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Alternative Functions of Grassland

Edited by

Jan Nedělník
Radek Macháč
Bohumír Cagaš

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ALTERNATIVE FUNCTIONS OF GRASSLAND

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Foreword

The role of natural and artificially established grasslands has dramatically changed in the last decades. With almost entirely their original role in forage production, grasslands have a lot of important qualities which can be of great value predominantly in non-forage uses, agricultural sustainability and environmental improvement, including maintenance of the present genetic resources of plants and animals.

In the Czech Republic there is a high proportion of cropland and a relatively low proportion of grasslands. Paradoxically, this is the reason why the importance of grasslands for non-forage uses is increasing. Grasslands have been playing an increasingly more important role in protection and formation of agricultural and non-agricultural landscape and in rehabilitation of localities disturbed by anthropogenic activities. Quite new is the utilization of grasslands in bioenergetics and rather specific is the use of grasslands for regeneration of man's physical and mental strengths (relaxation, sport).

Especially these alternative, but in no case secondary, functions are the topic of the professional talks of the 15th symposium EGF 2009. The present publication contains 134 contributions divided into three sections dealing with non-negotiable and alternative values of grasslands and also with methods of grassland protection. A special booklet contains summaries of all oral and poster presentations. Within the framework of mid-excursions participants will get familiar with methods of regeneration of grasslands and their non-traditional use.

We wish to express our thanks to a number of co-workers for their assistance in organising the symposium, for their preparation of texts and their numerous valuable suggestions. We would also like to express our gratitude and thanks to all the members of the organising and scientific committees, the external reviewers and anglicisers and the secretary of the EGF. Finally many thanks to the Ministry of Agriculture of the Czech Republic and sponsors for financial support in publishing the proceedings. Special thanks to M. Braunová for the preparation of articles for printing.

We believe that the 15th EGF Symposium will provide a forum for presenting new and interesting findings about grasslands. We wish all of you an enjoyable stay in the Moravian capital of Brno.

Jan Nedělník
Chairman of the Organising Committee

Bohumír Cagaš
Chairman of the Scientific Committee

ALTERNATIVE FUNCTIONS OF GRASSLAND

Contents

Opening Session

Session 1 – Non marketable functions of grassland

Invited papers

Offered papers

Poster Session 1

Opening Session

Development, current state and changes in grassland in the past year

Stypiński P.[1], Hejduk S.[4], Svobodová M.[2], Hakl J.[2] and Rataj D.[3]

[1]*Warsaw Agricultural University, Department of Agronomy, Warsaw, Poland*
[2]*Czech University of Life Sciences Prague, Department of Forage Crops and Grassland Management, Prague, Czech Republic*
[3]*Agricultural Paying Agency, Ministry of Agriculture, Slovakia*
[4]*Mendel University of Agriculture and Forestry in Brno, Brno, Czech Republic*
E-mail: stypinski@delta.sggw.waw.pl

Abstract

The present situation and state of grassland management in three countries in Central Europe (Poland, the Czech Republic, Slovakia) is presented on the base statistical data and official documents published by Ministries of Agricultural and Paying Agencies. EU enlargement in 2004 caused many changes in agricultural sector in those countries. Area of grasslands, particularly area of semi-natural pastures has decreased; also decrease of number of animals has been noticed. In the same time milk performance per cow increased. Milk quotas in those countries were not exceeded and they are rather treated as useful tools for milk market stabilization. Grassland role in forage production it is not such important like before, but the environmental role of grassland seems to be much more significant and it could be a challenge for grassland in future.

Keywords: grasslands, management, yields, environment, milk quota

Introduction

Membership in the European Union has resulted in a considerable increase in the amount of financial support allocated for agriculture in countries like the Czech Republic, Slovakia and Poland. After five years since EU enlargement we can observe some changes in different agricultural sectors. Following the EU accession there was a change in funding of agriculture which consisted in a reduced share of indirect subsidies for subsidies obtained directly by agricultural producers (Agriculture …, 2005). Before EU enlargement wide discussion had been observed inside the candidate countries and among different group of people farmers had many questions and they were rather against EU enlargement. The situation has been changed however and now farmers seem to be group of important beneficent. Implementation of EU Common Agricultural Policy caused different consequences in agricultural sectors. It is particularly interesting how new situation influenced on grassland area, management and importance in general national economy. The aim of this study was to estimate area, yields, past and present status of permanent grasslands in three chosen countries like Poland, the Czech Republic and Slovakia after introduction of free market economy and joining of the EU. The present role of grasslands in agriculture and state economy in connection with animal production has been also taking under consideration. Finally in CAP a lot effort is paid on nature conservation and environmental protection (Roeder *et al*., 2007). It is known that grasslands are very important in that policy, but on the other hand a lot of dangers and treats for grassland are observed in our region (Stypinski and Sienkiewicz-Paderewska, 2007; Zimkova *et al.,* 2007), so the basic question is if we are able to find the compromise between productivity and environmental role of grasslands. For practical point of view the next three other questions are also very important: (1) if CAP of EU before enlargement in 2004 took under consideration the needs and specific situation of agriculture of new members?; (2) what about present CAP, is it possible to accept not only general rules but some local circumstances as well?; (3) what about future CAP? Can we predict the direction and prepare some useful tools for implementation that policy to practice? On the base of statistical data and some experiences in those three countries we should answer those questions or to inspire people (researchers, advisory people but also farmers and policy makers) for intensive work on those subjects.

Material and methods

Statistical data from Czech Statistical Department, Polish Statistical Yearbooks, Material and documents from Polish, Czech and Slovak Ministry of Agriculture have been used as a base from this paper; also some unpublished documents from Ministries and Payment Agencies in Poland, Slovak and Czech Republics have been taken under consideration during preparation of this paper.

The present situation in grassland management in countries of Central part of Europe

Grasslands in the past played very important role in Central part of Europe, particularly in the mountains regions where they were used as fodder base for ruminant, mostly for sheep. At present moment however semi-natural meadows and pastures are not such important in animal feeding, total area of grasslands has decreased and they occupied about 10% of total area of those countries and about 25% of Agricultural Area (AA) – Table 1 (Reheul *et al*., 2007).

Table 1. Permanent grassland area in Poland, the Czech Republic and Slovakia in comparison to EU (source Eurostat, Agricultural Products, European Commission 2007)

	Total area (thousands ha)	Total area (%)	AA (%)
EU 25	51,652	13	32
EU 15	43,668	14	34
Poland	3,377	11	21
Czech Republic	844	11	24
Slovakia	525	11	27

The comparison of some agricultural and socio-economic indicators in chosen countries are presented in Table 2. It is clear that agriculture in those countries is not such intensive like in majority of UE, milk yield per cow is on the level 4–5 thousands kg per year in Poland and Slovakia, a little better in the Czech Republic, use of mineral fertilization and average stocking rate also indicates rather extensive agricultural production.

After introduction of free market economy in 1990 decrease of interest of grassland has been observed. The low agricultural efficiency has caused taking out of production a lot of former agricultural land. In Poland for example area of agricultural land decreases for

Table 2. Date regarding the socio-economic situation of chosen countries (source: Statistical Yearbook 2006, 2007, 2008, Report on Agriculture…, 2004)

Country	Poland	Czech Republic	Slovakia
Total area (mill ha)	31.26	7.9	4.9
Population (mill ha)	38.1	10.5	5.4
Utilized agricultural area (mill ha)	15.9	4.3	2.4
of which arable land (%)	77.3	71.8	60.8
grasslands (%)	21.1	22.7	30.4
Agricultural land area per capita	0.42	0.42	0.45
Annual milk yield per cow (kg)	4,271	6,068	5,100
Cattle in ml heads	5.5	0.57	0.59
Animal unit per 100 ha of UAA	34.5	35.5	26.5
Mineral fertilization (kg NPK ha^{-1})	93.6	86.3	50.9

3.5 millions. The area of grassland also has decreased during the last decade (Kasperczyk and Szewczyk, 2006) from 4.1 millions to 3.3 millions (Figure 1) and it has been particularly clear in the case of permanent pastures (Figure 2). During the last 25 year the area of pastures has decreased from 1.5 millions to 0.8 millions ha and very rapid drop was observed in that last five years, it means after joining Poland to EU. Situation in other counties in our region was similar, grazing is not such important like before and it is connected with the livestock husbandry. In the Czech Republic for instance National Statistical Department did not observe area of pasture and meadows since 2002, only total permanent grassland is recorded. Area of permanent grassland decreased also in Slovakia, in last decade since 1997 to 2008 area of harvest area of grassland dropped down from 824 thousands ha to 503 thousands, it means for about 40%. According to data published by Czech Statistical Department (www.czso.cz) we can also observe similar situation in permanent grassland area in the Czech Republic. It is known that large part of permanent grassland in our region is not used for forage production. The official date does not observed no-utilized grasslands, only set – aside arable land area is published (around 30–50 thousand ha during last five years in the Czech Republic, more than 1 million ha in Poland), but we are able estimate that about 20% of permanent grasslands are

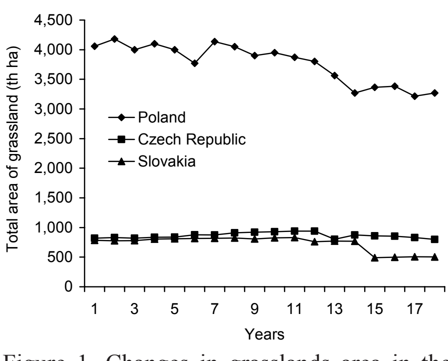

Figure 1. Changes in grasslands area in the years 1990–2007

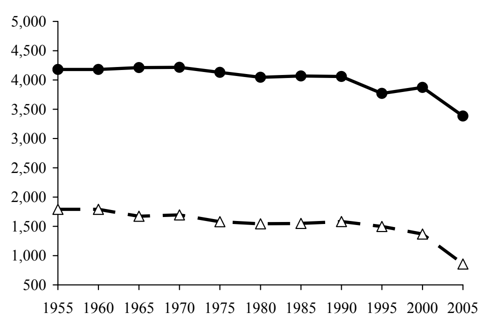

Figure 2. The changes in grassland area in Poland during the years 1955–2005 (thousands ha)

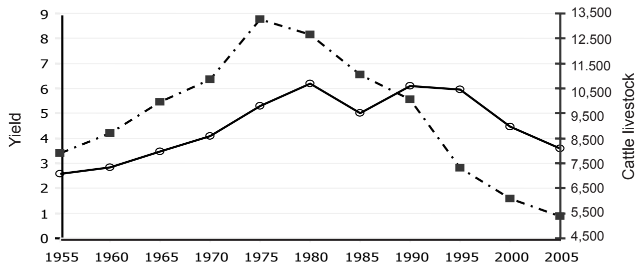

Figure 3. Cattle livestock (thousands heads) and grassland yields (DM, t ha^{-1}) in Poland during the years 1955–2005

not harvested for forage production in the Czech Republic, 600 thousand ha in Poland (18% of total grassland area) and probably more in Slovakia. These areas are abandoned, mulched or harvested for energetic purposes (burning or biogas production), but utilization of those area seems to be one of the most important task for future. We know that lack of utilization is one of the most important threats for grasslands (Stypinski and Sienkiewicz-Paderewska, 2007) and it is particularly important on the area of National and Landscape Parks. Permanent grasslands represent main source of forage for sheep, suckled cows, heifers and horses but only small proportion in feeding ration of dairy cows. Milk production is connected rather with fodder production on arable land, most of high yielding dairy cows are fed by silage maize, lucerne and other forage from arable land, also a lot of concentrate is used in intensive dairy farms.

Yields of permanent grassland are rather low in all tested countries, it is estimated that in Poland average dry matter yields is about 4 t ha^{-1}, in the Czech Republic about 3 t ha^{-1} and in Slovakia less than 2 t ha^{-1}. It should be stress also that those yields are very variable between years and they depend more from climatic conditions than from mineral fertilization (Figure 3). Low grassland yields are connected with the number of livestock as is presented in Figure 3 in the base Polish data from last 25 years.

In all countries the number of cows, particularly dairy cattle has decreased rapidly as is shown in Table 3. The similar situation has been observed in almost all Europe (Roeder *et al*., 2007) but in the same time the milk performance per one cow has increased what it could be demonstrated on the example of the Czech Republic (Figure 4). In Slovakia annual milk yield per one cow increased from 3,563 l in 1990 to 5,849 in 2008, in Poland in the same time from 3,100 to 4,326, respectively. Main reasons of higher milk performance per cow are not depended however from permanent grassland utilization or management. It is the effect of better animal genetic material, better forage quality and as it was said before feeding animals maize silage and use a lot of concentrates (included imported soya seeds). Preparations for accession to the EU, and consequent necessity of sanitary and veterinary adjustments not only in the agri-food processing, but also in agricultural

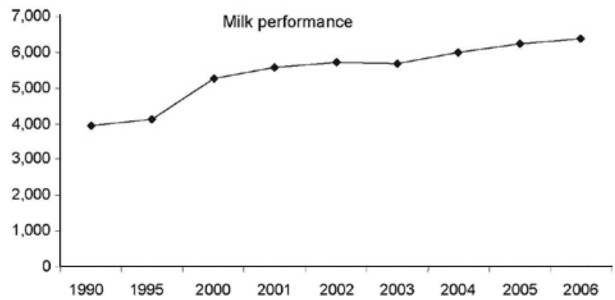

Figure 4. Average milk yield (litters per cow) in the Czech Republic in the years 1990–2006

holdings led to the elimination of small producers from the market. It was especially noticeable in the case of milk rearing, were small farms resigned from rearing 1–2 cows as we can observe in Poland for example (Agriculture and Food Economy, 2005). Good perceptivity for development of dairy sector after EU enlargement in our countries did not influence however for expected progress in grassland management. The reduction of holdings and elimination of small producers from market were one of the reason of grassland abandoning and reduction of area of permanent or semi-natural pastures.

Table 3. Changes in cow's number in Poland, the Czech Republic and Slovakia during the last 15 years (in thousands of heads)

Year	1990	1995	2000	2005	2007
Poland					
Cows	10,000	7,300	6,100	5,500	5,600
From that dairy cows	4,900	3,600	3,100	2,900	2,800
Czech Republic					
Cows	1,190	768	615	573	575
From that dairy cows	1,100	739	547	433	424
Slovakia					
Cows	548	355	271	229	215
From that dairy cows			242	198	180

Development of milk production in our countries is depended on many different factors. The special role plays milk price and milk quota system. Poland, Slovakia and the Czech Republic have established the milk quota system prior to accession to the EU. Milk quota system had rather positive effect on the stabilization of milk market and cattle breeding. In the case of Slovakia milk quota system aimed the purchase of milk through "guaranteed prices" (Agricultural Paying Agency, 2008). Since the accession of Poland, the Czech Republic and Slovakia to the EU those countries did not exceed the quota and

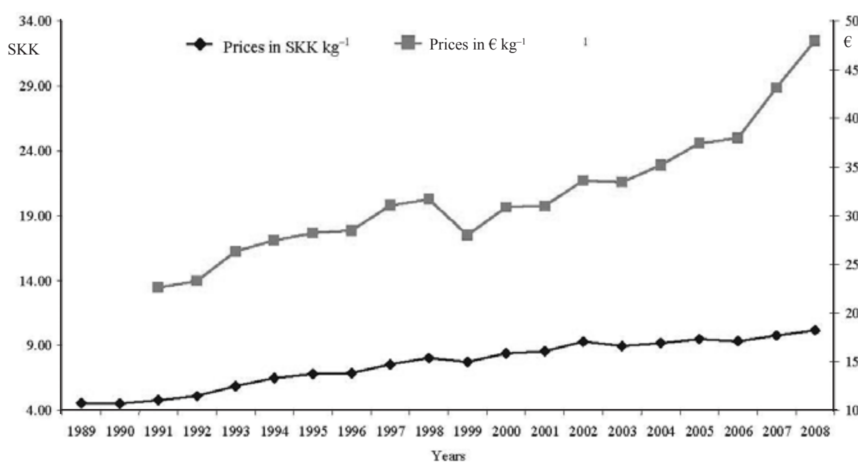

Figure 5. Development of average prices of raw milk in Slovakia (1989–2008)

Table 4. Milk quota system in chosen countries in the years 2004–2008 (source Slovak Agricultural Paying Agency, Polish Agricultural Market Agency, 2008)

Country	Milk quota (mill kg)											
	A	B	C	A	B	C	A	B	C	A	B	C
	2004/2005			2005/2006			2006/2007			2007/2008		
Poland	8,964	8,655	96.6	8,964	9,127	101.8	9,380	9,126	97.3	9,380	9,014	96.1
Czech Republic	2,613	2,500	95.6	2,613	2,600	98.1	2,785	2,600	93.3	2,785	2,750	98.7
Slovakia	1,013	875	86.4	1,013	984	97.2	1,040	975	93.7	1,040	988	94.5

A – assessed quota; B – quota fulfilment; C – % of utilization

quota fulfillment was about 95% (Table 4). It should be stress however that in local scale like in same region in Poland milk quota system has been criticized and treated as a kind of barrier of development of milk sector. According to the general opinion of experts milk quota system should be still existed in Poland, the Czech Republic and Slovakia because it is a guaranty of milk market stabilization.

Another important factor for milk production is a milk price. During the last 15 years increase of average milk price in all tested countries has been observed (Figure 5) but after accession to the EU stabilization of milk has been rather noticed. In 2007 cost of one litter of raw cow milk was in the Czech Republic about 8 CZK (0.40 €), in Poland 0.95 PZL (0.30 €), in Slovakia 9.31 SKK (0.25 €). Those prices seem to be not such bad but much more important is what it is possible to bay for milk and what are the relationships between milk price and some other goods like selected means of agricultural production. That comparison of those prices is not however optimistic. In Poland for example ten years ago for the new tractor "URSUS" it was necessary to sale 42 thousand litters of milk (Kasperczyk and Szewczyk, 2006; Statistical Yearbook, 2007) in 2006 more than 71 thousands, diesel price or price of chemical fertilizer is also much higher now then in 2000 in comparison to milk. Statistical data in Poland show that diesel oil price is four times higher than milk and ratio is worse now than 5 years before (Central Statistical Office, 2006). Very similar situation is observed in the Czech Republic and Slovakia what means that milk production is still not profitable in our region and farmers in those countries are usually not able to compete with farmers from Western Europe where means for agricultural production are cheaper than in Central Europe. The relatively low milk prices is also one of the reason that a lot of agricultural land, particularly permanent grassland is abounded in all tested countries as has been mention above. It is

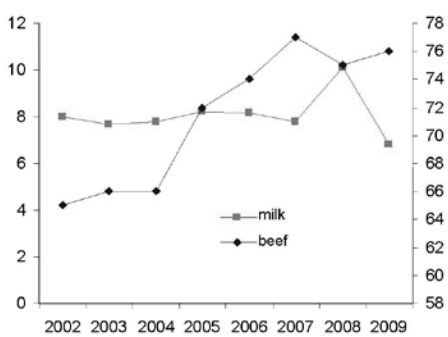

Figure 6. Farmer' price of milk and beef meet in the Czech Republic in the years 2002–2009

necessary to stress also that world economy crisis has negative effect on milk production and profitability. The milk prices in 2009 drop down rapidly in our region (see Figure 6, the example from the Czech Republic) and farmers are worried about future situation on European milk market. Maybe, like it was suggested in some previous papers (Zimkova *et al.,* 2007; Roeder *et al.,* 2007) probably in future the role of grassland in intensive milk production will decline but possibilities for grassland are still good for beef and sheep production, particularly on LFA (Jankowska-Huflejt and Domański, 2008) or in mountains regions (Zimkova *et al.,* 2007).

