productive	Newly seeded with species-rich mixture
Number of fields	2	3	6	7	4
Utilisation	grazing	grazing	cut for silage or hay followed by grazing	hayfield or first cut followed by grazing	hayfield or grazing
N-fertilisation kg ha^{-1} (inclusive manure)	240 (230-250)	80 (80-80)	60 (0-110)	20 (0-110)	10 (0-30)
DM yield ha^{-1} y^{-1}	13 (11-14)	12 (11-12)	9 (6-12)	6 (2-10)	7 (6-9)
Net energy content MJ kg^{-1} DM	6.3 (6.0-6.5)	6.5 (6.2-6.8)	5.6 (5.0-6.0)	5.0 (4.1-6.0	5.7 (5.3-6.0)
Number of plant species	9 (8-10)	8 (5-10)	16 (11-21)	20 (15-26)	33 (21-42)

Figure 1 shows the well known hump-shaped curve of species-richness versus productivity. Clearly the range of productivity for species-rich grasslands is rather broad. Seven out of the 22 grasslands combined a relatively high species-richness (more than 20 species) with intermediate to high productivity (more than 8 tons DM ha^{-1} y^{-1}. Three of them are grasslands with introduction of species-rich seed-mixtures. In future years we will continue the monitoring of these grasslands to get more information about the stability of production and floristic composition. We also hope to get more information about the possibilities of combining a relative high DM production and an acceptable net energy content with a high species diversity of the sward. In a long term grassland experiment (A. van der Werf, unpublished data) we found evidence that combinations of relative high grass production and rather high species number are possible.

Conclusions

In the first year of an on-farm research experiment a broad variation in DM production, net energy content of the grass and species numbers was observed. Highest species numbers were recorded after introduction of species-rich seed-mixtures. Some of the monitored grasslands combined a relative high species diversity with a good production. These are interesting fields for further research on multi-function grasslands.

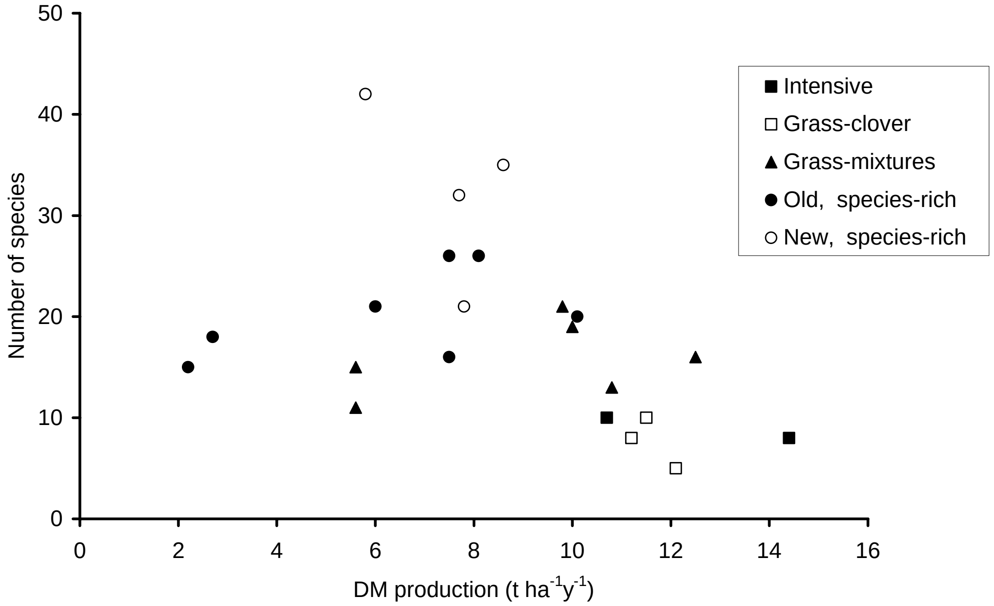

Figure 1. Relation between DM production (t ha^{-1} y^{-1}) and species-richness per 100 m^2 for five grassland types.

Acknowledgements

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Changes in land management system in the Sudety Mountains during the last seven decades

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Abstract

In south-west Poland, the Sudety Mountains are one of the regions where grassland is dominant. Sudety Mountains cover over 470,000 ha, of which 206,000 ha are agricultural land (meadows and pastures covering over half of it).