The importance of grassland in nature conservation and environmental protection

Permanent and semi-natural grasslands are very important not only as a source of fodder but they play significant role in environment. It is known (Stypinski *et al*., 2006; Stypinski and Sienkiewicz-Paderewska, 2007; Jankowska-Huflejt and Domański, 2008), that grasslands are able to protect soil against erosion, to reduce nitrate leaching and migration of minerals from croplands. Climatic and hydrological function of grasslands (flood control in depressions, flattering of flood wave) also indicate and confirm the specific role of grassland ecosystems. Rather extensive use of grassland in Poland, the Czech Republic and Slovakia is one of the key factor for biodiversity stabilization. Maintains of present status of grasslands and introduction of agro-environmental programs and agreements is one of the solution for sustainable development, it means the optimal and environmentally friendly utilization of nature resources like soil, water, plants and animal communities.

Taking advantage of natural and environmental value, rural tourism and agrotourism seems to be a good challenge for grass farmers. Environmental friendly policy is one of important tools of CAP and it is also much more popular in countries like Poland, the Czech Republic and Slovakia. It means however that it is necessity of implementation special environmental payments and substitutes for farmers whose decide to join to agro-environmental programs. In Poland those payments were predicted in Rural Areas Development Plants (RADP) which is to support a balanced development of rural areas and to improve the standard of agricultural holdings. To implement the Plan 3,592 million € were allocated in 2004–2006 of which 2,866 million € came from EU budget and about 800 million from the national budget (Agriculture and Food Economy, 2005). For grassland's management and protection the most important is the program No. 4 in RADP titled "Support for agro-environment measures and improved of animals' welfare". In the years 2004–2006 inside that program were two problems or tasks connected with permanent grassland – preservation of extensive meadows and protection of extensive pastures. At present moment one program exist "Extensive grassland" but some payments from farmers are possible from program Natura 2000 and on the frame of programs "organic agriculture " and "sustainable agriculture".

Similar programs connected with the grassland management and nature conservation exist in Slovakia, where the special meaning has a sub-program "Soil reclamation and protection" which is a part of budgetary program Agriculture and Food Production (Report of Agriculture and Food Sector, 2004). The aim of this program is to support farmers in their activity for soil protection (support of irrigation, liming, grassing). Stimulation of ecological agriculture and cultivation of crops for purposes other than food production (fuel plants for example) are also predicted in this sub-program. In all countries is an extra support to farming in agriculturally less favoured areas (LFA).

In the Czech Republic special subsidies were incorporated in Horizontal Rural Development Plan. This program supported grassland in part II (LFA, NATURA 2000, Agro-Envi) and the special attention has been paid on the ecological farming and proper grasslands management (9 variants of management have been promoted and supported by extra payments). Agro-environmental programs are mainly based on extensification of grassland management (late term of the first cut, limiting fertilization, keeping of strips with different harvest plant to ensure continuous source of food and hide for birds or other animals). Some more specific tools are also adopted like for example Czech ecologists involved into extensification measures limitation considering harvesting period that demands timing of grazing in order to assure seed production of endangered plants (e.g. orchids) and reproduction of animal. In Poland good example is a special program of protection of habitats with *Molinia coreulea* (Sienkiewicz-Paderewska, 2006, 2008; Stypinski and Sienkiewicz-Paderewska, 2007) or keeping the high floristic diversity on *Arrhenatherum elatoris* communities and wet rye-grass meadows (Kryszak and Kryszak, 2007).
The practical realization of those agro-environmental programs is not easy however and in all tested countries. They are often do not suit to farmers neither botanists or ecologists because of the schema is done in one individual way for easy verification by officers. Some diversification of those programs is important for better realization of the local situation, needs and demands. Farmers and advisory people also complain for bureaucracy. On the base some expertise, field studies and questionnaires it is possible to conclude that only small group of farmers is interested in agro-environmental agreements. The milk production in Eastern and Southern Europe is still mowing from grassland to arable land (Roeder *et al*., 2007) and even extra agro-environmental substitutes do not cause more farmer's interest of grasslands which are not such attractive in economical point of view like arable land. As a result grasslands are exposed on many treats, even on the area of National or Landscape Parks (Sienkiewicz-Paderewska, 2008).

Conclusions and final remarks

Joining the European Union by new member countries in 2004 was a great success and challenge for countries like Poland, the Czech Republic and Slovakia. Free market economy and system of payments and European substitutes helped agricultural sector and has had clear influence for national economy and development of agri-food sector. The positive influence of EU enlargement has been also observed in animal production. Decrease of number of animals (typical for the all of Europe) took place together with increase milk yield and animal performance because of progress in animal feeding, breeding and husbandry. That positive effect did not correspond however with grassland improvement and proper management. The area of permanent grasslands, particularly semi-natural pastures decreased and grassland's yields were variable and were estimated on the rather low levels. It should be also to underline that a large part of grassland is not used for forage production. The abounded land particularly on the LFA and marginal soils seems to be an important problem in all tested countries. The concept of proper utilization of those fallow lands is discussed by ecologists, farmers and policy makers because it is connected not only with forage production but also with nature conservation aims. It is known that lack of utilization, stopping of grazing or cutting could be one of the most dangerous threats for grassland biodiversity.
Implementation of agro-environmental programs and agreements in theoretical point of view should be good tools and to increase farmers activity and their efforts for keeping

semi-natural meadows and pastures. On the other hand it is a chance for extra profit for farmers what is especially important on LFA and marginal area where agriculture is very difficult and not profitable. Some farmers are interested in those programs, the positive phenomena is for example “fashion “ for organic and sustainable agriculture. Agro-environmental programs directly oriented to grassland management and conservation are not however so popular in practice like it has been expected. Maybe one of the reason is that those programs must be more adopted to the local conditions and circumstances.

The environmental role of semi-natural grassland and their different functions in nature conservation will be probably key factor of future grassland management but we should remember about grasslands as a main forage base for ruminants and horses. Probably milk production is not strictly connected with grassland’s utilization but beef and sheep production will be connected with permanent grasslands, especially in the mountain regions. The basic problem is however that both milk and beef production are in bad economical situation at this moment and it is difficult to predict future directions of those agricultural sectors. As an example we can present the variability of milk and meet prices in Poland, the Czech Republic and Slovakia.

Semi natural meadows and pasture always played important role in forage production in Central part of Europe. Their beauty, unique historical and environmental value, the special place in the landscape indicates grasslands as kind of common treasure. We can think about different scenarios and solutions but for sure everything must be done for grassland preservation and keeping for future generation.

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Selected indicators of productive and extraproductional management of grasslands in the Czech Republic

Kohoutek A.[1], Kvapilík J.[2], Cagaš B.[3], Hrabě F.[4] and Pozdíšek J.[5]

[1]Crop Research Institute Prague, Research Station Jevíčko, Czech Republic
[2]Institute of Animal Science, Prague, Czech Republic
[3]Oseva PRO Ltd., Grassland Research Station, Rožnov-Zubří, Czech Republic
[4]Mendel University of Agriculture and Forestry in Brno, Department of Animal Nutrition and Forage Production, Brno, Czech Republic
[5]Research Institute for Cattle Breeding, Ltd., Rapotín, Czech Republic
E-mail: vste@seznam.cz

Abstract

The total area of the Czech Republic (CR) is 7,886 thousand hectares, of which 4,277 thousand ha are farmland and 3,609 thousand ha are non-agricultural land. The climate of the CR is determined by mutual penetration and blending of oceanic and continental influences. Permanent grasslands (PG) cover 974 thousand ha, i.e. 22.8% of farmland (4,280 thousand ha) in the CR according to the land register. According to the data of the Czech Statistical Office (CSO) 932 thousand ha were agriculturally managed in 2007 with an average hay yield of 2.98 t ha^{-1}. Political changes after 1989 lead to a decrease in livestock number in the CR. The number of cows fell from 1,236 thousand in 1990 to 575 thousand in 2008 with a negative effect on the management and utilisation of grasslands in all production areas. Production of dairy cows reached 6,960 kg of milk with consumption of 0.30 kg of feed concentrate per kg in 2008. The main cattle stock breeds include Holstein (about 39%), Czech spotted (33%) and beef breeds (28%). Therefore the best solution to this unsatisfactory situation would be to increase the number of suckler cows by about 80 to 100 thousand heads, in addition to extending ruminant grazing. This means that with the present stock of dairy cows in the CR of about 405 thousand (per 100 ha of farmland noticeably lower number than the EU average), the number of suckler cows should increase to about 250 to 260 thousand. The Czech agricultural system was analysed with the method of carbon balance aimed at voluminous feedstuff structure in 1994–2007 and compared with the analysis from 1971–1985. It is obvious that the reduction of voluminous feedstuff production resulted in the reduction of active carbon production by 2,480 thousand tonnes of active carbon a year, that is by 31% with accompanying decrease of nonproduction functions such as water interception potential, biological activity of soil, etc. Grasses grown for seeds, which are an interesting and prospective branch of plant production in the CR, are an integral part of grasslands. The area of grass seed farms has been growing since mid-1990s. In 2006 the area was 18 thousand ha. The Czech Republic ranks 5th among EU countries in the seed farms area (annual production is about 10,000 t of certified seed) but it falls behind in average hectare yield. The total area of other extraproductional areas with grass cover is 171 thousand ha of non-agricultural land.

Keywords: Czech Republic, agriculture, grassland, carbon, cattle numbers, grass seed production

Characteristics of natural and climatic conditions in the Czech Republic

The total area of the Czech Republic (CR) is 7,886 thousand ha, of which 4,277 thousand ha are farmland and 3,609 thousand ha non-agricultural land. Agricultural land accounts for about a half (54%) of the total area of the CR. Of the total area of the CR 67% is situated at the altitude under 500 m, 32% at the altitude 500 to 1,000 m and only 1.05% at an altitude above 1,000 m. The medium altitude is 430 m. The areas with higher altitude (above 500 m above sea level) may be considered as less favourable for agricultural production. Due to the relatively high population density of the CR agricultural productivity is traditional even in these areas and to a limited extent up to 1,250 m a.s.l.

The climate of the CR is determined by mutual penetration and blending of oceanic and continental influences. It is characterised by a western airflow with prevailing westerly winds, intensive cyclonic activity and abundant precipitation. Oceanic influences are mainly felt in Bohemia, while Moravia and Silesia are more influenced by a continental climate. The climate is also highly affected by altitude and relief.

Permanent grassland and cattle numbers in the Czech Republic

Flora and fauna occurring in the CR are coniferous with the penetration of the main directions of the spread of plants and animals in Europe. Woods, especially coniferous, cover 33% of total area of the CR. Soil cover is also rather variable. The most common soil type found in the CR is fluvisol. Permanent grasslands (PG) cover 974 thousand hectare, i.e. 22.8% of farmland (4,280 thousand ha) in the CR according to the land register of the Czech Office for Surveying, Mapping and Cadastre. According to the data of the Czech Statistical Office (CSO) 932 thousand ha were agriculturally managed in 2007 with an average hay yield of 2.98 t ha^{-1} (Figure 1). Yield potential determined by accurate meadow experiments is more than double that amount (Kohoutek *et al.*, 2008).

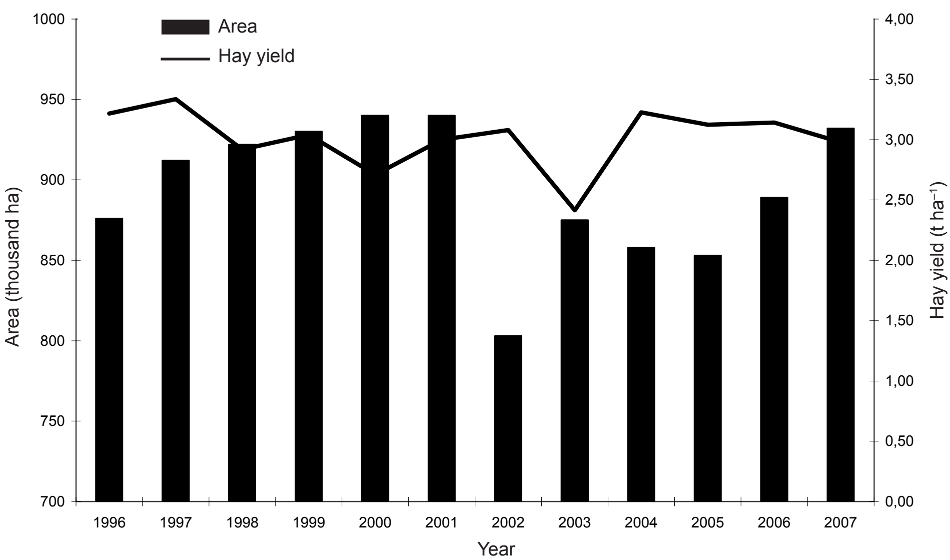

Figure 1. The area of permanent grasslands and an average yield of hay in the CR in 1996–2007 according to CSO (in 2002–2007 statistical measurement according EUROSTAT methodology)

The state agrarian policy requires at least two harvests of grassland per year with respect to permanent grassland management. This measure significantly decreases the risk of successful self-seeding of woods and spreading of ruderal weeds.
The political changes in the countries of Eastern and Central Europe after 1989 lead to a decrease in livestock. In the CR the number of cows fell from 1,236 thousand in 1990 to 575 thousand in 2008 (Figure 2) and this had a negative effect on the management

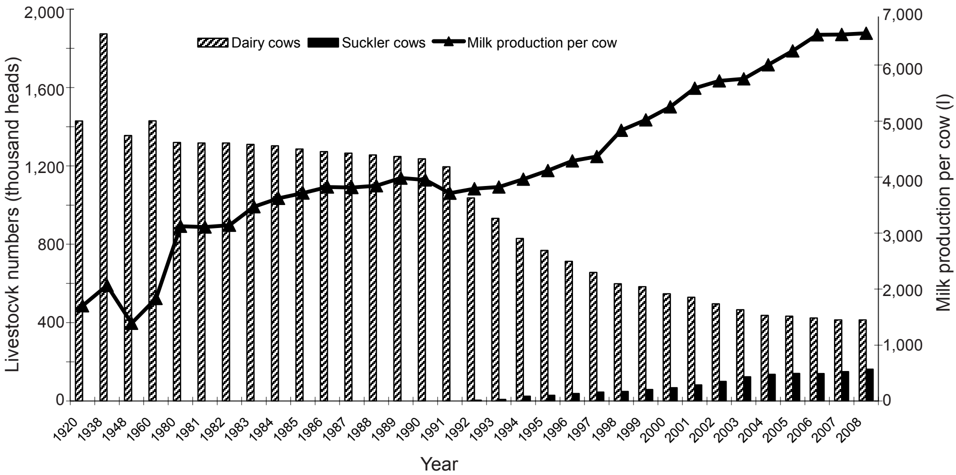

Figure 2. The development of numbers of dairy and suckler cows and milk yield per a cow in the Czech Republic in 1920–2008

and utilisation of grasslands in all production areas (about a half of cattle are reared in lowlands). Milk production of dairy cows reached 6,548 kg FCM with consumption of 0.30 kg of feed concentrate per kg FCM in 2007. The main cattle stock breeds include Holstein (about 39%), Czech parti-coloured breed (33%) and beef breeds (28%).

Permanent grasslands and their possible management

Permanent grasslands (PG) are according to Commission Regulation No. 796/2004 defined for bonus payments as “land used to grow grasses or other herbaceous forage naturally (self-seeded) or through cultivation (sown) and that is not included in the crop rotation of the holding for five years or longer.” From the viewpoint of landscape formation and environment protection, grasslands’ varied and unique composition is usually emphasised, as is difficult accessibility with machinery (steep sloping), erosion prevention, etc. Preservation of PG in the countries of the EU is thus a long-term priority of agricultural policy.
We can distinguish various methods of PG utilisation and their management. Utilisation of PG suggests forage consumption in its fresh state (grazing) or conserved (hay, grass silage) by animals. Ruminant rearing is a traditional, environmental-friendly method of PG utilisation and also natural and reasonable due to ruminants’ ability to process crude fibre. Grass vegetation is economically and ecologically destroyed during PG maintenance. For example, by mulching, by vegetation harvest and following composting, etc. This method is mostly applied when there is a shortage of animals for the consumption of grassland vegetation in some countries and regions. The main drawbacks of this meth-

od are the waste of valuable resource and especially a failure to meet extraproductional functions, e.g. development of rural areas, increase of work opportunities, etc. In the future we can expect higher utilisation of organic matter form PG for energy production.
The development of the PG area and of the main kinds and categories of ruminants and horses is presented in Table 1. It is obvious that while in 1990 to 2008 the area of PG increased by about 100 thousand hectare, which is by 12%, the number of cattle, sheep and goats decreased in the same period by 60, 57 and 59%, respectively. In 2008 the number of ruminants and horses can be estimated at 1,031 thousand of livestock units (LU). That is by 1,446 thousand LU and 58% less than in 1990 (Kvapilík, 1998, 2002, 2003; Kvapilík and Střeleček, 2003). This, and also the reduction in the number of grazing dairy cows and heifers, led to the decrease of PG utilisation, despite a considerable increase of number of suckler cows (to 163 thousand in 2008).

Table 1. The areas of PG and numbers of ruminants and horses in the Czech Republic

Year	PG (ha 1,000)	Cattle (1,000)	Cows (1,000)		Sheep (1,000)	Goats (1,000)	Horses (1,000)	LU (1,000)[1]
			dairy	suckler				
1990	833	3,506	1,248	20[2]	430	41	25	2,477
1995	902	2,030	768	37[2]	165	45	18	1,453
2000	961	1,574	548	67	84	32	21	1,123
2005	974	1,397	438	141	140	13	21	1,018
2006	976	1,374	423	140	148	14	23	1,003
2007	932	1,391	410	155	169	16	24	1,018
2008	933	1,402	406	163	184	17	27	1,031

Source: Czech Office for Surveying, Mapping and Cadastre; Czech Statistical Office
[1]cow, horse = 1 LU, sheep, goat = 0.15 LU, other cattle over 6 months of age = 0.65 LU; [2]estimate

The recent management of PG under ecological farming in the CR can be viewed positively. In 2007, 275 thousand ha of permanent meadows and pastures were included in the regime of ecological farming (Darmovzalová and Koutná, 2008). This is 29.5% of the PG area and 82.3% of the total area of soil managed according to the ecological farming regime (334 thousand ha). About 138 thousand head of cattle, out of which 4,485 were dairy cows (about 1.1%) and 63,520 suckler cows (39.0% of numbers in 2007) were reared on ecological farms at the end of 2007.
The PG area utilised by ruminants is given by the area of PG managed by one LU, resp., by the number of LUs managing one hectare of PG. The stocking density quoted in literature and reached in farming practice ranges from 0.5 to 2.0 LU per ha of PG. Commission Regulation No. 1782/2003 determines the stocking density for extensification payments to 1.4, resp. 1.8 LU per ha of field crops. Since the proportions of ruminants and horses utilising meadow and pasture forage are not precisely known in the CR, their numbers and proportions are estimated. Qualified estimates suggests that permanent grassland is utilised by 100% of suckler cows, sheep, goats and horses, 30% of dairy cows and 30% of LU of other cattle (heifers, fattening bulls, calves). Table 2 shows that about 463.3 thousand (i.e. 45%) LU utilise permanent grasslands out of total 1,030 thousand LU of cattle, sheep, goats and horses.

Table 2. Rough estimate of permanent grasslands utilisation in the CR (2008)

Farm animals	Overall livestock numbers		Per PG area[1]		
	heads (1,000)	LU[2] (1,000)	LU[3] (%)	LU[3] (1,000)	LU (%)
Suckler cows	163.2	163.2	100	163.2	35.2
Dairy cows	405.5	405.5	30	121.7	26.3
Other cattle	616.4	403.9	30	121.2	26.2
Goats	183.6	27.5	100	27.5	5.9
Sheep	16.6	2.5	100	2.5	0.5
Horses	27.2	27.2	100	27.2	5.9
Total	1,352.4	1,029.8	45	463.3	100.0

[1]933.1 thousand ha

[2]a cow, a horse = 1 LU; a sheep, a goat = 0.15 LU; other cattle over 6 months of age = 0.65 LU

[3]estimate of proportion and numbers of livestock utilising PG (grazing, fresh and conserved forage from PG)

The area of meadows and pastures utilised by livestock rearing presented in Table 2 depends on the area of PG allocated to one LU. Suckler cows make up 35% and dairy cows and other cattle make up 53% of LU utilising PG. With respect to this situation it can be assumed that in the CR one LU 1.2 to 1.5 ha, in ecological farming 2.4 ha of permanent meadows and pastures, 463.3 thousand LU of cattle, sheep, goats and horses utilise 555 to 695 thousand ha (60 to 75%) of PG. About 80 thousand hectares cannot be permanently utilised by farming (permanent wetland registered as meadows, balks, bosks, scattered plots in the country, self-seeding woods in the area, etc.). This means that about 160 to 300 thousand ha (17 to 33%) of PG could not be utilised for livestock rearing. This area would only need to be maintained to remain in a natural and cultural condition. To improve this indicator in the CR it would be necessary to extend the grazing of dairy cows, rearing of heifers, and fattening of cattle (especially heifers and steers), to increase the number of ruminants utilising PG and to change from extensive to intensive management of PG by an increase in cutting frequency. The number of dairy cows decreases as the result of the regulation of milk production by quotas and as the milk yield increases. Grazing of dairy cows and other livestock, except for suckler cows, stagnates mainly for economic reasons. Therefore the best solution to this unsatisfactory situation would be to increase the number of suckler cows by about 80 to 100 thousand heads, in addition to extending ruminant grazing. This approximate calculation is also supported by the data presented in Figure 3.

The data suggest considerable variability of suckler cows' as a proportion of dairy cows among the EU-15 and EU-12 countries. In the former group of countries the number of suckler cows reaches in average 66% of dairy cow numbers with a variability form about 6% in the Netherlands to 199% in Spain. The number of suckler cows in the twelve new EU countries reaches in average only 5% of dairy cows with variability from 2% in Romania to 50% in Slovenia. Despite the many factors influencing this indicator (number of dairy cows, proportion of PG on farmland, negotiated quotas of milk and suckler cows, etc.), we can consider the EU-15 average (around 65%) to be the optimum state, resp. the target parameter for the CR. This means that with the present stock of dairy cows in the CR of about 405 thousand (per 100 hectare of farmland noticeably

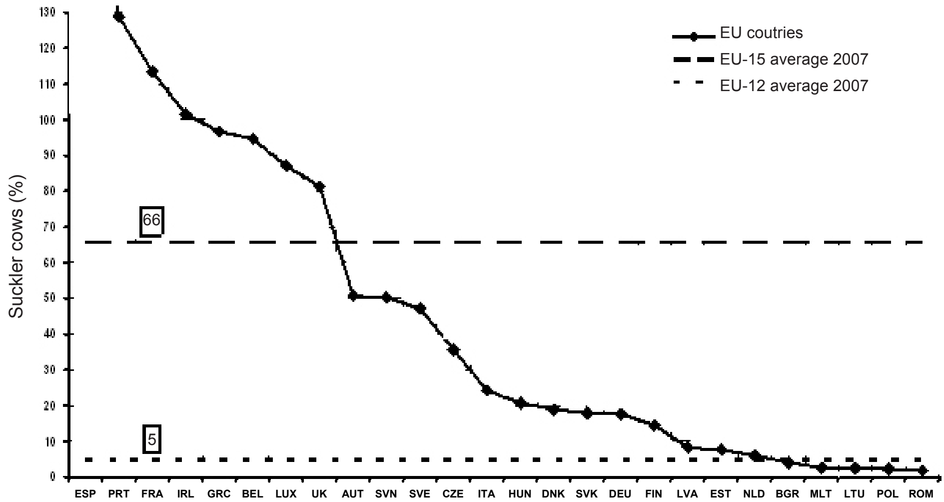

Figure 3. The number of suckler cows compared to dairy cows (2007, %)

lower number than the EU average), the number of suckler cows should increase to about 250 to 260 thousand. This would increase the number in the cattle category, which would allow ecological and economic utilisation of the present area of PG and its slight increase. This solution is desirable for necessary erosion prevention and the fulfilment of other extraproductional functions from the viewpoint of the agrarian policy of CR and common agricultural policy of the European Union.

The effect of management and utilisation on production and botanical composition of PG in the CR

Dry matter production of grasslands from long-term pratotechnique trials in the CR (6 sites) with different intensities of utilisation and different levels of fertilisation reached 6.78 t ha^{-1} DM in the average of five harvest years (2003 to 2006) and 16 alternatives; dry matter production is significantly lower in four-cut and three-cut utilisation in comparison with extensive two-cut utilisation ($P < 0.01$) from 7.52 t ha^{-1} (I4-two-cut), resp. 7.06 (I3-two-cut) to 6.47 (I2-three-cut), resp. 6.07 t ha^{-1} (I1-four-cut, 1st cut by 15th May). That means that the dry matter production in four-cut management is 80.7% in comparison with extensive two-cut management. Nitrogen fertilisation highly significantly increased ($P < 0.01$) dry matter production in comparison with zero fertilised alternative, resp. fertilised only with PK from 5.09 (zero fertilised), resp. 5.47 (PK fertilised), to 7.67 (N_{90}PK), resp. 8.89 t ha^{-1} (N_{180}PK) when fertilised with nitrogen at the rate of 180 kg ha^{-1} N. Nitrogen production efficiency reached 18.8 kg DM per 1 kg of applied nitrogen in the average of N rates (Kohoutek *et al.*, 2008).

When considering the effect of PG utilisation intensity on botanical composition, it was proven that changing utilisation intensity from four-cut to two-cut management (extensive) significantly decreases the number of species in the vegetation from 82.1 (four-cut management) to 74.0 (extensive two-cut management). This trend is similar at all levels of fertilisation from the zero-fertilised alternative to the rate of nitrogen of 180 kg ha^{-1} N, which represents load of 2 LU ha^{-1}, see Figure 4 (Kohoutek *et al.*, 2008).

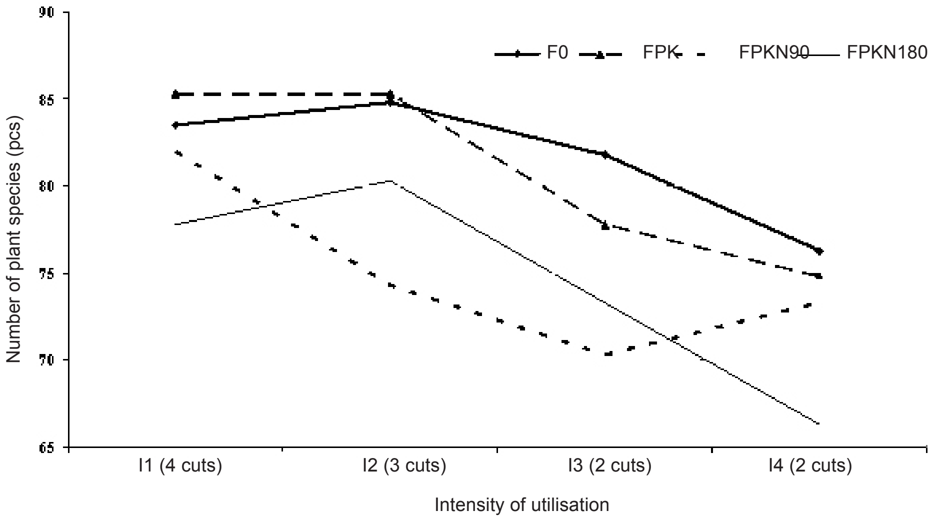

Figure 4. The change of number of plant species present in PG depending on cutting frequency and fertilisation level

The analysis of the structure of voluminous feedstuff in Czech agriculture with regard to ruminants

The Czech agricultural system was analysed with the method of carbon balance (Kudrna, 1985; Kohoutek, 2002) aimed at voluminous feedstuff structure in 1994–2007 and compared with the analysis from 1971–1985. The internal structure of the agricultural system underwent a significant decrease in livestock after 1990 and an improvement of voluminous feedstuff production per 1 LU which has recently covered ruminants' consumption including the indigestible reserve. Though the structure of bulk feeds did not change in terms of stabilisers, which is the forage from perennial and permanent grassland of higher quality, the influence of cummulators, which is maize to silage, became stronger. This is expressed by the high value of parameter η_0, the ratio between cummulators and stabilisers, that in 2007 had the value $\eta_0 = 0.438$, which exceeds the value $\eta_0 = 0.274$ from the early 1970s by 1.6 times.

In the Czech agricultural system cummulators still prevail over stabilisers, which are expressed by a negative effect on soil properties. The optimal structure of cummulators and stabilisers at the present number of LU in the CR in 2007 and dry matter production, 4.5 t per LU by year (including a 20% reserve for losses during conservation, storage, handling and feeding) would be reached at a production level of 5,384 thousand DM of voluminous feedstuff composed of 1.23 t DM of silage corn and 3.27 t DM of forage from perennial fodder plants and permanent grasslands per LU and per year. Optimal annual silage corn production for given cattle numbers is 1,158 thousand t DM and 4,226 thousand t DM of perennial fodder plants from arable land and grasslands in the CR (Figure 5). Stabilisers production in the Czech agricultural system in 2007 should have been 319 thousand t higher and production of cummulators should have been 513 thousand t lower, which represents a reduction of sown areas of silage corn by about 50 thousand ha to reach the balance between cummulators and stabilisers. Forage production from permanent grasslands must be directed at the increase in area, yield and

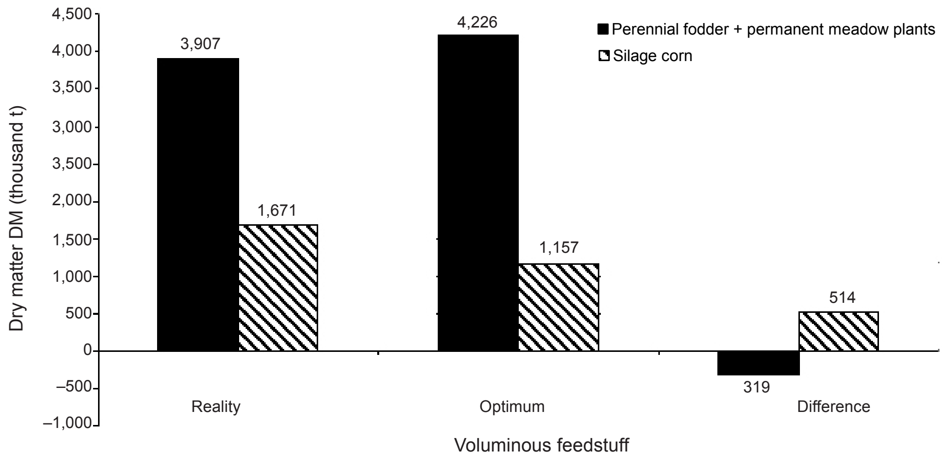

Figure 5. The analysis of dry matter structure of voluminous feedstuff in the Czech agricultural system in 2007 (thousand t)

quality of forage to compensate for the negative influence of acid silage and the high proportion of feed concentrates (0.25–0.30 kg cow^{-1} day^{-1}) in the ration per litre of milk. It is obvious that the reduction of voluminous feedstuff production resulted in the reduc-

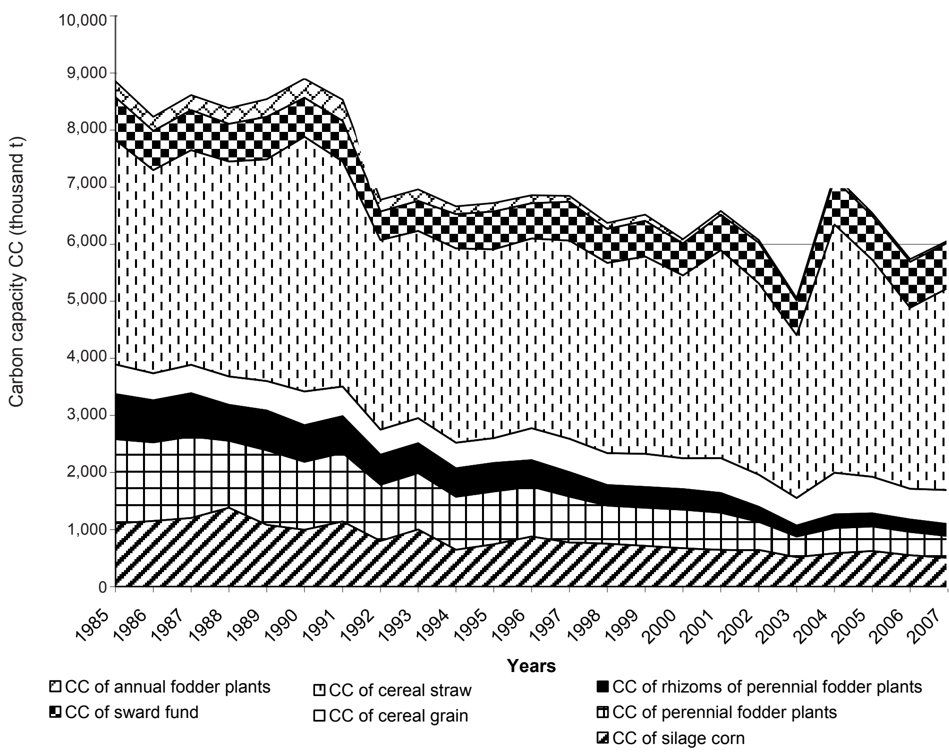

Figure 6. The decomposition of the Czech agricultural system (carbon volume after conversion by animals)

tion of active carbon production (Figure 6). The production of active carbon decreased by 2,480 thousand t of active carbon a year in 2001–2007 in comparison with the period of 1985–1991, that is by 31%, which significantly decreases potential plant production (in conversion to cereals by 4,464 thousand t year^{-1}). At the same time the extraproductional functions of the agricultural system are decreasing (especially water retention and soil biological activity; simultaneously soil volume weight is increasing, i.e. soil density increases). The Czech agricultural system is now at the stage of radical inhibited harmonic movement, which limits further use of industrial fertilisers. Tension in the resources of active carbon is expressed by the effort to concentrate carbon resources from grasslands under carbon consumers in production areas with the production reduction of sources of active carbon from mountainous and submontane areas including cattle herd movement to the lowlands. The importance of active carbon of cereal straws gains importance in the agricultural system.

Grass seed production

Grasses grown for seeds, which represent an interesting and prospective branch of plant production in the CR, are an integral part of grasslands. What, it must be asked, has characterised Czech grass seed farming over the last 15 years? First of all, a decrease in home consumption of seeds from plant fodder species, which is caused by the slow renovation of meadows and pastures, linked with the recent decrease of animal production. On the other hand the need for lawn and regeneration mixtures has been on the increase. The area of grass seed farms has been growing since mid-1990s. In 2006 the area was 18 thousand ha. The Czech Republic ranks 5th among EU countries in the seed farms area (annual production is about 10,000 t of certified seed) but it falls behind in average hectare yield. The most important species – from the viewpoint of sown area and seed production – are varieties of *Lolium* genus – especially both forms of Italian ryegrass and perennial ryegrass, then tall fescue, timothy grass, and red fescue. Czech grass seed farming distinguishes itself by an extraordinary wide range of grass species (about thirty species). More than three quarters of seed farm in the CR multiplicate the foreign varieties which are not registered in the State Variety Book. A typical feature is also a lower intensity of seed production of many grass species in comparison with Denmark, the Netherlands, and Germany and slow financial turnover, especially with perennial grass species (Table 3).

Seed farms under organic management make up only one percent of the grass seed industry. Grass seed producers receive subsidies for area (SAPS) and also additional subsidies form national resources (TOP-UP). However, these do not make grass seed production much more attractive.

With an eye to the future one must ask what the opportunities and prospects are for seed farming in the CR. Grasses grown for seed belong among what are called ‘little crops’, but they should not disappear from the assortment of field crops for agricultural, environmental and economic reasons (especially in marginal regions). They have a positive effect on soil structure and they can work as a natural “interrupter” for some “big crops”. Pre-crop value of individual grasses grown for seed strongly varies depending on their varieties: the worst are red fescue, tall fescue and tufted hairgrass, while dog’s-tail, and ryegrasses belong among the best species (Macháč and Macháč, 2006). They are a part of the cultural agricultural landscape, prevent erosion and perennial species especially act as a natural habitat. Also, their aesthetic function cannot be overlooked. To prevent their disappearance from

Table 3. The areas, production and average yield of grasses grown for seed in the CR in 2007 (Cagaš and Macháč, 2008)

Variety	Certified area (ha)	Production (t)	Average yield (kg ha^{-1})
Phleum nodosum	59.41	10.4	175.0
Phleum pratensis	2,010.37	600.9	299.0
Festulolium	2,070.54	1,067.1	515.0
Lolium hybridum	670.05	404.5	604.0
Lolium multiflorum subsp. *italicum*	1,869.81	1,645.8	880.0
Lolium multiflorum var. *westerwoldicum*	2,888.53	2,238.7	775.0
Lolium perenne	1,884.19	801.24	434.0
Festuca rubra	2,597.29	950.2	366.0
Festuca pratensis	2,520.96	1,183.6	470.0
Festuca ovina	91.83	28.8	313.0
Festuca arundinacea	1,162.48	512.2	441.0
Poa palustris	5.71	1.4	243.0
Poa nemoralis	62.32	33.6	539.0
Poa pratensis	367.90	30.8	84.0
Poa compressa	0.83	0.0	0.0
Holcus lanatus	0.03	0.0	0.0
Deschectarempsia caespitosa	20.49	7.2	349.0
Arrhenatherum elatius	56.85	8.37	147.0
Cynosurus cristatus	29.91	18.4	615.0
Alopecurus pratensis	80.83	9.8	121.0
Agrostis capillaris	116.16	13.5	116.0
Agrostis gigantea	200.38	61.7	308.0
Agrostis stolonifera	18.74	0.0	0.0
Dactylis polygama	7.00	0.0	0.0
Dactylis glomerata	1,011.49	181.8	180.0
Bromus inermis	1.20	0.1	58.0
Bromus marginatus	11.35	8.3	730.0
Anthoxanthum odoratum	12.09	0.7	57.0
Trisetum flavescens	79.40	8.4	106.0
Total	9,868.11	9,827.1	495.0

the Czech countryside, it is necessary to increase the intensity of their management. The development of areas and grass seed production is presented in Table 4.