The Sudety Mountains are a region that experienced a complete population exchange. After the Second World War, people of German origin had to emigrate according to international agreements. Newcomers from lowlands did not know the specific problems of highland agriculture. The change of land use and ploughing of mountain meadows caused much damage in that period.

The agriculture 'collectivity movement' and promotion of large national farms reached Sudety too. The establishment of the large-scale agriculture farm complex 'Agrokompleks Sudety' resulted in a development of large cattle farms. This, in turn, disturbed the balance in the natural environment and caused problems with water availability and its quality.

The last period, dominated by economic reforms and political transformations, was not favourable for the Sudety region. In the last decade, ruminants have disappeared, and again cash crop cultivation has become the main production trend. The Sudety region still is considered to be a significant problem. In this report, methods of land management and trends of agriculture activity from the Second World War to the present day will be presented.

Keywords: Sudety Mountains, land structure, land management

Introduction

The Sudety Mountains are located in the south part of a south-western macro-region of Poland. Sudety covers over 470,000 ha, of which 206,000 ha are agricultural land (meadows and pastures covering over a half of it). This is a highland region that causes more problems than other mountain areas in Poland. Has the lack of a stable and relevant policy for less favoured areas such as the Sudety over the last 70 years been a reason for their being economically neglected? The authors of the paper discuss this issue from a historical point of view, beginning from before the Second World War until the present day.

Land management before the Second World War: Before the Second World War, the Sudety was densely populated (Tomaszewski, 1968). This was mainly enhanced by industrial development and easy access to natural resources. In that period of time, villages in the Sudety were overcrowded and people used soil of a low fertility and productivity potential. Plough tillage was applied even at the altitude of 700-800 m asl. The cultivation system was adapted to environmental conditions. In the lowest areas, a three field system was applied: cereals (or root crops), cereals with undersown red clover and red clover. The percentage of legumes was 15-30 %, but in the higher zones it increased to 50 %. The system used at that time protected the soil from erosion but ploughing was applied on fields on steep slopes (Dzieżyc, 1960).

Methods of land management immediately following the Second World War: After the Second World War, the Sudety region was influenced by many changes, both demographic and economic. The Sudety experienced a complete population exchange. Before the end of the war, migration of people had started, hence, the inhabitants of Sudety had a different nationality. Despite the efforts to repatriate people from other mountain regions, the majority of the newcomers were originally from lowlands. Many farmers did not know the specific features of a highland agriculture and tried to apply methods used on lowlands. During that time the fields that were supposed to be fallow lands or used in a different way, were also ploughed. You can read in the contemporary press releases of how proud the authorities were of the fact that more ground was ploughed in those days than before the war: 'Polish farmers plough and sow on the fields of 45^{o} slope that were considered useless by the German farmers' (Bac, 1948). More crops, mainly wheat, potatoes and beetroots were cultivated, even as high as at 600 m asl. The increase of arable lands enhanced wide scale erosion. There are known cases of a thin arable ground layer sliding totally down the slope after intense rainfall (Hryncewicz *et al*., 1999).

Land management in 1950-1990: The choice of crops and land management structure underwent many changes during this time, mostly because of the contemporary economic situation. After 1950, people started to migrate from rural areas to the cities. The main reason for this was an obligatory collectivity movement, and, as a result, many villages and farms were deserted. For 20 years, agriculture in the highlands and lowlands was similar. The same rules were applied in relation to obligatory deliveries, and later taxes and other financial duties (Nietupski, 1989). As time passed, agricultural activity ceased in the severe environment (both climate and soil conditions). Many farmers found a job outside agriculture and left their farms deserted. Thus, in Sudety an agricultural structure with a large collectivised sector was created.

Sudety attracted an increased interest in mid-1970s, when 'Agrokompleks Sudety', a large-size farm complex was established. In that period, intensive animal production based on mountain pastures and fodder crop production was introduced. The new farm buildings were not adapted to mountain conditions. Environment protection was not preserved. In such buildings animals were dying of diseases and the production was low (Nietupski, 1989). The arable lands were covered with fodder crops, mainly red clover alone and in mixtures with grasses. The use of these crops was from 15 % in areas 450-600 m asl to 25 % in the lowest altitude areas.