To maintain and further improve the position of grass seed farming in the CR it is necessary to focus on only a few varieties where we can attain good yields (with careful regard to soil and climatic conditions, high risk of diseases and pests, etc.) exceeding the profitability limit (mainly ryegrasses, *Festulolium* ssp., meadow fescue). On the contrary,

Table 4. The development of areas, production, export and import of grass seeds in the CR in 2002 to 2007

Year	Certified area (1,000 ha)	Production (1,000 t)	Yield (kg ha^{-1})	Export		Import (1,000 t)
				2002	(%)	
2002	11.6	3.9	334	3.2	84	
2003	10.3	5.1	490	4.2	83	1.8
2004	14.0	9.0	645	7.1	79	2.0
2005	16.1	7.6	468			
2006	18.1	9.7	533	4.7	49	1.5
2007	19.8	9.8	495	3.5	36	2.3

we have to avoid varieties with relatively low yield and which cannot compete with top grass seed farms abroad (e.g. Kentucky bluegrass). We should also look to developing the technology for organic grass production.

Other (extraproductional) lawns

The total area of other extraproductional areas with grass cover is 171 thousand hectares of non-agricultural land. The inner structure is presented in Table 5.

From the analysis made by Šimek (2002) of 20 functional types of city greenery it is obvious that lawns dominate and cover 2/3 of total area of subject functional types. The above mentioned lawns cannot be classified as the highest quality category of parterre lawns (A). Only 2.7% of lawns belong to park lawns (B), 92.7% to the category of so-called meadow lawns (C) and 4.5% to non-standard lawns (D). The data demonstrate

Table 5. Summary of selected groups of other extraproductional areas with grass cover as a part of non-agricultural land (according to the data of ČÚKZ Prague, 2009 edited by Hrabě *et al*., 2009)

Group of areas	Area with extraproductional grassing	
	(1,000 ha)	(%)
Municipal park and other green foliage	22.3	12.6
Sports areas and recreational greenery	18.7	10.6
– out of which football pitches	6.0	3.4
Burial sites	2.0	1.1
Cultural and educational areas	0.3	0.2
Railroads (embankments and others)	8.3	4.7
Motorways	1.1	0.6
Roads and other communications	63.7	36.0
Waterways natural and artificial	23.7	13.4
Water reservoirs natural and artificial	11.2	6.3
Ponds and wetlands	19.8	11.2
Total	176.9	100.0

low quality of lawns even in spa towns. The range of extraproductional lawn areas, and ensuring their significant environmental, ecological, health, landscape, sport and recreational functions require expert handling by both management and executive teams (supply firms and groundsmen). Another pre-requisite is providing quality information to the consumer about the significant environmental impact of greenery on their life and quality of environment and efficient exploitation of this natural resource.

Golf courses and football pitches

Football pitches only cover 6.1% of the total area of town greenery. Only a quarter of pitches of the first league stadiums belong to the highest category (A) and these are the pitches with heated surface.

At present the Czech Golf Association (ČGA) associates golf clubs (GC), professional and amateur golf players and the Czech Association of green keepers (ČSG).

96 golf clubs are accredited for playing golf, which represents nearly 50% of all golf courses in Central and Eastern Europe. These golf courses can be divided into 9-hole (70 courses), 18-hole (23 courses), and 27-hole (3 courses). The quality of golf greens reflects the qualification of green keepers and opportunities for their further training. A number of them have received excellent practical experience from long-term placements in Scotland, Great Britain, Germany and the USA. The current economic crisis results in lower attendance on golf courses and has hindered their development. Quite a number of golf courses have remained incomplete for a considerable time.

Price developments of agrarian products in the context of food and the economic crisis

The fragile balance of the global wheat market was demonstrated in 2007 when cereal prices doubled as a result of an increased demand for bio energy resources, including cereals. As Sonia Phippard, the director of the European Department of the British Ministry of Agriculture, said in her presentation at the conference on the future of the Common Agricultural Policy held in Prague in October 2007, the shortage of cereals is directly related to the introduction of bio fuels and the American effort for energy self-sufficiency. This radically changes the view of the role of agriculture in the last decade and its future prospects, and Europe must react promptly. Therefore in September 2007 the European Parliament liberalised the rule stating that farmers had to set a part of land aside which led to the ploughing of 2.7 mil ha and sowing it with cereals. A favourable cereal year in Europe resulted in the production of over 300 mil t of cereals which was followed by a price fall. The lower price of cereals decreased the costs of feed concentrate for animal production but it did not help its profitability. During 2008 the price of milk dropped to 7.40–7.60 CZK l^{-1}, in some cases even under 7.00 CZK l^{-1} in autumn 2008. Compared with a price of 9.50–10.0 CZK l^{-1} in the spring 2008 it is obvious that milk production as a key branch of animal production is not profitable and farmers lose 1.50–2.50 CZK l^{-1}. Similar conditions are a worry for cattle farmers too. This situation is not sustainable over a long period of time and could lead to the liquidation of a number of cattle farms, as happens with pig farms, and further lead to the loss of Czech agricultural competitiveness and opens up the Czech market to import expansion from EU-15 surplus production through supermarket chain stores and finally to the reduction of Czech agriculture. The global financial and economic crisis can only further deteriorate the situation of Czech agriculture.

Conclusion

Long-term national and international experience provides evidence that permanent grasslands are best utilised by the breeding of ruminants both from ecological and economic viewpoints. In the CR it is mainly through the breeding of suckler cows and sheep, and horse breeding. A smaller part of the total permanent grasslands area is utilised by dairy cows and heifers and conserved forage (hay, haylage and silage) is used for feeding all kinds and categories of ruminants. In this way production (meat production, animal breeding, dairy production) and extraproductional (preservation of natural countryside, cultural landscape, prevention of soil erosion, conservation of biodiversity and protection of water resources, etc.) functions are mutually combined. Lower market incomes are compensated for by EU payments and from available sources of the national budget with respect to less favourable natural and production conditions and a demand to fulfil extraproductional functions.

Green forage from grasslands is a relatively cheap feedstuff. Meadows and pastures provide the best ecological soil preservation against erosion and nutrient leaching. Grassland farming is another method of production that approaches the ideal of a closed production cycle. In the social context grassland farming is the most suitable type of farming in the mountains and highlands and can help to keep these areas inhabited. Permanent grasslands are an elementary part of a cultural countryside, providing conditions for a good quality of life and the prosperity of the local communities and also foster conditions for recreation and the ecological production of quality foodstuff in the heart of Europe.

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Session 1

Non marketable functions of grassland

Grassland beyond conventional food markets – economic value of multifunctional grassland: An analytical framework as contribution from agricultural economics

Lehmann B.

Agricultural Economics – Agri-food & Agri-environmental Economics Group, Institute for Environmental Decisions, Department of Agricultural and Food Sciences, ETH Zurich, Zurich, Switzerland
E-mail: lehmann@ethz.ch

Abstract

Grassland covers around 25% of the world land surface. Primarily given by the grassland-related production of food for humans the economic importance of the grassland is obvious. A big share of milk and meat is grassland-based. From the non-market perspective, grassland represents a huge potential for environmental functions. Negative impacts on environment caused by agriculture have also to be mentioned. The environmental functions of grassland can be assessed and evaluated economically. There are different methods to quantify its economic importance. From the given facts there is a long way to an economically sounded policy framework. The policy design in European agriculture is moving from market related support to specific support of environmental and partially other functions of agriculture. The importance of the functions of agriculture perceived by society is reflected by the policy design. Like agriculture in general, grassland-based agriculture as well has to build its economic future onto three pillars: onto the market for commodities, the market for environmental-linked products and services, the public support for non-marketable functions which a sustainable willingness to pay for exists.

Keywords: grasland production, economic inportance, environmental funciton

Grassland 25% of the world's terrestrial surface

The main function of agriculture is to produce food and feed for animals. Agriculture uses a third of the worldwide land surface. The worldwide 5 billion hectares of agricultural land covers 1.4 billion ha cropland, of 0.1 billon ha permanent crops and 3.5 billion ha permanent pasture. The grassland surface is about 4 billion ha worldwide (Table 1).
Grassland is therefore an important part of the world terrestrial ecosystem.
Primarily the agro-ecosystem grassland is due to produce feedstuff for farm animals. Originally the actual grassland surfaces used to be natural grassland (with wild animals) – and especially in Europe – forest areas. During the last thousands of years, agriculture transformed the ecosystems into agro-ecosystems with more or less natural elements. Grassland can show different productivities, from very low ones (of Mongolia for example) to very high ones in the best agronomic conditions and grass varieties. Grassland can have several characteristics which can differ as follows::

- agronomic and contextual conditions
- types of species of grass and other plants (botanic composition)
- natural grassland and grassland integrated in crop rotation

Table 1. Land cover and the importance of the grassland surface (2005)

	(Mill. ha)	(%)
World's land surface	14,838	100
Deserts, rocks	4,093	28
Urbanized area	360	2
Wetland	1,500	10
Forests	3,952	27
Agricultural land	4,933	33
– Permanent pasture	– 3,403	– 23 (of world land surface)
– Permanent crops	– 130	– 1
– Arable land	– 1,400	– 9
– "Grassland"	– approx. 4,000	– > 25 (of world land surface)

– productivities (yields per ha)
– forms of use from pastureland to meadows with several cuts per season
– intensities in input use (fertilizer, chemicals for weed control)
– plot size
– degrees of proximity of the urban world (remote, very rural, rural, periurban, urban)
– impacts on elements of the local ecosystem (water, biodiversity, landscape, air)
– appearance which can be perceived and assessed individually in a different way.

The characteristics of the grassland are primarily determined by an agricultural rationale within natural and legal constraints. The latter can have a link to the so called non-marketable functions of grassland.

Why non-marketable functions?

Non-marketable functions of agriculture have been defined for the last 25 years. In earlier times they were not an issue. It is important to reflect that in a changing context of agriculture within the market and society. A series of challenging conditions for agriculture and grassland production increased the necessity to deal with non-marketable issues of agriculture. As far as European conditions are concerned, it may be mentioned:

(1) The fact that the high support led to an expensive and overproducing agriculture in many countries: therefore from a public point of view agriculture uses too much land, is to input intensive, creates negative external effects for the environment (such as physically or perceived ones).
(2) The pressure towards improvement of competitiveness implies a change of farming systems which can have a negative impact on the ecosystem; this can lead to a less appreciated landscape or can endanger the agro-ecosystem viability.
(3) The fact that in urbanized areas the demand for more recreational values and also more intrinsic ecological values led agriculture to find arguments to satisfy them by the concept of multifunctionality.
(4) Policy reforms – under the WTO and societal pressure – tend to reduce the absolute amount of support by tariff reduction and implement cross compliance direct payments. Greening the support was and is still a means for rent seeking.

Agriculture moved from a food production concept to a multi-stakeholder concept. Multifunctionality implies this. The Figure 1 below illustrates the multiples interactions identified around the landscape issue in the alpine regions:

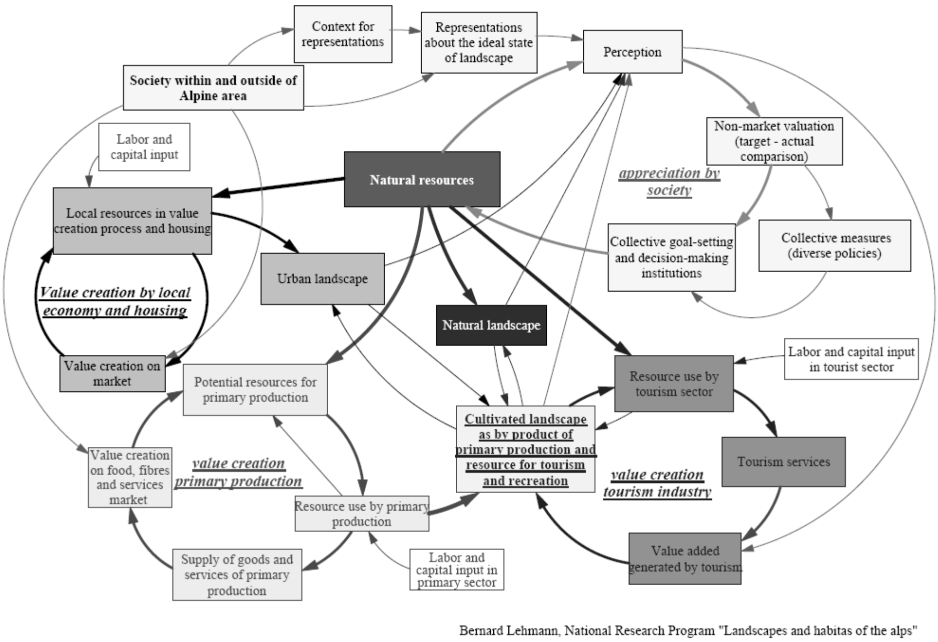

Figure 1. Agricultural landscape, from en externality to a resource for society

The agricultural production process is on the one hand closely linked to other indirect users of the landscape like tourism and on the other hand embedded by the society who is defining environmental (landscape) goals and defining schemes for the regulation. Agricultural landscape (and its different dimensions) is no longer considered only as a positive externality; society considers it as a resource which taxpayers pay for.

Economic conception for the appraisal of environmental issues

Economics studies human behaviour as a relationship between ends and scarce means which may be used alternatively. Economics is the study of the trade-offs involved when choosing between alternate sets of decisions. “Scarcity” means that available resources are insufficient to satisfy all the wants and needs. Absent scarcity or absent alternative uses of available resources means, there is no economic problem. The thus defined subject involves the study of choices as they are affected by incentives and resources.

In economics there is an individual and a collective perspective. Individuals and firms are searching the best allocation of the scarce resources in order to have the best efficiency (between costs and benefits). In a classical economic approach reduced to commercial interactions between individuals the collective allocation of the socially leveled resources corresponds to the aggregation of the individual situations.

Table 2. The classical approach

	Private	Social
Benefits	Beneficiary pays in commercial transactions	Total of all individuals
Costs	Cost carrier is compensated in commercials transactions	Total of all individuals

Everyone maximizes his private benefit, but since everyone pays for any benefits he receives, and bears only the corresponding costs, the result of this private-benefit maximization (marginality conditions) is that social net benefits are maximized.
As we have already heard, human activities produce side effects on environment. Especially agricultural activities cause effects on the natural environment, so-called external effects. In presence of externalities, which happens often by using natural resources, the above assumption is no longer true. There may be a market failure. In maximizing their private net benefits, people will overlook some (external) costs and benefits, and maximization of private benefits will no longer lead to maximization of social net benefits.

Table 3. The environmental economics approach

	External	Private	Social
Benefits	Beneficiary does not pay	Beneficiary pays	Total of both
Costs	Loser is not compensated	Cost carrier is compensated	Total of both

External effects can be considered as a positive or negative impact perceived by not commercially involved people. Their welfare can be improved or reduced by the existence of externalities. These aspects have to be taken into account in order to reach a situation which can be considered as social optimum. The challenge represents the definition of these external effects and their economic assessment.

The case of negative externalities

Negative externalities cause damages for not directly involved persons. The stronger the effect is the higher will be the marginal damage for third persons (increasing marginal damage costs). On the other side, the causer (the polluter) of the externality has increasing marginal abatement costs the more he has to reduce the externality. The social optimum is not given at the point of zero negative externality but at the point where the marginal abatement costs correspond to the marginal damage for third persons. For this theoretical optimum, following aims have to be met:
– The damage (the costs for third persons) has to be determined; often indirect ways are necessary, like the determination of the costs for cleaning the polluted water.
– The abatement costs have to be quantified (they can differ from one causer to the other).
– The causer of the negative externality has to be motivated, economically incited or legally forced to reduce the negative impact on thirds.
– Very often there is not clear who is the causer in economic terms (increasing urbanization around agriculture).

Following types of policy instruments can be implemented in case of negative external effects:
– Recommendations, codes of practice.
– Compulsory legal norms.
– Economic instruments, like taxes or cross compliance linked direct payments, whereas the payment has principally other goals (like income support).

The supply of goods – in case of negative external effects – is economically too cheap and too important; therefore the producer and the consumer surplus (economic surplus = income, rent) are too high compared with a situation of optimally internalized externalities. The internalization causes an upwards shift of the supply function and another repartition of welfare between the commercial partner on the one hand and the concerned group of third persons on the other hand.

The case of positive externalities
Positive externalities, like the negative externalities are not provided or caused intentionally. They are a side effect of a production process. As long as no third persons are (positively) concerned of the physical presence of these side effects, the economic surplus of the consumers and suppliers (commercial transaction) is socially optimal. The existence of positive externalities implies the fact that there is a demand for. The externality provides utility. But there is no market for that type of good, because there is no excludability (if I pay, other persons will also be beneficiary of this good without obligation to pay for) and principally no rivalry. As long as these two conditions are given, the positive externality has a public good character. If only the non-excludability is given, the externality is a common good (see matrix below). Agricultural landscapes as externality of agricultural activities have a public good character with partially the character of commons (rivalry between different types of use of this good, psychic recreation, biodiversity, soft or invasive tourism).

Table 4. Public goods, private good and hybrid forms

	Non-excludability	Excludability
Rivalry	common goods (open access goods)	private goods
Non-rivalry	public goods	club goods

The supply of goods related to positive external effects is from a social optimum point of view too small; therefore the producer and the consumer surplus (economic surplus = income, rent) are too small compared with a situation of optimally internalized externalities. The internalization causes an upward shift of the demand function and another repartition of welfare between the commercial partner on the one hand and the society (third persons) on the other hand.
Due to the free rider problem (non-excludability), the provision of public goods in an optimal quantity has to be organized by so-called policy measures. They can have international, national, local range. Another conception consists of bilateral arrangements between providers of demanded external effects and relevant individuals or groups (NGOs). The free rider effect is not completely eliminated but significantly reduced. The willingness to pay for of the relevant groups is the criteria for the determination of the necessary economic incentive for the provision of this type of good.

The problem of the reference syste*m*

Each human activity has an impact on the environment, which can be observed from two perspectives:
– Human activities in general use natural resources in a production process (air, light, water, soil, plants, and animals).
– Human activities influence the environment, the natural environment through the production process. The impact is not in the target intention of the activity; it is an unintentional mostly undesired side effect (production of waste, loss of biodiversity, water

and air pollution). Agricultural landscape is to some extend an unintentional side effect of agricultural activities.

Regarding the environmental impacts of grassland agriculture we can distinguish following aspects:

– The occupation of space.
– The transformation of the traditional ecosystem in an agro-ecosystem with specific characteristics; this transformation process led clearly to another diversity of species and another appearance in comparison to the original situation; this can be considered as loss and gain at the same time.
– Potential transformation of the natural resources shared with other groups of society (water, air, space, landscapes). This can lead to conflicts in resource use.

Society on the other side increased the use of partially the same natural resources used by agriculture (water, space, recreational needs, sports, tourism, etc.); considering the landscape and landscape related dimensions of agricultural areas, society consider some aspects as loss and other aspects as gain. Changes in society can lead to another appreciation of this balance between losses and gains (positive values).

Therefore it is absolutely imperative to be aware of the fact that there is not only one side of the medal called "non-marketable functions of grassland" or "economics value of multifunctional grassland". Moreover distinction between negative and positive impact is a question of appreciation. The reference point or reference system is thereby not the original situation but more the ideal or whished situation seen from society. This wishful situation is strongly related to the existing knowledge in society about ecological issue and the importance accorded to the needs of future generations (in economic term: the discount rate).

Policy design in Europe in the frame of the economic conception

Policy measures are conceived and implemented, when there is a market failure. This analysis of the actual policy frame for agriculture shows that the market-support measures are decreasing and the environment-related measures increased. We can identify three stages of agricultural support (past, present, future).

The economic theory – especially environmental economics – helps to improve the effectiveness (does the measure help to achieve settled goals) and the efficiency (are the costs in a good relationship to the benefits) of the public means invested in agriculture. Public money is more and more allocated to environmental and other valuable functions of agriculture for society. This does not mean that the past policies where ineffective and inefficient, what often is written and said. Price support was a very effective and also efficient measure to increase production after World War II. No direct payment would have had this effect. Price support helped the farmers to work with less market induced risks; they had a more stable panning horizon. The main changes, which occurred later where:

– Supply grew faster than demand to the given price level, in western industrialized countries.
– The environmental benefits were not high enough.
– The negative pressure on the environment was too high.
– Societal needs to environmental issues grew rapidly.

Due to these changes, policies had to adapt their conceptions in order to avoid environmental linked market failures. The greening of the policies had to take place. The

Table 5. Changing policy concepts

	Past	Present	Future
(1) Markets	– Import tariffs – Export subsidies – Intervention prices – Guaranteed prices	– Reduced market related support measures – More quality and labelling embedment measures	– Low market related support measures – Significant quality and labelling embedment measures
(2) Negative impact on natural resources	– Regulations (restrictions)	– Regulations – Direct payments under cross compliance conditions (related to income)	– Regulations
(3) Positive (whished) functions in context of multifunctionality	Not targeted direct payments (decoupled income support)	– Targeted direct environmental payments	– Specific well targeted direct payments for environmental services
(4) Farmers income		– Decoupled income direct payments (multifunctionality)	– Income support (family farm orientated)

conception of environmental economics helped to design the policies more and more in direction of effectiveness and efficiency under the new changed conditions.
In fact the policy design is a complex issue, due to the fact that the property rights between the users and the society in general are not precisely defined. Users, in our case farmers can use the natural resources in a given way (best practices). These best practices reflect the knowledge of the relevant experts (Who delimits the circle of the experts?) and take into account economic aspects, at least for competitiveness issues. Due to the fact, that the conditions all over the world are very different you cannot design a pure policy frame without the consideration of these differences. Consequently policies will – when they support environmental functions of agriculture, of grassland – also reflect the opportunity costs of the farmers. The economic value of these functions is one side of the equation, the opportunity costs of the farmers are the other side. We can therefore have different constellations (Table 6). These differences have to be considered by international comparisons.

Table 6. Public willingness to pay and farmer's opportunity costs

	High opportunity costs for farmers for the provision of environmental functions	Low opportunity costs for farmers for the provision of environmental functions
High public willingness to pay of the public sector (government/relevant population)	Very high environment related payments (including income payments)	Tendency to high environment related payments (incl. income payments)
Low public willingness to pay of the public sector (government/relevant population)	Tendency to low environment related payments (including income payments)	Low environment related payments (incl. income payments)

The willingness to pay for environmental services reflects the societal needs and the perceived scarcity. Different methodological approaches can be used in order to determine the willingness to pay for.

– The Travel Cost Method (TCM) assumes that the value of a site is at least as high as the amount spent on travelling at this place. This is a kind of private willingness to pay for something which cannot directly be transferred into a public willingness to pay for: Moreover the aggregation should only be made among the effective visitors of the site.
– The Contingent Valuation Method (CVM) estimates the willingness to pay of individual for a given environmental good (like a described landscape) or a described change in natural environment; it is assumed that this stated value corresponds to the amount which would be allocated to this issue in reality. In the aggregation of this individual values, questions about "the relevant" population have to be answered (Where is the limit? The taxpayer of a country, others?) This shows that the value of an environmental good can differ from the aggregated amount of a selected population.
– The hedonic pricing Method (HPM) quantifies the differences which can be observed in a market when it is obvious that the price of the marketed good can be influenced by an externality. Related to agricultural landscapes this method can give indications about the value of a given landscape through the price differences of flats. Under "ceteris paribus" conditions the differences of the quality of a landscape can be isolated and quantified. The latter has been realized in a Swiss National Research Program "Landscapes and Habitats of the Alps". The beauty of sceneries and partly the presumed ecological value have a significant effect on the prices of a flat.
– Other methods like the Method of Discrete Choice help to gain information about the preference of the public (selected persons) concerning environmental issues (rankings, preferences under given budget restrictions).

These methods do not deliver data which could be used directly in the fixation of amount of policy measures. There are too many restrictions for a direct implementation. Nevertheless they help to be aware of the orientation to give to the policies; they help to make a selection of the criteria which are more important and of such that are less important. From an economic point of view society can have opportunity costs when supporting agriculture-linked environmental services. In other terms society could have preferences for other types of ecosystem services which are less agriculture-linked. To some extend – in given situations – agriculture delivers second best solutions in environmental services. In periods of abundance of food the marginal value of agricultural linked environmental functions can be lowered (current observations in CVM analyses). This can be summarized under the "more wilderness" request.

This observation leads to another important issue which has to be taken into consideration: the time range for the valuation. Economics differ between use values and non-use values. Use values lay the focus on the present, non-use values more on the future. This future can be in a short or more long run perspective. It is obvious that every economic valuation has this limit and weakness; nobody can really define the value for the following generations. This is especially important for non-reversible processes, for situations in which we let only few options for the next generations.

The potential overlap between market and non-market

The division between marketable and non-marketable functions leads to the assumption that limits between both categories are strict. Some of the so called non-marketable

Table 7. Potentially economic values of grassland related goods and services, an overview

	Total economic value					
	Use values				Non-use values	
Categories of value	Direct use value	Indirect use value		Option value	Bequest value	Existence value
	Material use value	Immaterial use value	Intrinsic value/ functional benefits	Future direct and indirect values	Value of leaving use and non-use values for future generations	Value from knowledge of continued existence
Grassland related values of goods and services	Production value of grass biomass	Recreational/amenity values of the grassland landscape	Ecological function	Environmental options Production options	Functionality of the ecosystem	
	Animal production Energy production Fibre production	Recreation scenery	Sustainable functionality of the agro-ecosystem Contribution to whole ecosystem (biodiversity, CO_2 sequestration, water retention)	Recreation scenery Animal production Energy production Fibre production	Agro-ecosystem	
Economic valuation	Benefits realized by farmers on market for standard or differentiated products	Indirect market benefits (recreation related activities) realized by tourism and farmers Public support for agriculture for environmental services	Public regulation and support for agricultural functions related to the preservation of the viability of the ecosystem and agro-ecosystem Target groups: in the future living people (actual and future generations)			

functions have some potential to be remunerated by a market transaction instead of a public policy program.

In order to define the real potentialities of these possibilities, it is useful to use the rivalry-non rivalry/excludability-non-excludability concept. When excludability can be achieved, a market solution can be possible. Following examples, related with food and/or environmental issues show that there is a real potential:

– Food products which include (compared to the standard) a higher (or declared higher) degree of environmental protection [special ecological products].
– Food products which include a higher (or declared higher) functionality for health support related to an environmental friendly (or traditional) agricultural production [cheese from regions in which grass or hey is much more important than concentrated feedstuff].
– Food products with a location linked reputation [geographic indications].
– Parks with entrance fee.
– Label regions, in which there is one single marketing concept.

All these types of market orientated approaches can be successful when some conditions are fulfilled:

– There is a real differentiation in the product or the product linked service which can be identified.
– There is consumer segment who is potentially interested in the proposed offer and who has a willingness to pay for that type of product or service. Awareness for environmental issues can lead to a certain willingness to pay for environmental public goods as well as for environment-linked marketable products and services.

Economists tend to say, that the potential of the market for environmental services should be considered as an important pillar beside public policy programs. “Hybrid” form can also be identified when there is a public support for such type of initiatives.

In the future direct payments will be more focused on environmental services which are effectively not marketable and which have a high value for the preservation of the viability of the ecosystem and of the support of positive interactions between the agro-ecosystem and the whole ecosystem.

Further changes in future

Future will bring new challenges which are to some extend different from the past challenges and to some extent reinforce the existing ones.

– Due to the population growth and to the changes of the consumer habits, food demand in terms of calories and protein will double in the next 40 years.
– Due to climate change the localisation of the productive rain-fed agricultural areas will move; this also has implications for grassland since irrigation will be expensive (physical and economic water scarcity, rivalry between water users).
– Grassland based agriculture is also – due to the ruminants – a cause of climate change. Due to the quasi mono functionality of natural grassland (regarding agriculture) on the one hand and the future food needs of mankind on the other hand, the principal solution is to improve techniques in order to reduce this impact on the climate. Local reductions with shift of the production in other areas of the world do not contribute to mitigation.

Conclusion

Grassland occupies a significant part of the terrestrial land surface. Therefore the responsibility of the farmers and agronomists towards society is enormous. The role of grassland consists primarily of producing high quality feed for high quality food. The environmental services of grassland production will be a joint product of the principal function. But the provision of ecosystem services will be very important in future because this contributes to the sustainability of the agro-ecosystem as a “conditio sine qua non”. The often discussed approach consisting in seeing in grassland production as a mainly provision of ecological services with “food production as joint product” will not be the main case in future. Probably this will be either the case in regions with low opportunity costs (low profitability from the market) or/and high willingness to pay. The above mentioned changes will give more importance to agriculture as such. The market will – in the long run – offer a better economic support to agriculture than the world market did in the last 20 years. The rivalry between ecological aims of society and food needs will remain, may be with one difference: there will be a real trade-off. In the past the marginal value of food production was much lower than the marginal value of ecological services. This will not simplify the actual life of all experts, but help agriculture to be a highly appreciated part of economy and society.

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Non-marketable functions of grasslands

Starczewski K.[1], Affek-Starczewska A.[2] and Jankowski K.[1]

[1]*University of Podlasie, Grassland Department, Siedlce, Poland*
[2]*University of Podlasie, Agricultural Ecology Department, Siedlce, Poland*
E-mail: laki@ap.siedlce.pl

Abstract

The basic function of grasslands is to provide feed for livestock. Additionally, green areas play an important role in the cultural landscape. This article demonstrates the importance of their non-marketable functions. Extensively used meadows and pastures are distinguished by their high aesthetic value. Usually these are multi-coloured plant communities useful for various forms of recreation or as a pasture, where one can meet some interesting local breeds of ruminants or horses. Grasslands play an important role in the regeneration of human fitness; all the better, if they are compared with the more attractive elements of the landscape, such as, for example, afforestation and water reservoirs. The presence of such forms of land cover contributes to the development of various forms of tourism, including eco-tourism. The article presents protective and non-agricultural features of grasslands also.

Keywords: grasslands, aesthetic qualities, agricultural landscape, meadow, pasture

Introduction

The majority of Europe's countryside has been shaped by long-term agricultural use (Mander and Jongman, 1998). An inseparable element of these landscapes is traditionally used grasslands, one of the oldest forms of land use. Their origin is associated with the development of pastoral civilisations. The need to ensure food security inclines people to explore ways of obtaining food, regardless of the season of the year and possibly on a small area. Hence plants and animals needed to be domesticated.

Initially, the main function of grassland was providing feed for livestock, but meadows and pastures served other functions, such as forming part of gardens and parks (Majdecki, 1993) or becoming part of defence systems (Bogdanowski, 2002).

Grasslands are an indispensable element of the sustainable agricultural landscape; they serve the protection of biodiversity and the broadly comprehensive protection of the environment. The health and aesthetic qualities of grasslands are very important, especially in areas attractive to tourists. The value of grasslands can also be considered in terms of culture. Their place in the landscape is related to the history of agriculture, changes in the management and use of land, and the historical forms of settlement (Szałygin, 2000).

Meadows and pastures, as elements of the landscape, are associated with the immaterial value linked with the idea of national identity and artistic inspiration. The purpose of this article is to consider these features of grasslands which are not linked directly to agricultural activity, but in favour of maintaining the various green areas in the agricultural landscape.

Grasslands as part of the cultural landscape

Poland is a country in which grasslands cover about 1/5 of the total area of land used for agriculture. Compared to countries such as Germany, France, and the Netherlands, this is a relatively small percentage (Figure 1). The grasslands in the landscape of Poland and other countries of northern and eastern Europe have, at least in part, retained their semi-natural character, but they are disappearing very quickly (Muller 2002; Pärt and Söderström,1999).

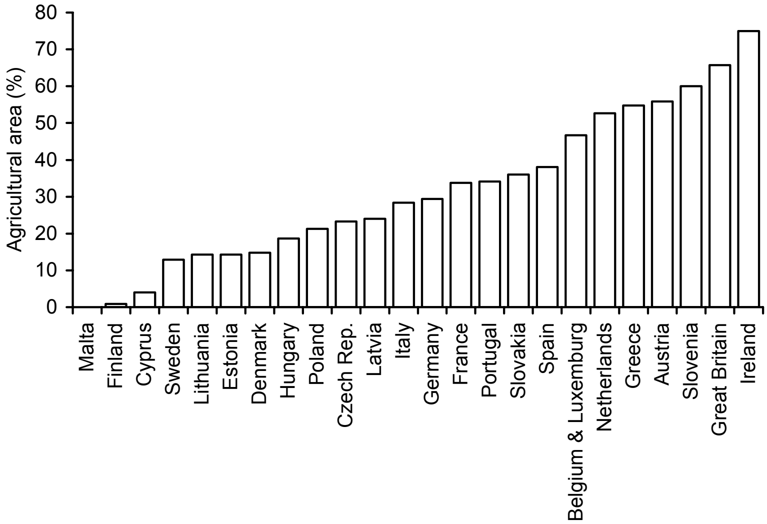

Figure 1. Percentage of grassland in the total agricultural area in the countries of the European Union (the CSO)

The role of meadows and pastures as the main source of food for animals is being reduced as a result of the decreasing population of ruminants and changes in farming technology. The reduction of pasture, both in the general area of the country and in the agricultural area, is noticeable (Figure 2).

Since 2000 the grassland area in Poland has decreased by 656 thousand ha; this is about 17% (the CSO). In addition to the reduction of the area of grasslands, the flora in these areas is also changing. The main factors which have a significant impact on these changes can include the cessation of their use for economic reasons (Kucharski, 2000), or the formal legal terms of the assumptions nature conservation in national parks (Stypiński and Piotrowska, 1997).

Increasingly, we see abandoned meadows and pastures, neglected and left to their fate. According to estimates, approximately 1/3 of grasslands are not used (Marks and Nowicki, 2002). A lack of appropriate care results, after a few seasons, in adverse changes in their flora, primarily as a result of uncontrolled succession. Areas that are disused create a depressing feeling the lack of host. The withdrawal of many species of wild animals from green areas was noted above, such as the number of species of birds from the Biebrza National Park after the cessation of mowing grass or changes taking place in the mountain pastures in the Tatra Mountains and Bieszczady Mountains after the cessation of grazing sheep (Reklewski, 2000). Even mowing meadows once during the season allows

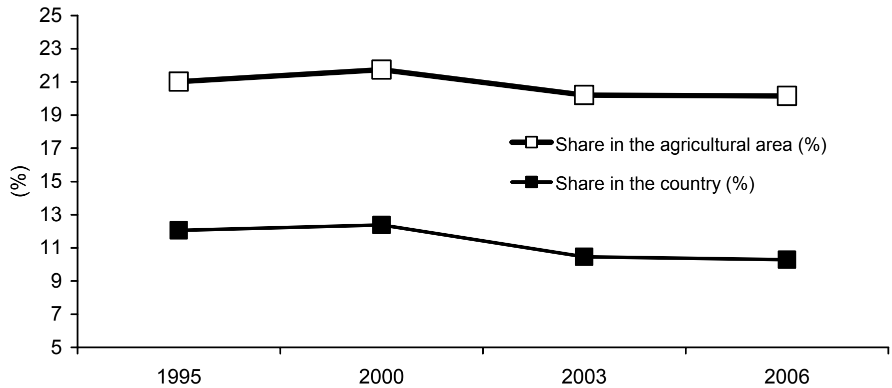

Figure 2. The share of the total grassland area of Poland and of the total agricultural area (the CSO)

valuable species for agriculture in terms of natural interest to be maintained in greenness and growth, such as *Anthoxantum odoratum, Dactylis glomerata*, *Phleum pratense, Lolium perenne*, and *Cynosurus cristatus* (Stypiński and Piotrowska, 1997).

If the turf is no longer cut valuable species are displaced by the mass of emerging ruderal and grass species of low economic value, for example *Deschampsia cespitosa*, which, in a few seasons, can almost completely take over a neglected meadow. At the same time, herbs disappear almost completely from abandoned meadows (Grygierzec and Radkowski, 2004).

The cessation of agricultural use of meadows and pastures can also encourage self-sown trees and shrubs that do not have any technological value, which put natural and man-made grassland communities that are valuable in terms of agriculture in the 'bush' (Ćwikła *et al*., 1999a).

Meadows and pasture communities are no less differentiated in terms of species composition than forest communities, but most of them are more accessible and easier to penetrate (Janecki, 1999). The floristic diversity of meadows and pastures results from the varied conditions of humidity, trophic level, and meadow farming.

For production the most valuable meadows and pastures are placed in the habitats included in the row *Arrhenatharetalia* (Wysocki and Sikorski, 2002). In terms of flora they are very rich and diverse communities. Various shades of green dominate in freshly-mown fresh meadows, mainly through grasses, where the background is a constant game of colours and forms of flowering plants. But this wealth depends in a large part on the intensity of use. Abundantly fertilised fresh meadows and pastures are relatively monotonous, because fertilisation is a factor favouring grasses, which supplant dicotyledonous plants (Kucharski, 2000).