Land management after 1990: In the last decade, after economic reforms and political transformation agriculture and land management has deteriorated. The percentage of fallow lands has risen (up to 30 % in some areas). Now they are covered with useless bushes and trees (Advisory Program, 2000). The ruminant production has disappeared from Sudety, and now the main trends are commercial crops production, mainly cereals (Table 1). The most alarming feature is that large areas of arable lands are not covered with plant layer in winter, especially in the zone above of 500 m asl. In higher altitude zones of Sudety, agricultural activity is disappearing. After 60 years of Polish administration in Sudety, it is still a highly problematic region.

Table 1. Sowing structure in Sudety farms depends on altitude zones at the end of 1990s.

Crops	Altitude zones (m asl)		
	300-400	400-500	> 500
Winter cereals	37.8	31.5	22.2
Spring cereals	31.4	40.2	49.1
Root crops (incl. potatoes)	17.6 (3.8)	15.2 (5.7)	17.7 (9.3)
Industrial crop	10.4	4.7	3.6
Pulse crop	1.4	2.2	0
Fodder legumes	0.1	0.6	0.3
Other	1.2	5.6	7.1

Conclusions

In the last years, the structure of land use has changed. In specific environmental conditions, especially in lower altitude areas commercial crops are dominating because farmers see the demand for them on the market. From the ecological point of view this choice is unfavourable. A change in the production trends is necessary in Sudety. The changes in land management for the last decades have shown that less favourable areas require systemic support based on stable foundations. The agricultural and structural policy carried out in Poland for the last decades towards Sudety have led to depopulation and economic breakdown. The best method of land management in Sudety is extensive ruminant production and feed production from grasslands and crop fields – permanent legumes and grasses (Dobicki and Szulc, 1999).

This beneficial system of land management should be supported by interventions for farmers working in unfavourable environments. Yet, it is impossible in the current difficult financial situation that Poland experiences. However, in a few decades it may be unavoidable to finance expensive programs of another people settling and populating in Sudety.

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GIS and Multivariate Analysis as useful tools for forage resources management: a case study in Mallorca Island (West Mediterranean)

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Abstract

Data compilation and processing on land uses are very important steps to manage forage and livestock resources. In this sense, Geographical Information systems (GIS) and multivariate statistical analysis can be helpful in the decision-making process.
A compilation of the available information on agricultural land use, natural vegetation and livestock from each municipality in the Mallorca Island (West Mediterranean basin) was carried out. These data have been used to create a GIS in which different information layers provide an overview of the forage and livestock resources situation in Mallorca. In addition, a cluster analysis was performed in order to group the municipalities in homogeneous *forage regions*, and to identify the main characteristics of each region.
This methodology appeared to be useful to integrate and analyse simultaneously a large and dispersed amount of variables that could not be done by descriptive statistical methods. In the case study of Mallorca Island, this methodology has allowed us to divide the Island into four homogeneous areas according to the variables analysed. It provides useful information for environmental assessment, rural development policies and agricultural resources management.

Keywords: forages, GIS, land uses, livestock, Mediterranean basin, multivariate analysis

Introduction

Nowadays, research and administrative institutions generate large amounts of information in many disciplines that can be useful for forage resources management. To compile and to process this information is of major interest in order to benefit from it. Nevertheless, the classical approach through descriptive statistical methods cannot take into account simultaneously the large number of variables involved. The Geographic Information System (GIS) is a powerful technology to compile, to process and to analyse this information. On the other hand, the multivariate statistical analysis is a tool very useful for large data set analysis. The combination of both tools can be helpful in the decision-making process.
In this work, we have compiled data from different sources related to agricultural land use, natural vegetation and livestock for each municipality in the Mallorca Island. These data have been processed and analysed using GIS technology and multivariate statistical analysis in order to make it comprehensive and useful for decision-makers.

Materials and methods

We compiled the available information related to agricultural land use, natural vegetation and livestock from each municipality in the Mallorca Island, from two main types of sources: cartographic and databases from the local administration. We took the II National Forestry Map (1992) as the main cartographic source, and it was complemented with the '*Directiva*

Hábitats Map' (DGCN, 2002) and with aerial photographs (2001). The study area was divided into three main land use types following the II National Forestry Map: non-productive, agricultural and forestry areas (using ArcGIS program, 2002).

In a second step, the forestry areas were classified into 14 different types taking into account the predominant plant species and their potential as a forage resource. This classification was done following the cartographic sources mentioned above.

In a third step, the agricultural areas of each municipality were classified into 11 different types, which represent the predominant crops. This classification was done following the databases compiled by the administration, in which the number of hectares per crop and per municipality is recorded.

After data compilation, we obtained a database with the percentage of surface covered by each class of land use: 14 natural vegetation classes and 11 agricultural land uses. A cluster analysis (SPSS statistical package) was performed with this database in order to group the 53 municipalities of Mallorca.

In addition, and similarly to the classification of the agricultural areas, the livestock census (TRAGSA, 2002) was used to characterise each municipality, determining the relative importance of each species (sheep, cow, goat, pig and horse) in the total livestock pressure. In order to counteract the differences in resource consumption between species, these were normalised to UGB units.

Results and discussion

The municipalities of Mallorca were classified into four different types after the cluster analysis (Figures 1 and 2). The first one comprises the municipalities located in the western mountain region of the island (Serra de Tramuntana), where the agricultural land use only represents 25 % of the total area and the extensive and natural forage resources predominate (Type 1 in figures 1 and 2). By contrast, the second type is mainly agricultural (almost 80 % of the total area) and lies in the central and eastern plains of the island, where the semi-intensive cereals and forages represent an important part of the resources (Type 2 in figures 1 and 2). The third group is characterised by an intermediate situation, in which approximately 50 % of the area is agricultural and 50 % is occupied by natural vegetation (Type 3 in figures 1 and 2), comprising those municipalities that represent a transition between the central plain and the western mountains, as well as the northeastern hilly region. The fourth type only comprised the municipality of Escorca and it was clearly separated from the other types by the cluster analysis (Type 4 in figures 1 and 2). Escorca is located in the highest area of the western mountains and is characterised by a high proportion of range areas (more than 90 % of the total area).

Livestock distribution in Mallorca was partially related to forage resources. Sheep are the most common livestock in Mallorca, representing 68 % of total UGB. However, their importance varies between the different types (from 66 % of total UGB in type 2 to 90 % in type 4), being greater in natural vegetation dominated areas. By contrast, cattle and pigs only represented an important part of the livestock in the type 2 areas (11 % of total UGB and 18 %, respectively), where cereals and semi-intensive forage resources are more common.

Conclusions

GIS and multivariate analysis can be helpful to integrate and analyse simultaneously a large and dispersed amount of variables that cannot be done by descriptive statistical methods. In the case study of Mallorca Island, this methodology has allowed to divide the Island into four homogeneous areas. It provides useful information for environmental assessment, rural development policies and agricultural resources management.