Dicotyledonous plants such as *Leucanthemum vulgare*, whose white inflorescences appear particularly attractive before the first mowing, or the yellow flowering *Ranunculus repens*, *Taraxacum officinale, Lotus corniculatus*, and *Lathyrus pratensis* give meadows the appearance of coloured carpets, dominated by inflorescences of grasses, creating a delicate voile, whose colour is dependent on the dominant species and the phase of their development (Kozłowski, 2002). In the spring fresh meadow are decorated with white capitulum *Bellis perenis*, and then *Achillea millefolium*, pink *Trifolium pratense*, and *Campanula patula*, and the unique and beautiful blue *Veronica chamaedrys*. In late summer these meadows are decorated with violet *Geranium pratense* and white blooming *Heracleum sphondylium* (Trąba, 1999).

Extensively used fresh meadows are a valuable component of landscapes used for recreational purposes, because in contrast to forest communities there are no restrictions on access to direct sunlight. Semi-natural grass communities produce a lot of oxygen, about 100–150 dt ha^{-1} $year^{-1}$ (dry-ground forests, depending on the type, produce 140–350 dt ha^{-1} $year^{-1}$), as well as various essential oils, organic acids, and esters (Krzymowska-Kostrowicka, 1991). Simultaneously a grassy surface can absorb about 1.5g ha^{-1} h^{-1} carbon dioxide. It means that 25 m^2 of grassland can absorb and use for its own purposes all the CO_2 which one person produces by exhalation in one hour (Krzymowska-Kostrowicka, 1991).

Grasslands serve a protective function for the soil. Thanks to them the results of wind erosion and water erosion are reduced. Indirectly, then, grasslands also protect water reservoirs against sedimentation by eroded materials (Carrow, 2005).

Grasslands also have filtration and detoxification properties. These relate to the absorption of gases and heavy metals (including lead, strontium and cadmium) which are rendered inactive and deposited and partly neutralised in the root layer. For this reason green areas can be treated as a kind of biological filter that protects surface waters (Adams and Saxon, 1979).

The microclimatic function of a green area depends on lowering the temperature of the air on hot days by about 5–7°C and an increase in humidity of 6–13% over the grass surface as compared to a hard surface (concrete, asphalt). This is the result of the relatively large surface of transpiration of grasslands. During the day transpiration may be between 100 g to 200 g of water per hour. The consequence of this process is a reduction in summer of the daily fluctuation in the temperature of 2–4°C and a significant reduction in surface temperatures in the grassland compared to hard surfaces (asphalt) of up to 20°C (Brodniewicz, 1974). The influence of grasslands on the temperature and humidity of the lowest air layer is greater when the plants are higher and more compact (Wysocki, 1994).

The height and compactness of the turf also affects the inhibition of wind speed, by about 10% compared to a hard surface. It makes it difficult to move dust from one place to another and reduces the creation of "dust storms". The vegetation occurring on grasslands is recognised as a factor in promoting a hygienic environment (Wysocki and Medrzycki, 1976; Skorupski, 1984; Wysocki *et al*., 1984).

Grasslands have the ability to absorb odours and are self-cleaning (Wysocki and Korzeniewska, 1980). Their surfaces absorb large quantities of even the most annoying odour, regardless of whether the odour comes from organic sources or as the result of the treatment of burned materials. Even small grass surfaces – of a few 100 m^2 – have a deodorant impact on the lower atmospheric layers.

A very important factor determining comfort and opportunities for recreation is noise. Its intensity decreases with an increase in the distance from the source of noise emissions. Changing the ground cover from a hard (for example concrete) surface to grass results in the reduction of noise by 3 dB (Bolund and Hunhammar, 1999).

Fertile pastures are generally situated both on lowlands and the lower forest zone in the mountains. The main factor shaping these communities is not, as in the case of meadows, mowing but intensive grazing.

In the plant composition of pastures there are many species resistant against mechanical damage and defoliation, such as *Lolium perenne*, *Agrostis capillaris*, *Poa annua*, and dicotyledonous plants: *Bellis perennis*, *Trifolium album*, *Potentilla anserina*, and *Potentilla reptans.*

Many landscapes are shaped by the presence of animals, such as mountain and xerothermic grasslands (Fijalkowski *et al*., 2000). Pastures are a special variety of landscape in which animals bring a traffic element. The relationship between animals and the grass grazed by them influences the rich flora found in pastures. Thanks to this the possibility of protecting certain endangered species appears, for example, the last habitat in Poland of *Plantago coronopulus* (Songin, 1999).

The layout of the pasture, the kind of fence, and the plantings accompanying sodding areas are not without significance. Plantings are used by animals for protection against the sun or wind and also as a place to rest (Schalitz *et al*., 1999). Traditional grazing systems form the basis of eco-tourism, mainly by the restitution of local breeds of livestock and products (Warda and Rogalski, 2004). Traditionally used semi-natural pastures are nesting places for many species of birds, including those which can only find favourable living conditions there (Pärt and Söderström, 1999).

Communities whose existence is associated with the maintenance of grazing animals are very rich in the floristic respect. Among these belong steppe grasslands developed on fertile soils. These communities are among the most beautiful herbaceous communities in our country, with a variation of colours and aromas throughout the growing season. Species associated with these communities are the violet-flowering *Salvia pratensis*, *Reseda lutea*, *Thalictrum minus*, *Galium verum* with yellow flowers, or the white *Trifolium montanum*. Some of the plants growing on grasslands are medicinal plants which were collected by the local population both for personal use and for sale (Fijałkowski *et al.,* 2000).

In areas attractive to tourists pastures may be used for recreational purposes as areas of high natural absorbance. After adaptation this can be as high as 100 persons ha^{-1} day^{-1} (for comparison a dry-ground forest can take 6–15 persons ha^{-1} day^{-1} without damage to communities, an oak forest – 4 persons ha^{-1} day^{-1}). In the French Alps and Pyrenees about 65% of the pastures are crossed by hiking paths with designated places for rest and shelter for tourists. In the winter these areas are used for winter sports (Warda *et al*., 2004).

Similar activity, although very informal and on a much smaller scale, can be observed in Poland. Pastures are often used as sports fields. In regions where the relief allows, ski runs are organised with the necessary infrastructure. Xerothermic grasslands may take a considerable tourist traffic (20–40 persons ha^{-1} day^{-1}), but the penetration should be restricted because of the unique nature of these communities and their sometimes less convenient location on slopes (Krzymowska-Kostrowicka, 1991). The presence of different species and breeds of local animals such as sheep, fallow deer, and even lambs may be important for the attractiveness of pastures (Ćwikła *et al*., 1999b).

Wet meadows are equally biodiverse and interesting from the aesthetic point of view, but in economic terms they are much less important than fresh meadows. Extensively used wet meadows come into existence in flooded river valleys and depressions in the land, accompanied by the increasingly rarely seen midfield water reservoirs. *Caltha palustris*, *Ranunculus acris* or *Crepis paludosa* stand out in yellow against the dark green background. Beside them you can find intense violet and pink *Lychnis flos-cuculi*, *Cirsium rivulare* and *Polygonum bistorta* with its unusually magnificent corncob-shaped inflorescence.

Because of the wet and soft soil, in principle, they are not suitable for penetration, except by marked paths and eventually foot-bridges. Dryer areas may take about 5 persons ha^{-1} day^{-1}, but their presence, particularly during the flowering period, considerably raises the aesthetic value of the landscape, especially in conjunction with ponds, lakes and rivers, or in the vicinity of afforestations. A factor limiting the availability of these kinds of meadows is the massive emergence of mosquitoes and other insects (Krzymowska-Kostrowicka, 1991).

The role of grasslands is not limited to their visual aspect in the landscape. Research shows that grassy vegetation largely using nitrogen fertilisation limits its leaching (Kopeć, 1999) and may contribute to the treatment of groundwater (Baryła and Kotowski, 1999). Meadows and pastures placed along roads in rural areas are a buffer zone between the hardened surface and fields under cultivation (Pauwels and Gulinck, 2000).

Wet meadows accompanying midfield ponds are a natural obstacle to access to water, and also capture a large part of the biogens flowing from agricultural land, and therefore limit the rate of degradation of midfield small water reservoirs (Kochanowska and Ramiszewska, 1999).

Because of their high demand for water, of the order of 450 to 700 mm per year (Roguski, 1997), grasslands limit infiltration into the depths of the soil profile and thereby minimise the migration of nutrients out of the zone of rootworm plants, and the danger of their entering into groundwater (Roguski, 1997). In research conducted in the area of the Małe Pieniny outflow coefficients from meadows in July and August ranged between 1.5% and 11.6% of rain precipitation, while the outflow from fallow land represented 31.8% and 33.4% of rain precipitation (Misztal, 1997).

Permanent grassland is also characterised by very good anti-erosive properties – 100 times better than plants grown in crop rotation and 200 times better then roots (Tałataj, 2001). Especially in areas where the earth's surface has been heavily sculpted they stabilise the soil and absorp significant amounts of rain water, which can prevent floods in the lower parts of the mountains (Grynia *et al*., 1999).

Conclusion

Meadows and pastures are special places in the agricultural landscape. Those remaining in economic utilisation are much more diverse in terms of species and habitat than field crops. There is no doubt that next to intensively used meadows and pastures, those grasslands which cant agricultural value should also find their place, because they perform various functions.

(1) Extensively used meadows and pastures are characterised by a wide variety of habitats, while providing support for many species of plants and animals.

(2) Multicoloured meadows and pastures in the statement of afforestation and ponds influence the attractiveness of the landscape, such as the presence of different, often local species and breeds of animals on pastures.

(3) Grasslands, especially pastures, as a general rule have major recreational absorbance and can be used to practise various forms of leisure activities, such as games, hiking, and winter sports.

(4) Because of their filtration and detoxication properties, stimulant effects on the immune and physical system, and aesthetic values, communities of meadows and pastures are important in the regeneration of human fitness.

(5) Grasslands, because of their highly developed root systems and heavy demand for water, protect against soil erosion and nutrient leaching into the depths of the soil profile.
Semi-natural meadows – pasture communities – however require careful protection, taking into account the specific requirements of habitat and care. Unfortunately, more and more pasture which has lost its economic importance is subject to rapid degradation. In Poland, as in other European countries, protecting such habitats has become one of the main objectives of the sustainable development of the agricultural industry.

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Farm structure and grassland phytodiversity – A comparison of beef and dairy cattle farms

Stroh H.G.[1], Klimek S.[2] and Isselstein J.[3]

[1]*University of Göttingen, Research Centre for Agriculture and the Environment, Göttingen, Germany*
[2] *Federal Research Institute of Rural Areas, Forestry and Fisheries, Johann Heinrich von Thünen-Institute, Institute of Biodiversity, Braunschweig, Germany*
[3]*University of Göttingen, Institute of Crop Science, Department of Grassland Science, Göttingen, Germany*
E-mail: Hans-Georg.Stroh@agr.uni-goettingen.de

Abstract

In this study we investigated the influence of two different livestock systems on phytodiversity in temperate managed grassland. Within our study area a total of 30 farms were selected that were grouped into 15 spatially neighbouring pairs, each consisting of one beef and one diary cattle farm. Plant species richness and species cover was estimated at eight grassland fields within each farm (*n* = 240). At the field scale our results revealed that species richness (α-diversity) was significantly higher in beef cattle grasslands. Soil nutrients (phosphorus and potassium content) did not differ significantly between fields of the two different farm types while the nitrogen input was significantly lower in the beef cattle fields. At the farm level (γ-diversity) no difference in species richness was found, which indicated that dairy farms generally have potential to maintain or restore species rich grassland at least at the whole farm level.

Keywords: α-diversity, γ-diversity, managed grassland, nitrogen input, whole-farm approach

Introduction

Local abiotic site conditions and management influences have been pointed out as the main drivers for species diversity in managed grasslands (Klimek *et al*., 2007). Recent studies have further stressed the importance of the effect of farm structure on patterns of plant diversity (Andrieu *et al*., 2007).
The main objective of this study is to investigate the effect of farm type (beef vs. dairy cattle farming) on patterns of diversity in managed grasslands. We hypothesised that beef cattle farms manage their grassland fields less intensively than dairy farms due to the lower feeding requirements of the livestock and therefore would have higher plant species diversity.

Materials and methods

The study area encompassed the district of Northeim, a region of rural structure, located in southern Lower Saxony, Germany. Mean annual temperature of the area is 8.5°C, mean annual precipitation ranges from < 600 to 1,050 mm**.** The geological substrate is formed by both calcareous and siliceous bedrock and loess- and fluvial sediments.

In order to test the effect of farm type on plant diversity, we selected a total of 30 farms within our study area that were grouped into 15 spatially neighbouring pairs, each consisting of one beef and one diary cattle farm. On each farm eight fields of permanent grassland were sampled, representing different management types (pasture, mown pasture and meadow) of *Arrhenatheretalia* communities.

At the field level, vegetation relevés of 25 m^2 plots were made within floristically homogenous stands to analyse species composition and abundance. We calculated the number of plant species (α-diversity) and the species evenness. At the farm level, we further calculated species richness by pooling vegetation data from all eight fields within a respective farm (γ-diversity).

At the farm level, open questionnaires were used to obtain data on farm structure, bovine standard livestock units (SLU) and management practises. Further, data of livestock, amount of forage and grassland area were calculated using local tables of animal nutrition to estimate the feeding requirement of the farm livestock per ha grassland (NEL MJ ha^{-1}), further referred to as farm specific pasture performance.

At the field level, soil samples were taken at a depth of 0–10 cm to measure phosphorus and potassium content using the CAL-method. A quantitative measure of nitrogen input per field was estimated using records from the farmers on fertilisation, stocking densities and grazing cycles. These records were converted to N-values (kg N ha^{-1} yr^{-1}) by using local standardised tables of N-contents.

Vegetation data was analysed using the TURBOVEG-software. Statistical analyses were conducted using the R-2.6.0 software.

Results

The management variables at the farm level did not differ significantly between the two farm types (Table 1). The pasture performance varied widely within each farm type, in particular within the grasslands managed for dairy production.

Table 1. Farm-level variables (mean and range values) related to the farm structure. *P*-values were derived from a Wilcoxon rank-sum test (n.s. = not significant)

	Beef cattle farms (*n* = 15)			Dairy cattle farms (*n* = 15)			*P*-level
	mean	min	max	mean	min	max	
Grassland area (ha)	24	5	75	35	11	76	n.s.
No. grassland fields	17	8	38	20	8	52	n.s.
SLU ha^{-1} grassland	2	1	4	3	2	4	n.s.
Pasture performance (NEL MJ ha^{-1})	19,642	1,727	38,896	31,390	246	64,269	n.s.

At the field level, the calculated N-input was significantly larger in dairy cattle grassland fields compared to those of beef cattle (Table 2). The soil related variables P and K content did not differ significantly between the two types of cattle farming.

The accumulated species richness across the eight relevés per farm (γ-diversity) did not indicate a significant difference between the farm types. No correlation was found between γ-diversity and pasture performance (beef: $r_s = -0.41$, $P = 0.13$, dairy: $r_s = 0.17$, $P = 0.56$).

Table 2. Field-level: Soil-nutrient variables (mean and range values). *P*-values were derived from a Wilcoxon rank-sum test

	Beef cattle grasslands (n = 120)			Dairy cattle grasslands (n = 120)			*P*-level
	mean	min	max	mean	min	max	
Nitrogen input (kg N ha^{-1})	71	0	339	167	0	468	***
Phosphorus (mg 100 g^{-1})	7.1	1	31	7.3	1	27	n.s.
Potassium (mg 100 g^{-1})	10.4	1	63	9.3	2	77	n.s.

*** = $P < 0.001$, n.s. = not significant

A total of 199 taxa, including 20 bryophytes, were detected in our relevés. On the fields of beef cattle farms, 161 plant species were found, and on fields of dairy cattle farms 154 species. The comparison of species richness per plot (α-diversity) indicates a significantly higher number of species richness for beef cattle grasslands ($P < 0.001$) (Table 3). The evenness was also higher for beef cattle grasslands but only at $P < 0.05$. No correlation was found between N-input and α-diversity of beef cattle fields ($r_s = -0.05$, $P = 0.58$). Dairy cattle fields showed a weak, but significant correlation ($r_s = -0.22$, $P = 0.02$).

Table 3. Plant diversity measures (mean and range values). *P*-values were derived from a Wilcoxon rank-sum test

	Beef cattle grasslands (n = 120)			Dairy cattle grasslands (n = 120)			*P*-level
	mean	min	max	mean	min	max	
Species richness (α-diversity)	19	7	40	16	5	35	***
Evenness (α-diversity)	0.70	0.43	0.88	0.67	0.25	0.88	*
	Beef cattle farms (n = 15)			Dairy cattle farms (n = 15)			
Species richness (γ-diversity)	50	31	79	47	34	71	n.s.

*** = $P < 0.001$, ** = $P < 0.01$, * = $P < 0.05$, n.s. = not significant

Discussion

In our study, plant species richness (α-diversity) was significantly higher in fields managed for beef cattle production compared to fields managed for dairy production. This result indicates that beef cattle farms support a higher level of plant diversity than cattle farms. The difference might be attributed to the impact of N-input, which was significantly higher in dairy cattle grasslands. However, the correlation between N-input and species richness was rather weak in both farm types. As we did not found any significant differences in soil nutrients, beef cattle farming might have a positive effect on plant diversity. The high mean value of species evenness within both farming types indicates that community composition was mainly determined by relatively few but evenly distributed species.

At the farm level, the difference in species richness (γ-diversity) between both farm types levelled off. Moreover, the total species number of each farm type was rather similar and 116 out of 199 species occurred in both farm types. Therefore, our results indicate that dairy farms generally have potential to maintain or restore species rich grassland at least at the whole farm level.

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Historical maps as a tool for the ecological evaluation of grassland

Zarzycki J.[1], Misztal A.[1] and Kopeć M.[2]

[1]*Agricultural University of Cracow, Department of Ecological Bases of Environmental Engineering, Cracow, Poland*
[2]*Agricultural University of Cracow, Department of Agricultural Chemistry, Cracow, Poland*
E-mail: janzar@ar.krakow.pl

Abstract

The protection of semi-natural plant communities requires an inventory of their occurrence and the present state of their preservation. The aim of this work is to assess the possible use of historical maps for a preliminary determination of high nature value areas. Based on 344 phytosociological relevés done in the Beskid Sądecki, it was found that 82% of the plots classified as rich floristic community of *Gladiolo-Agrostietum*, and 94% of the plots categorised as mat grass communities (*Hieracio-Nardetum*) were present in areas which had been used as grasslands in the 1980s. In turn, 58% of the floristically poor communities of ryegrass meadows (*Arrhenatheretum*) occurred in areas which had been arable lands in that period. Readings from the maps, which date from the second half of the 19th century, showed that land use methods at that time were not closely connected with the current plant community. It was found that no impact had been made on the number of species by the land use pattern in the past, but in the former arable lands, there were fewer protected species. It is suggested that a period of at least 30–40 years of land utilisation as grassland is necessary for developing floristically rich meadows.