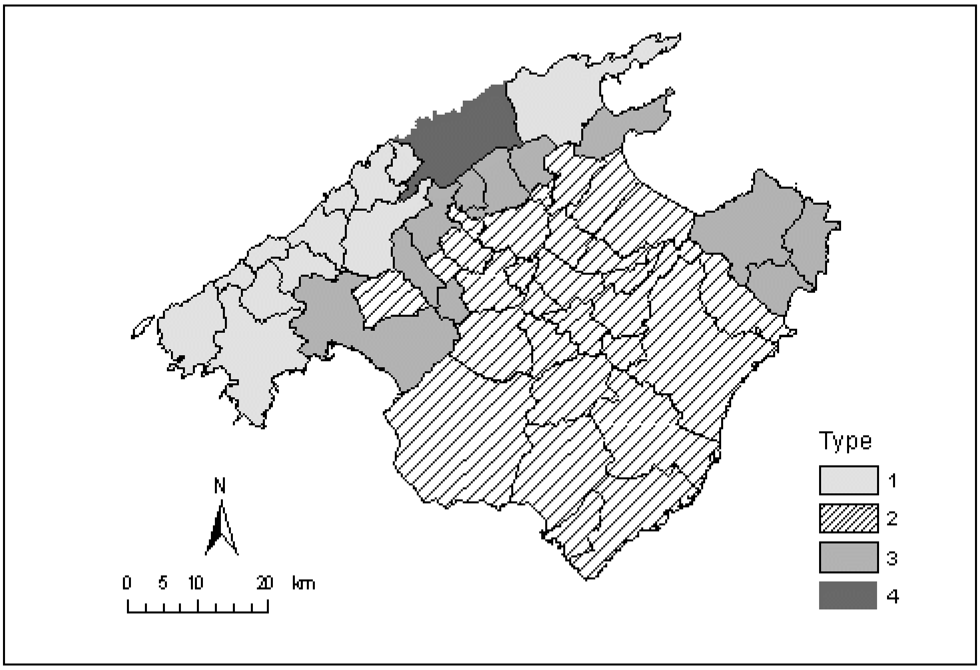

Figure 1. Municipal classification in Mallorca depending on agricultural land use and natural vegetation. Type 1: extensive forage resources predominated areas; Type 2: semi-intensive cereals and forages predominated areas; Type 3: mixed extensive and semi-intensive resources predominated areas; Type 4: Mediterranean grazed shrublands predominated areas.

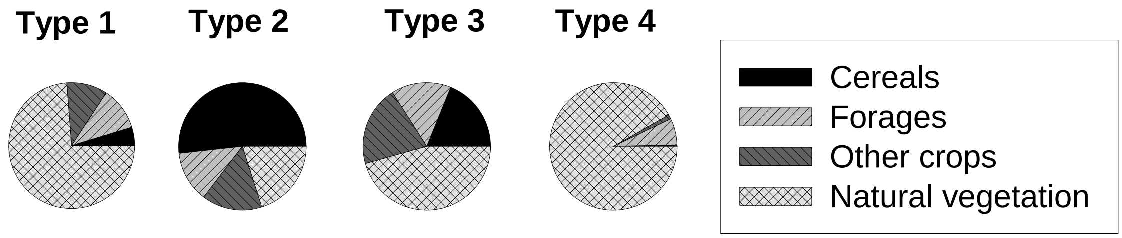

Figure 2. Land use in each region type in Mallorca. Type 1: extensive forage resources predominated areas; Type 2: semi-intensive cereals and forages predominated areas; Type 3: mixed extensive and semi-intensive resources predominated areas; Type 4: Mediterranean grazed shrublands predominated areas.

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Synthesis and perspectives on EGF2004: Land Use Systems in Grassland Dominated Regions

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Abstract

Grassland research in Europe is active and responding to rapidly changing political, economic, social and environmental circumstances. It is widely accepted in the research community that grassland must be increasingly multi-functional. As well as producing food it must protect soil, water and air, and it must conserve and restore biodiversity and the landscape. In producing food for which there will in future be little or no market support, it must be used efficiently and at low cost, and/or grassland products must command a price which reflects high quality in terms of taste, health, animal welfare and the value of the landscape from which they come. And new knowledge must be discussed between researchers, farmers, other stakeholders and the public. This paper summarises a conference at which all these aspects have been discussed.

1 Introduction

We give here our personal views of this large conference as gained from reading and listening, between us, to all 13 invited papers, virtually all of the further 60 oral presentations, and viewing most of the 289 poster presentations published in the proceedings. We have structured this short paper into the five themes identified by Steffen in his Foreword, and have attempted to pick out key messages, particularly where thinking has progressed substantially in recent years, and where gaps in understanding remain. We refer to papers by their first author and their page number.

2 Policy context

Burtscher (3) opened the conference by highlighting that agricultural activity is of paramount importance for the identity of the EU.... but it must meet the expectations of society as a whole, and respond to international challenges. This means respect for the environment, food safety, health and welfare. It also means decoupling support payments from production. These drivers resulted, in 2003, in fundamental changes to the Common Agricultural Policy (CAP). And the CAP will apply in the same way across the EU, including all the new member states which increase the number of farmers by over 60%.

In Switzerland, our host country, the same drivers have resulted in similar policy developments (Bötsch, 5), with a great reduction in production-related subsidies. Here multifunctional land use, with support for public benefits of landscape and conservation, has received even greater emphasis in recent years (Jeangros, 11; Durgiai, 49; Gotsch, 52).

We felt that critical comments on the resulting restraints on grassland productivity were expressed with less emphasis than in the recent past, and overall there was little dissent at the meeting from this multifunctional vision. The majority of papers, including those from new EU member and non-member states, referred to environmental or socio-economic aspects of land use.

3 Balancing economy and ecology

Hodge (27) addressed the delivery of public goods at least cost. Scheringer (61) in Germany and Rosef (88) in Norway, demonstrated that simple prescriptive schemes may not deliver the desired outcomes (eg due to conflict with farmer's business aims, lack of buy-in from farmers and other stakeholders) and hence, though having low transaction costs, may represent poor value-for-money. Hodge concluded that policies need to be sharply targeted at what society wants, highlighted alternative approaches, and suggested that grassland research should encompass social science and focus on the whole range of land use outputs.

Dabbert (38) suggested that in the dairy sector only those farms with high yields and low labour/ kg milk will survive. We think this is doubtful, but we do agree with his conclusion that there is potential for farmers to combine agri-environment schemes with marketing products at a higher price. Shaw (91) described one such initiative – 'White and Wild' milk.

One of the underlying drivers of research, particularly in hill and mountain areas, is the ecological and landscape consequences of land abandonment. Posdisek (82) from the Czech Republic described the decline of cattle and sheep numbers by over 50% since1990 and the likelihood of decimation of botanical diversity of grassland. Hejcman (213) also from CR, showed that, where livestock were available, grazing could be an acceptable alternative to mowing for maintenance of species-rich meadows. Fatyga (76) from the Sudeten region of Poland described the abandonment of over 30% of grasslands and their designation for biomass production. In the alps reduction or cessation of grazing is also recognised as threatening biodiversity (Erschbamer, 284), and runoff for hydroelectric power (Körner, 278).

4 Benefits and Risks for Society

Lehmann (105) identified the multiple benefits that grasslands provide for society, and considered how these could be valued economically. He identified non-use values, including those that result from the knowledge of continued existence of grassland, and use values including biodiversity and resource protection. Valuation methods based on assessing the preference of consumers are often used by economists but tend to neglect functional benefits and therefore miscalculate the total economic benefits of grassland. The imperative of evaluating all outputs echoed Hodge's conclusions.

4.1 Biodiversity

Biodiversity in grassland is a major functional benefit and was a strong thread woven through several sessions. Progress has been made in:

– how to conserve (Santa-Maria, 207; Cop, 222) and restore (Hald, 174; Kazoglou, 225; Hofmann, 243; Korevaar, 246;) biodiversity

- the consequences of this for herbage production (Palmborg, 183; Zarovali, 201; Pacurar, 216; Paoletti, 258) and grazing value (Tonioli, 204).
- landscape ecology (Amiaud, 198).
- ecosystem functioning in alpine and sub-alpine zones (Muller, 281; Lavorel, 287).

Greater understanding of the functioning of ecosystems has been generated by the pan-European BIODEPTH project (Spehn, 177; Scherer-Lorenzen, 180). This showed that plant communities with higher diversity were more productive and utilised resources (light and N) more effectively. They are most effective at N uptake if additional N input through fixation occurs.

There is also welcome interest in soil biodiversity, and Breure (195) showed a negative correlation between above-ground farming intensity and below-ground functional diversity. He described the development of a Biological Indicator for Soil Quality.

Questions still remain :

- The importance of intraspecific biodiversity
- Local reserves versus widespread preserved areas, eg Swiss Ecological Compensation Areas.
- A better definition of the aims of increasing grassland biodiversity – for farmers, citizens and grassland researchers.
- More precise evaluation of benefits and costs.

4.2 Environmental impacts were also a significant topic.

Benoit (117) reviewed the impact of grassland on water. If soil is compacted by heavy grazing, high runoff can occur. There are also problems with N leaching, particularly under intensive grazing, and contamination of water by bacteria, viruses and parasites from livestock. Nevertheless he concluded that appropriately-managed grassland has a positive effect on water quality. In much of W Europe, though not in UK, the area of grassland has declined in the last decade. He advocated a halt to this, and recreation of grassland particularly along river corridors. This could also be positive for wildlife.

Much research has addressed the better evaluation of management impacts on environment quality: the effect on NO3 leaching of irrigation (Burs, 343) and rotations (Bobe, 346); the effect of N fertiliser and slurry on gaseous emissions (Ammann, 130; Lampe, 334); effect of grazing with cattle or sheep on CO2 fluxes and C sequestration (Casals, 136).