Keywords: mountain grassland, land use history, biodiversity

Introduction

Grasslands in the mountains are characterised by large species diversity. Many of them belong to the richest floristic plant communities in Europe (Pärtel *et al.,* 2005), and were included in Annex I of the Directive as habitats of importance to the Community. Shrinkage of the area of high nature value grasslands has been observed throughout Europe, caused by increased intensive utilisation. In the Polish Carpathians the principal threat to meadows and pastures that are worthy of protection is abandonment of utilisation. In undertaking protecting measures, the first stage is an inventory of the existing resources. In Poland, apart from some protected areas, this type of inventory is incomplete. Although the grassland area in the mountains for many years has been maintained on the same level, a considerable part of it has recently come into being as arable land (Zarzycki, 2008). The "old" grasslands, in turn, have undergone transformation into forest area. Many studies have proved that species diversity is connected with the duration period of a meadow's utilisation (Ejrnæs *et al.,* 1995; Austrheim *et al.,* 1999). For analyses of land use patterns, archive maps can be used (Cousins, 2001). Grasslands in the Polish

Carpathians are mosaics of small surface areas of various past land use patterns, and of diversified nature value. This considerably hampers searches for nature value areas. The objective of this work is to assess the possible use of historical maps for a preliminary determination of high value nature areas, based on the grassland's duration period.

Materials and methods

Research was done in the Radziejowa Strip that is a part of the Sądecki Beskid. Grasslands occur at altitudes that range from 340 m to almost 1,000 m a.s.l. The largest area is occupied by a specific brown soil (leached and gleyed). The average annual temperature varies from 3°C to about 1.5°C in the summit parts of the mountains, and the total annual precipitation ranges from 800 mm in river valleys to 1,100 mm on the mountain tops.
In the study area, 344 phytosociological relevés of 100 m^2 were made. The sites of the conducted surveys were selected in a manner which reflects the diversity of plant communities occurring in the grasslands of studied areas, which also included the highest variability range of the habitat factors. The classification of the plant communities was based on a numerical analysis conducted by the MULVA 5 program (Wildi *et al*., 1996).
In order to determine the land use pattern of the areas in the past, cadastre maps were used (dating from the mid-19th century, prepared on a scale of 1:2,880), as well as topographical maps on a scale of 1:10,000 dating from the 1980s. Species nomenclature followed that of Mirek *et al.* (1995) and syntaxon nomenclature that of Matuszkiewicz (2005).

Results and discussion

The grassland plant communities were classified into three basic plant associations. The association of *Arrhenatheretum* occurred in the sites that were the most favourable from an agricultural point of view. It is characterised by a dominance of a variety of cultivated grasses such as: *Dactylis glomerata*, *Arrhenatherum elatius* and *Phleum pratense*. In the sward a large share contained cultivated leguminous species, e.g. *Trifolium pratense* and *T. repens*. These communities are distinguished by an average number of 35.9 species per relevé, but they are usually the common species. 67% of the phytosociological relevés classified this association as being on land which had been used as arable fields in the mid-19th century, and 58% of the surveys were in that category in the 1980s (see Table 1). The *Gladiolo-Agrostietum* association was described by a rich species composition (on average 39.8 species per relevé). Depending on the habitat and utilisation conditions, apart from the dominant grasses such as *Agrostis capillaris* and *Festuca*

Table 1. The share of phytosociological relevés classified into particular communities according to the land-use pattern in the past (%)

	n	Land use			
		mid-19th century		1980s	
		arable land	grassland	arable land	grassland
Arrhenatheretum	151	67	33	58	42
Gladiolo-Agrostietum	139	50	50	18	82
Hieracio-Nardetum	54	24	76	6	94

n – number of relevés

Table 2. The share of phytosociological relevés with the protected plant species according to the land-use pattern in the past (%)

	n	Land use			
		mid-19th century		1980s	
		arable land	grassland	arable land	grassland
With protected species	159	40	52	26	54
Without protected species	185	60	48	74	46

n – number of relevés

rubra, many species of herbs and legumes occurred. This community developed on land that was both in the form of arable land as well as grasslands in the mid-19th century. The *Hieracio-Nardetum* association is dominated by *Nardus stricta* and species of poor habitats such as *Potentilla erecta* and *Luzula luzuloides*. These communities are characterised by poor growth and few species (on average 29.5 per relevé). 76% of the patches in this association occurred on land that had previously been grassland (in the mid-19th century), and 94% of them had been grasslands in the 1980s. No relationship was found between the number of species per relevé and the land use method in the past, which is in contradiction with the results reported from other countries, where the duration of meadow utilisation significantly affected the number of recorded species (Austrheim *et al.,* 1999; Bruun *et al*., 2001). In the studied area the patches with the smallest number of species are typical both of the *Hieracio-Nardetum* and *Arrhenatheretum* associations. The number of species is not the only decisive criterion for the high nature conservation value (Critchley *et al.,* 2002). Analysing the appearance of legally protected species, it has been found that protected species occurred only in 26% of the relevés that had been arable lands in the 1980s, and in the case of grasslands from that period, this share amounted to 54% (see Table 2). Referring to the land use pattern, diversity significantly decreased from the mid-19th century. In the studies conducted in Sweden, it was proved that the greatest impact on vegetation was made by land use methods dating from earlier than 200 years ago. It seems that in the terrain under study the high nature value communities do not appear on areas marked as arable land on maps dating from the 1980s and therefore utilised as a meadow for a period shorter than about 30 years.

Conclusion

Land use method in the past, read from historical maps, is not unequivocally connected with high conservation value communities. But it still enables the determination of areas in which the occurrence probability of such communities is high, and such terrains where it is low. The most suitable maps can be derived from different historical periods depending on the investigated region.

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Permanent grassland as turf grass for landscape, sport and tourism. Research needs and future perspectives in Austria

Herndl M., Krautzer B. and Schaumberger A.

Federal Research and Education Center for Agriculture, Raumberg-Gumpenstein, Austria
E-mail: markus.herndl@raumberg-gumpenstein.at

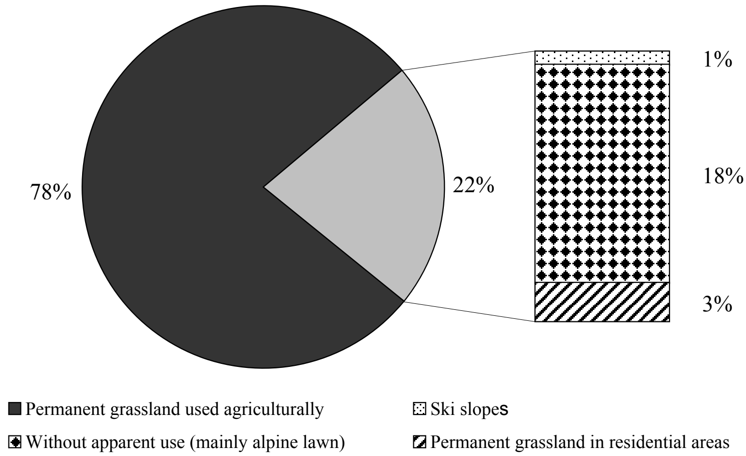
Abstract

Turf can be defined as permanent grassland that consists mainly of perennial grass species and is not used agriculturally. In Austria about 6% of the federal territory is covered with turf in the broadest sense. Skiing, golf and hiking tourism basically depend on the beautiful appeal of the turf. Research is needed to meet the requirements of touristic facilities, as well as the increasing expectations of society on environmental protection and the requirements of turf managers and producers. Discussions with turf providers, managers and users resulted in the following three main research areas and needs for Austria: (*i*) turf variety testing, (*ii*) water and pest management, (*iii*) environmental quality. Turf variety testing in this context means the establishment of a testing system subsequent to that in Germany, which operates with growth trials for the use of varieties for turf. To meet site-specific turf water requirements in Austria, the optimization of management practices that consider mowing height and frequency, variety selection and nutrient regime is the priority research need. The main research area regarding pest management should be the pathogen-host-environment interactions of the two main fungi (stem rust, snow mould). As management of turf in urban areas can have implications for natural resource conservation, research on input-use-efficiency followed by developing site- and lawn-specific guidelines that maximize environmental benefits is needed.

Keywords: lawn, permanent grassland, turf grass, turf research, turf variety

Introduction

According to its use, permanent grassland can be divided into agriculturally used grassland and grassland that is not used agriculturally. Agricultural permanent grassland according to EG regulation Nr. 796/2004 is defined as areas which are used for cultivation of grass or other forage plants that are manually or naturally sown and have not been a component of a crop rotation of an agricultural holding for at least five years. Permanent grassland which is not used agriculturally means, in principle, different types of lawn consisting mainly of perennial grass species. In Austria in 2006, 78% (ca. 17,800 km^2) of permanent grassland was used agriculturally, whereas approximately 22% (ca. 5,000 km^2) were allotted to alpine lawn (without use), ski slopes, sports and recreational facilities (Figure 1). Permanent turf grassland not only adds to our quality of life, but in some parts of Austria it is also an important basis for tourism facilities. A more prosperous population, especially in Eastern Europe, is increasingly demanding more from current recreational facilities such as golf courses and ski slopes. New facilities will have to be constructed and turf will play an important role in recreation in touristic areas. The growing expectation of tourism and society for turf grass requires research on management strategies to meet economic and environmental aims.



Source: ÖSTAT (2005) Landcover Austria, Geographie Klagenfurt (M. Seger)

Figure 1. Usage of permanent grassland in Austria

Material and methods

Background of turf research in Austria. Up to 1990, turf research in Austria was mainly charged by regional institutions. The main research and testing station was in Rinn, Tyrol. At this station, turf varieties were tested for their use in lawn turf and questions regarding management of landscape lawns (skiing areas) were considered. Since the early nineties, turf research has mainly taken place in private companies, for example turf producers or turf providing enterprises. Comprehensive discussions with Austrian turf providers, managers and users indentified three main research areas: (*i*) turf variety testing, (*ii*) water and pest management, and (*iii*) environmental quality.

Results and discussion

Turf variety testing. *Present status* – During the last decades many turf grass species were treated by breeding companies and as a result, for some species (e.g. *Lolium perenne*), many varieties were released (Bundessortenamt, 2006). To use the best adapted varieties for a site or a management system is an important part of the best management practice. In the best case, the varieties should require reduced inputs of water, pesticides, fertilizers and labour, withstand biotic and abiotic stresses, while providing the pleasant lawn desired by users. Up to now there has been no commercial or governmental turf grass testing station or breeding company situated in Austria. Thus, when using varieties, greenkeepers, turf producers and turf grass sellers have to rely on descriptive variety lists from other countries or to test the varieties in their own field experiments.
Research needs – Facing the total absence of testing and examination facilities for turf varieties, the first step would be to establish an independent and centralized testing organization. Subsequent to the testing system in Germany, growing trials for the use of varieties for turf should be installed. The screening test should be done according to the applicability for (*i*) park and ornamental lawns, (*ii*) deep cutting, (*iii*) sports ground use, or (*iv*) landscape lawn (Bundessortenamt, 2004). Furthermore, main goals should be to

test site-adaptability and abiotic and biotic stress tolerance of the newly released varieties under Austrian conditions.

Water and pest management. *Present status* – To meet turf grass needs, water management is a key factor. It primarily affects turf growth and nutrient use efficiency, but also the losses of pesticides and nutrients to the environment. For some turf varieties fundamental plant-water relationships are known, but the related parameters can differ and interact with site-specific parameters such as soil properties, atmospheric evaporative demand or the irrigation method (Leinauer, 1997). Considering the hydrological atlas of Austria it can be noted that the federal territory can be divided into a relatively wet West and inner alpine part, and a dry South and North-eastern part (Fürst *et al*., 2007). Grass management, for example mulching, is suitable for continental weather conditions in the East but not for the high-precipitation conditions in the West. The most important problems associated with the use and management of turf grass are caused by fungi. Currently, the accurate diagnosis of turf diseases relies more on techniques based on isolation and identification of fungal pathogens than on the diagnosis based on expression of symptoms that can lead to misidentification (Smiley *et al*., 2005). In Austria, the main pathogens are stem rust in the dry eastern part, and snow mould in the wet western part. These fungi reduce aesthetic appeal and decrease property value.

Research needs – Turf water-use efficiency could be increased by a more site-specific management and monitoring. To meet site-specific turf water requirements in Austria, management practices should be developed that deal with mowing height and frequency, variety selection and nutrient management. Furthermore, an improved irrigation technique for a wide range of soils and environments that minimizes on- and off-site water concerns would be a great achievement. The investigation of pathogen biology and as well as the pathogen-host-environment interactions of the two main fungi occurring in Austria (stem rust, snow mould) should be the first research aims. Applying and developing new biological tools for the identification of fungal, bacterial or viral pathogens should accomplish the research needs regarding pest management.

Environmental quality. *Present status* – In Austria, turf systems such as city parks, residential lawns, turf farms and golf courses are an integral component of the landscape. To enhance their functional and aesthetic value they require substantial inputs of water, fertilizers and pesticides with potential consequences for environmental safety. Studies on movement of nutrients have focused on a small scale such as fairways or single golf greens and suggest that properly managed turf systems may not cause contamination of surface and subsurface water (Hardt, 1994).

Research needs – To determine and promote the environmental, cultural and economic benefits of turf, research regarding efficiency of management practices to reduce movement of nutrients and pesticides is needed. A main focus in Austria should be to increase input-use-efficiency including rate, time and methodology and developing region- and species-specific guidelines for turf production systems that maximize environmental benefits. Based on this, an optimization tool for turf managers for greatest economic return that comply with local and regional environmental regulations and standards should be made.

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Diversity of dung beetles (Scarabaeoidea, Hydrophilidae) in mountain pastures

Šlachta M., Frelich J. and Tonka T.

University of South Bohemia, Faculty of Agriculture, České Budějovice, Czech Republic
E-mail: slachta@zf.jcu.cz

Abstract

The diversity of the community of dung beetles was examined on three dairy farms in the Czech Republic at an altitude from 575 to 790 m a.s.l. The beetles were collected in baited traps in six sampling periods from April to October 2008. On each farm the traps were placed in two pasture sites and in one forest site and baited simultaneously. In total thirty-nine species of coprophagous Scarabaeoidea and Hydrophilidae were recorded in the samples. There were no significant differences in species composition between farms or between pasture and forest sites. Species abundancy and Shannon index of diversity (H′) did not differ between the farms ($P > 0.05$), but it was significantly higher in pasture than in forest sites ($P < 0.01$). This indicated a preference of most dung beetles for open pastures. Grazing thus substantially contributes to a diversity of dung beetles in mountains.

Keywords: dung beetles, diversity, Scarabaeoidea, Hydrophilidae, pasture, cattle

Introduction

Dung beetles are a highly specialized trophic group adapted to consumption of herbivore dung (Hanski and Cambefort, 1991). They play a key role in nutrient cycling in pastures (Gittings *et al*., 1994). Wide-spread abandonment of grazing in the last century resulted in a reduction of species diversity and in disappearance of some species of coprophagous beetles in the Czech Republic (Juřena *et al*., 2000). In mountain areas a seasonal cattle pasture has however been retained and the expansion of beef husbandry in the last two decades has lead to a further development of grazing. Little attention has been paid to coprophagous fauna in mountain pastures. The aim of this study was to examine the diversity of dung beetles on cattle pastures where the grazing had not been interrupted in the past and where a well preserved coprophagous fauna may have been expected.

Material and methods

The experiment was carried out on three dairy farms in Novohradské hory and Šumava Mountains in the south-west of the Czech Republic. The farms were located at an altitude of 575, 790 and 730 m a.s.l. in about 50 km distance. Seasonal grazing by approximately 100 cows of the Czech Fleckvieh and Holstein breeds has been practised there continuously for more than forty years. The grazing started in May and finished in October. The pasture swards appertained to the *Lolio-Cynosuretum* association (Frelich *et al*., 2006). Pastures were surrounded by a landscape with diverse habitats formed by forests, meadows, crop production fields and small littorals. The beetles were collected in pitfall traps baited with 1.5 l of fresh cow dung, which was collected from the stalls. The set of three traps in one-meter distance was used in a single sampling trial and the material collected in the three traps was pooled. On each farm the triplets of traps were placed in two pasture sites in 1-km distance (Pasture 1, Pasture 2) and in adjacent coniferous forest up to 300 m from the Pasture 2 site and about 10 m inside a forest. Sampling was executed simultaneously in six one-week sampling periods from April to October 2008. Collected material was identified to species and specimens were counted. Beetles of Scarabaeoidea in samples appertained to families Scarabaeidae and Geotrupidae. The nested ANOVA (Statistica, StatSoft, Inc., 2005) was used for evaluation of the effect of the sampling Period (1–6), Farm and Site (Site nested in Farm) on species abundancy (log-transformed numbers of individuals) and on diversity of community (value of Shannon index of diversity; Magurran, 1988). Since the Farm effect was found to be insignificant ($P > 0.05$), two-way ANOVA with factors of Season and Site was applied followed by post-hoc Tukey's test.

Results and discussion

In total 21,366 specimens of thirty-nine coprophagous species were identified in samples. Four species appertained to Geotrupidae, twenty species to Scarabaeoidea and fifteen species to Hydrophilidae families. This comprised 27% and 68% of the coprophagous species of Scarabaeoidea and Hydrophilidae respectively in the Czech Republic (Král, 1993). The species composition was similar on farms (thirty species common for all of them), which indicates a relatively uniform composition of the community in the examined area (over distance of about 150 km). Species abundancy and community diversity (Shannon index) did not differ between the farms ($P > 0.05$; nested ANOVA). However, the sampling period (1–6) and the sampling site (Pasture 1, 2 and Forest) revealed significant effects on both the abundancy and diversity ($P < 0.001$ and $P < 0.01$ for Period and Site, respectively). The seasonal effect was expected and could be well explained by species-specific differences in the seasonal patterns of adult activity (Gittings and Giller, 1997). Two species of *Aphodius prodromus* and *Aphodius sphacelatus* contributed 51% of the total number of collected individuals, although their activity was restricted to autumn and (mainly) early spring. On the other hand a typically sum-

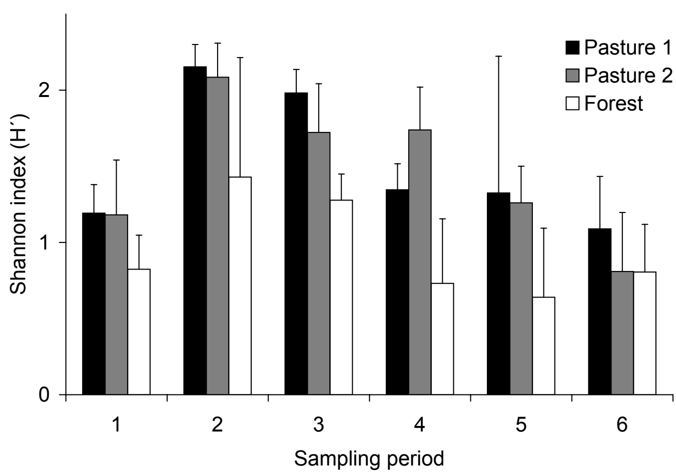

Figure 1. The mean values and standard deviations (n = 3, data pooled from three farms) of Shannon index of diversity in collected material from three sampling sites inside a farm area (Pasture 1, 2 and Forest) from six sampling periods in 2008 (1 – April, 2 – May, 3 – June, 4 – July, 5 – September, 6 – October)

mer peak of activity was recorded in *Aphodius rufipes* (7% of all collected specimens) and *Aphodius rufus* (see also Šlachta *et al*., 2008). Highest diversity was revealed in May samples and it declined gradually in next sampling periods until October (Figure 1). Significantly lower abundancy and diversity was recorded in forest in comparison to pasture sites ($P < 0.01$; Tukey's test). This was evident in all the sampling periods (insignificant Site versus Period interaction; $P > 0.05$; two-way ANOVA). Although the species composition was similar in samples from both the habitats, substantially more beetles of most species were collected in pasture traps than in forest. This cannot be explained by the distance of forest traps from pasture sites (up to 300 m from Pasture 2) or by unevely distributed dung in the trapping sites in April (no grazing) and in May (grazing had progressed only to Pasture 1 area). The results thus indicate a preference for open pasture by most of recorded species. Only two species were more abundant in forest samples: *Anoplotrupes stercorosus* (a forest specialist) and *Aphodius distinctus*. Thus most of the species were linked to open pasture stands and relied on the presence of grazing animals on these sites. By this way the pasture management contributes to a biodiversity of mountain grasslands.