An emerging impact was identified by Burkhardt (322) – veterinary antibiotics (VA) in animal slurries. In Switzerland about 50% of all antibiotics administered are used in animal production, and approx 80% is excreted. Input of VA into soils may be substantial, especially in grassland areas, and high levels have been found in watercourses.

The impact of land and animal management on the environment is large-scale and long-term, but most research is short-term and local. Future research must address this. Huguenin-Elie (772) described the Swiss Agricultural Life Cycle Assessment which attempts to comprehensively assess forage systems. Preliminary findings suggest that at farm level a co-existence of areas with high and low intensity management might be better than medium intensity over the whole farm area.

5 Efficient use of natural resources

5.1 Dairy systems

Jarvis (361) reviewed best practice in nitrogen management, focusing on dairy farms. Building on much research, many improvements are possible at farm level, particularly in manure management. This requires farmers to recognise, and have confidence in, the N value of manures, and the soil's ability to mineralise N. Farm studies show that, often, they do not. Bleken (672), looking at dairy farms across Europe, also found low N efficiency and advocated more extensive, forage-based, systems.

Peyraud (373) reviewed dairy cow grazing management. This is also a mature subject and, like manures, placing greater reliance on grazing requires higher farmer confidence. A large pan-european project – Grazemore – has enabled knowledge to be synthesised and decision-support packages to be developed (Mayne, 584 ; Delagarde, 650). It was also encouraging to hear that an EGF dairy group is being established.

But the question remains - how to balance profit and environment in dairy systems? The consensus here was that, overall, grazing is an important component of sustainable systems, *but*

- Grazing limits milk yields, so need more cows = more methane (Oldham, 867).
- Grass is high in N, which is poorly used by ruminants, leading to high risk of loss via NO_3, NH_3 and N_2O (eg Saarijarvi, 337).
- Reducing nutrient leaks via one pathway may result in higher losses via another – 'Pollution swapping' (Jarvis)

We are still waiting for whole system evaluations and demonstrations relevant in most of Europe.

5.2 Can plant breeding provide solutions ?

Grassland scientists often expect plant breeding to provide solutions where management options are limited. We observed at the conference that this expectation tends to turn away from a general increase in forage productivity to more specific requirements related to the production system of interest.

For intensive grazing systems, Peyraud (373) identified the following:

- Extend growing season of perennial ryegrass
- Improve forage intake
- Make alternative species like red clover adapted to intensive grazing; there is considerable genetic resource available (Boller, 386), and useful genetic variation for tolerance to defoliation was detected (Collins, 389).

Opportunities for plant breeding were also suggested for tolerance to ozone (Lötscher, 139) and for adaptability to grass-clover mixtures (Collins, 486). However, the requirement for new varieties do pass national list trials before having a chance to enter the European market might hinder the rapid availability of breeding progress to farmers (Caradus, 392). In addition, the long time required and the limited funding available for developing varieties with the desired specific traits make it rather unlikely that these will become available soon.

In order to speed up progress, there is a need to better integrate grassland science, genetic resource conservation and plant breeding.

5.3 Use of legumes and mixed swards

The role of legumes in sustainable grassland systems is widely acknowledged and a topic of important research efforts. There is increasing interest in legumes other than white clover:

- Red clover is being studied particularly in NW Europe (Bakken, 442; Deprez, 469, 498; Nykanen-Kurki, 513). It's productive potential on a range of soil types is high, and breeding and management for persistence under grazing is progressing (Marshall, 389).
- Lucerne (alfalfa) is also of great interest particularly in E Europe on calcareous and other well-drained soils because of it's high production and drought resistance. Problems. Including seed production, are being addressed (Slepetys, 445; Vasileva, 448; Stevovic, 454)
- Peas and vetches, as high-protein forages, are also of interest in SE (Mihailovic, 457; Kertikov, 460) and NW (Nesheim, 942) Europe.
- Birdsfoot trefoil has lower production, but is adapted to poorer soils and has condensed tannins, offering protein protection and freedom from bloat (Hopkins, 504; Nilsdotter-Linde, 1062)
- In a new and very large series of experiments across Europe, Canada and Australia (Sebastia, 483) mixtures of legumes and grasses from different functional types are being evaluated. These seek to increase stability and reliability.

5.4 Ley-arable rotations re-discovered

An EGF Working group on grassland resowing and grass-arable rotations had been launched at the previous EGF general meeting at La Rochelle (vol 7 in this series) and a progress report was given by Taube (520). While the benefit of grassland resowing as measured by long term dry matter productivity compared to well-kept permanent grassland remains debatable, and breeding progress did not change this view (Soegaard, 523), ley-arable rotations appear to have the potential of combining the high productivity of a newly established sward with a reduction in necessary N-fertilizer inputs (Nevens 532). This is particularly true when grass-legume mixtures are sown (Kryszak, 535). Several contributions dealt with the benefits of grass-legume leys for the succeeding arable crop (Nevens, 532; Vertes, 526; Conijn, 541).

6 From forage to food quality

6.1 Forage quality

Oldham (867) reviewed forage quality for dairy cows in the context of continued increase in genetic potential for milk yield. He foresaw a polarisation of systems: large intensive farms producing commodity milk and small extensive farms adding value. Both could be accommodated with acceptable welfare, provided genotypes and management were balanced.

The focus in research on forage quality is changing from general nutritive value to individual compounds, such as vitamins (Nadeau, 891), carotenoids (Muntean,

1049), minerals (Grzegornczyk, 921; Ignatovic, 960) and fatty acids (Chow, 981), accepting that the consumer wants ruminant products to originate from an appropriate diet.

We note some research and development opportunities:

- Turn cows into new paddock in the evening to benefit from diurnal change in WSC (Smit, 951)
- Mycotoxins from Fusarium may cause feed safety problem in late autumn/winter grazing of Lolium and Festuca (Laser, 1014)
- High levels of phytoestrogens in clover silage could pass to milk and have beneficial health effects for humans – need to re-assess potential fertility problems in cattle? (Sakakibara, 984).

6.2 Quality of products

The impact of livestock feeding and management on quality of milk and meat is an expanding area. And at this conference human health aspects predominated rather than organoleptic quality.

Martin (876) reviewed the effect of feed on milk components of interest to consumers – fatty acids, carotenoids, vitamins A and E and global antioxidant status. He concluded that varying diet composition can change milk compostition rapidly and efficiently. Milk from fresh grass-based diets, compared with concentrates, maize silage or hay, was higher in all these components. Leiber (1139) confirmed this for CLAs and Elgersma (1136) found that content of beneficial omega-7 FAs decreased rapidly with decreasing herbage allowance. She also noted that, in the Netherlands, milk from cows grazing for more than 5 hrs/day can achieve a higher price.

Gebbing (1130) confirmed the possibility of tracing food provenance; he found that meat from maize-fed cattle had a different C-isotope signature from grass-fed stock.

7 Transdisciplinary research and knowledge exchange

This was an excellent theme and it was a pity that people had started to leave the conference by the final morning.

Fry (1157) reviewed integrated research. He noted that this was seen as more likely than disciplinary studies to solve management problems in multifunctional grassland landscapes. There had been a rapid expansion over the last 20 years of large-scale integrative projects, but given the challenge of working across disciplines expectations from funders were unrealistically high. He saw stakeholder participation as the critical factor. Despite being largely driven by funders, integrated research is popular with researchers. But they worry about publication, and recognition. Journal editors claim to welcome such work, though reviewers may differ. Academic merit systems are currently tailored for disciplinary approaches and require revision.

Wielinga (1168) addressed the question of how scientific knowledge impacts upon farmers and decision-makers. He traced the changing concepts of knowledge from the prevailing ‘expert oriented’ view of 1950-1970, through the ‘market-oriented’ view of the

1980s when extension services in W Europe were privatised, to the current 'network-oriented' concept. He proposed that for knowledge to make an appropriate impact healthy networks are needed. And these require people working to bridge science and practice who have the time, space and recognition to not only network, but to take ownership and lead the process.

Other papers provided examples of involving the users of research, at the beginning of projects (Mayne, 584), and even better throughout (Baars, 1181). There was also a forward-looking example of involving the community, and schools, in the research and knowledge exchange process (Bele, 1184).

8 Acknowledgments

EGF2004 was a large, high quality conference, superbly organised and wonderfully friendly. We thank the organising committee for inviting us to give this concluding paper. We found it to be very demanding, but very rewarding.

Index of Authors