Conclusions

In total thirty-nine species of dung beetles were recorded in pastures. Higher species abundancy and diversity was found in pastures than in a forest. This suggests an association of most species with open pasture sites and indicates a contribution of grazing management to the biodiversity of mountain grasslands.

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Mowing impacts on invertebrate models

Humbert J.-Y.[1,2], Ghazoul J.[2], Sauter G.J.[1] and Walter T.[1]

[1]*Agroscope Reckenholz-Tänikon Research Station (ART), Zurich, Switzerland*
[2]*Swiss Federal Institute of Technology (ETH), Institute of Terrestrial Ecosystems, Zurich, Switzerland*
E-mail: jean-yves.humbert@art.admin.ch

Abstract

Agricultural mowing techniques have evolved considerably through mechanization in recent decades, and yet scientific knowledge on their impacts on field fauna is limited. The direct impacts of different mowing techniques (motor mowers with cutter bar and rotary mowers with or without conditioner) were tested in the field on wax models of invertebrates. The size of the models, their microhabitat, the tractor wheels and the cutting height were also investigated as factors that could potentially affect mowing-caused damages. Rotary mowers were found to be more damaging than motor bar mowers, and conditioners more than doubled damage to the models. Larger models were more vulnerable than smaller models and models put on the ground were strongly impacted by tractor wheels.

Keywords: grassland, cutting, harvesting, invertebrate conservation, caterpillar

Introduction

In the last decades emphasis on the high biodiversity value of grassland (e.g. Vickery *et al.,* 2001), has promoted more extensive forms of management and efforts to restore degraded meadow systems. Usual meadow management recommendations include no fertilization input and one or two cuts per year after the flowering period. While these recommendations may be sufficient to sustain floral diversity, agricultural mowing techniques have evolved considerably through mechanization in recent decades. Scientific knowledge on the impacts of mechanized meadow harvesting on field fauna remains, however, very limited (Humbert *et al.,* 2009). Thus there are considerable uncertainties about field population responses to the mowing process. These uncertainties need to be addressed to develop effective guidelines for the management of extensive meadows, whose primary function is ecological compensation and the conservation of biodiversity.

In this study, the direct impacts of different mowing techniques (motor bar mower and rotary mowers with or without conditioner) were tested on models of invertebrates. The size of the models, their microhabitat, the tractor wheels and the cutting height were also investigated as factors that could potentially influence mowing-caused mortality.

The project was initiated, because of a large interest from stakeholders and is supported by local authorities (13 out of 26 Swiss cantons).

Material and methods

Invertebrate models and machines: We quantified the impacts of four different mowing techniques on cylindrical models of invertebrate made from bee wax. There were two sizes of models based on common caterpillar bodies: ‘small’, 4 mm diameter × 20 mm; and ‘big’, 8 mm diameter × 40 mm. There were two different mowing machines, a hand motor mower with finger cutter bar (AEBI am 41, cutter bar width 1.9 m) and a tractor front rotary drum mower (CLAAS corto 3150F, cutting width 3 m). While the bar mower was used only for one treatment, the rotary mower was used for three treatments with different cutting heights and with or without a tractor rear flail conditioner (Kurmann K618). The four mowing treatments were:

1. Bar mower, cutting height 6–7 cm
2. Rotary mower, cutting height 6 cm, without conditioner
3. Rotary mower, cutting height 9 cm, without conditioner
4. Rotary mower, cutting height 6 cm, with conditioner.

Experimental design: There were four grass plots to test the different mowing techniques: The plots were 1.7 × 2.5 m for the bar mower treatment and 2.5 × 2.5 m for the rotary mower treatments. In each plot there were 200 invertebrate models: 50 small and 50 big models were placed on the ground and 50 additional of each size were tied in the grass, 20 to 30 cm above the ground. A fifth treatment on a plot of 2.5 × 2.5 m where the grass was already mown was added to test the impact of the tractor wheels only on ground models. The mowing treatments were randomly allocated to the plots and the experiment was replicated four times in different meadows. After mowing, the models were recovered and returned to the lab for inspection of mechanical damage. The percent of damaged models were recorded.
Data analysis: Linear models were used. The treatment comparisons were adjusted for the differences among blocks (replicates).

Results and discussion

The damage engendered by different mowing equipments and tractor wheels on invertebrate models were investigated. The differences in damage between the treatments are the main interests here. The absolute value of damage to models is unlikely to reflect exactly the impacts on real insects (notably caterpillars), but is expected to reflect relative impacts among treatments (Figure 1).

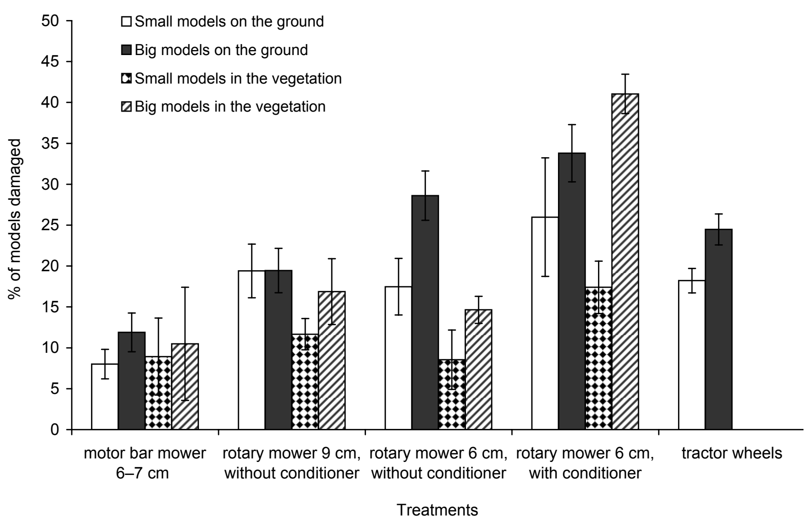

Figure 1. Percentages of models damaged for the four different mowing techniques plus the tractor wheels treatment (mean values ± SE)

The first linear model tested the influence of the mowing techniques, the size, and the strata (ground vs. vegetation) on the percentage of damaged models, and thus did not included the damage caused by tractor wheels. The linear model showed significant effects of mowing, size and strata. The small wax models of a stratum were always less damaged than the big ones in the same stratum. This is in the line with Oppermann *et al*. (2000) where larger grasshopper individuals were more affected by mowing than smaller ones. The damages engendered by the three rotary mowing techniques were significantly different from the damages caused by the motor bar mower. As well, the impact of the rotary mower at 6 cm with conditioner was significantly higher than the impact of the two rotary mowing techniques without conditioner. However, there was no difference between the rotary mower cut at 6 cm without conditioner and the rotary mower cut at 9 cm without conditioner. This is expected in our experiment where the models were smaller than 4 cm, but for bigger organisms, such as amphibians, the cutting height has a strong influence and is recommended to be set at 10 cm (Humbert *et al.,* 2009).
Four additional linear models were examined including only one type of wax model and the tractor wheels effect. The tractor wheels were damaging about 20% of the wax models placed on the ground. This effect was not significantly influenced by the cutting height and the use of a conditioner. Mowing with a hand motor bar mower caused less damage on the ground-placed wax models, presumably because the machine is considerably lighter and the wheels are smaller than those of a tractor. For the motor bar mower and the two rotary mowing treatments without conditioner, damage to the wax models placed in the vegetation ranged between 9 and 17%, and were not significantly different among treatments. However, when a conditioner was added to the rotary mower (using the same cutting height of 6 cm), the damage increased significantly by two to three times. This increase of impact caused by a conditioner has also been shown for honey bees (Frick and Fluri, 2001), grasshoppers and amphibians (Oppermann *et al.,* 2000).

Conclusion

The outcomes are in agreement with the results of other studies on amphibians and arthropods (see Humbert *et al.,* 2009). They confirmed that conditioners should not be used in meadows where conservation of the inhabiting fauna is an issue of consideration. The results also imply that hand bar mowers cause less damage than rotary mowers, particularly for ground invertebrates due to the smaller weight and wheels of the machine. The extrapolation of the recorded damage on models to mortality rates of real caterpillar-like invertebrates needs further investigation.

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Comparison of surface runoffs from grasslands and arable land

Hejduk S.

Mendel University of Agriculture and Forestry in Brno, Department of Grassland Management and Fodder Crop, Brno, Czech Republic
E-mail: hejduk@mendelu.cz

Abstract

Surface runoff from agricultural land is an undesirable phenomenon as it reduces the amount of the soil water available to plants, decreases the underground water supply and it can contribute to floods. This paper deals with an evaluation of surface runoff in the system of experimental plots at the Research Forage Station in Vatín (Czech-Moravian Highlands). Experimental plots were covered by 2 types of grassland (managed in extensive and standard ways), maize, winter wheat, potatoes and bare soil, used as control variant. Surface runoff volumes were measured throughout the whole year. During the vegetative period, both types of grassland showed a distinct protective outcome and prevented effectively the surface runoff. However, in the winter period, the intensively managed grassland lost its positive effect on the surface runoff reduction. Within the growing seasons of 2004–2008, the least average runoff proportion of precipitation was found on the grasslands managed in both a standard and extensive way (1.3% and 1.0%, respectively), while the highest runoffs were measured in potatoes and maize stands (9.5% and 8.3%, respectively). Reversely, the highest runoffs in the winter period were found on grasslands managed in a standard way, while the lowest on the extensively managed ones (1.0% and 0.4%, respectively).

Keywords: surface runoff, grassland management

Introduction

Grasslands fulfil a number of ecological functions and one of the most important for landscape hydrology is the control of water flow. Very important is their capacity to prevent and/or reduce surface runoff, which is an undesirable phenomenon in practically all territories. Surface runoff reduces the amount of soil water available to plants, decreases the underground water supply and it can contribute to local floods and water erosion.
Results presented in this paper document a good capacity of grasslands to eliminate the occurrence of surface runoff after downpour rainfalls in the summer season. This effect is associated with the all the year round vegetation cover of the soil, which prevents the destructive impact of rain drops on soil aggregates. Reversely, grasslands managed in a standard way lose this protective function in winter (Hejduk and Kasprzak, 2004) as a result of the soil compaction, faster thawing of snow on grassland stand and a slower disappearance of the frozen soil horizon.
The objective of this study is to demonstrate the importance of grasslands in a landscape from the hydrological point of view, but also to point out the importance of grassland management for its ability to eliminate surface runoffs, mainly in winter period.

Materials and methods

Presented results were obtained on the basis and analysis of data on surface runoffs recorded in the years 2004–2008 at the Vatín Research Station (49°15'5"N, 15° 58'15"E), in the Czech Republic. There are twelve experimental plots at the station (10.0 m^2, inclination 5°, sandy loam cambisol, altitude 540 m). One half of the plots was exposed to the south and the other to the north, so that each crop variant was exposed to both orientations. The plots were adapted so the amounts of surface runoff could be measured. Experimental plots were covered with the following agricultural crops during the growing season:
(1) Permanent grassland – standard management (3 cuts, 100 kg N + PK); (2) Permanent grassland – extensive management (2 cuts, without fertilising, sward not harvested before winter period); (3) Bare soil (control); (4) Winter wheat (sown without tillage after potatoes); (5) Silage maize; (6) Potatoes (typical crop in the studied area).
Permanent grasslands were established in 2001. Variants 3 to 6 were changed according to the crop rotation plan. In winter period the following types of the soil condition were used for measurement:
(1) and (2) Grasslands as mentioned above; (3) Loose soil after tillage (200 mm depth), plain surface; (4) Wheat stubble; (5) Maize stubble; (6) Winter wheat sown after potatoes without tillage.
Average values of surface runoffs from each soil type were calculated from both slope orientations. Statistical analyses were performed using ANOVA (Statistica 7.1, StatSoft) with multiple comparisons according to Tukey (P-value = 0.05).

Results and discussion

The greatest differences of surface runoffs and simultaneously the highest protective effect of grasslands were determined after downpour rains in the summer period (see Table 1). The highest surface runoffs occurred on bare soil without weeds, along with the presence of wet crusts on the soil surface developed by previous rains. Surface runoff volumes during the growing period were significantly higher in potatoes, silage and bare soil stands compared to other plots.

Table 1. Typical surface runoffs occurred after a downpour rain

Soil cover	Surface runoff (m^3 ha^{-1})	
	South slope	North slope
Grassland standard	2.5	2.5
Grassland extensive	2.0	2.0
Winter wheat	9.0	3.0
Potatoes	130	110
Silage maize	100	100
Bare soil	140	120

Level of precipitation: 16.1 mm, date: June 4th 2008, duration: 20 min, maximum intensity: 2.2 mm min^{-1}. Soil crust was developed one day before, soil surface was wet

Surface runoffs were substantially lower in winter compared to the summer period (see Tables 2 and 3). The reason was associated with a mild course of the last 4 winters and

frequent summer storms. Unlike in the lowlands, high winter surface runoffs have been recorded several times by Hejduk and Kasprzak (2004). In the highland stand at Vatín the long term snow cover protected soil against deep freezing. Subsequently, the thawing snow water could infiltrate into the soil to a greater degree. The only significant difference was found between the volumes of winter surface runoff from the grasslands managed in extensive and standard ways.
The great variation of data for individual years has been caused by different weather patterns and by the diverse quality of the soil surface before the respective runoff events.

Table 2. Comparison of surface runoffs in the growing season of individual soil covers in the period of 2004–2008 (m^3 ha^{-1})

Growing season (V–IX)	Soil cover					
	grassland standard	grassland extensive	wheat	bare soil	maize	potatoes
2004	53.2	34.4	89.6	416.0	363.2	449.1
2005	43.1	40.3	606	136.7	128.1	105.5
2006	48.4	35.2	28.1	213.4	206.6	120.7
2007	32.8	27.3	31.4	385.4	350.3	374.3
2008	56.8	44.8	99.9	808.3	483.6	728.8
Sum of 2004–2008	234.3	182.0	309.6	1,959.7	1,531.8	1,747.6
Proportions of precipitations (%)	1.3	1.0	1.7	10.6	8.3	9.5

Table 3. Comparison of surface runoffs in winter periods over individual soil covers in the years of 2004–2008 (m^3 ha^{-1})

Winter season (X–IV)	Soil cover					
	grassland standard	grassland extensive	wheat stubble	loose soil	maize stubble	winter wheat
2004/05	34.1	12.9	13.1	12.3	21.8	38.4
2005/06	24.8	11.2	16.6	7.9	8.3	3.0
200607	54.6	14.0	23.8	36.6	22.2	51.3
2007/08	27.1	14.9	29.6	17.4	10.6	17.2
2004–2008	140.5[a]	53.0[b]	83.1[ab]	74.1[ab]	62.8[ab]	109.9[ab]
Proportions of precipitations (%)	1.0	0.4	0.5	0.6	0.6	0.8

[a,b] different letters indicate statistically significant differences between the volumes of runoff ($P < 0.05$)

Conclusions

The presented results confirm and show the extraordinary ability of grasslands to eliminate surface runoffs resulting from downpour rains occurring in the summer. They also demonstrate the marked influence of grassland management on the formation of runoffs, particularly in winter period, when the grasslands managed in a standard way totally lose this protective ability.

The lowest surface runoffs for the whole year were formed on extensively managed grassland (two cuts per year, without fertilising, last cut at the end of August). In the summer period, the highest surface runoffs were recorded in maize and potatoes stands (8.3 and 9.5% of precipitation, respectively). Intensively managed grassland caused the highest surface runoffs in the winter period (1.04% of winter precipitations).

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Alternative use of different grassland types: I. Influence of mowing on botanical composition and dry matter production

Britaňák N., Hanzes Ľ. and Ilavská I.

Plant Production Research Centre, Grassland and Mountain Agriculture Research Institute, Research Station, Poprad, Slovakia
E-mail: brinor@isternet.sk

Abstract

We investigated the influence of mowing on the development of three grassland types in a mountainous area of the Slovakia: Treatment 1 was de-intensified permanent grassland, Treatment 2 grassland abandoned for approximately 10 years, and Treatment 3 the same grassland but mowed grassland once a year, Treatment 4 weedy grassland caused by over-fertilisation, and Treatment 5 the same sward, but mowed once a year. Despite the differences in soil characteristics after two years of exploitation, a (both qualitative and quantitative) convergence in botanical composition occurred. Logically, a divergence was detected between managed and non-managed treatments of abandoned and weedy grassland. The abandoned grassland was distinguished by higher dynamics than the weedy one in divergence. During the two years of the investigation, mowing decreased the dry matter production of the abandoned grassland from 4.61 Mg ha^{-1} to 2.30 Mg ha^{-1} in the abandoned grassland and from 5.53 Mg ha^{-1} to 3.83 Mg ha^{-1} in the weedy grassland.

Keywords: botanical composition, dry matter production, grassland types, similarities

Introduction

In the Slovakia over 350,000 ha are not managed and/or ca12,000 ha are weedy as a result of overexploitation or bad folding. As Tilman *et al*. (2006) stated, biofuels derived from low-input high-diversity mixtures of native grassland perennials can provide more usable energy, greater greenhouse gas reductions, and less agrichemical pollution per hectare than corn grain ethanol or soybean biodiesel. Moreover, these biofuels can be produced on agriculturally degraded lands and thus do not need either displace food production or cause loss of biodiversity via habitat destruction (Tilman *et al*., 2006). Experiencing the boom of renewable energy resources, e.g. corn ethanol in the US (Tyner, 2008), we have focused on an alternative use of herbage from different types of grassland in the biofuel production. Two types of non-managed grassland (abandoned and weedy) grassland can provide biomass for biofuels. We assumed that introducing of one-cut-a-year management on non-managed grassland will cause a change in the botanical composition coupled with a modification of production level in comparison to non-managed grassland. Changes in botanical composition and dry matter production were compared with de-intensified semi-natural grassland.

Material and methods

In 2006, a field experiment was established at a site near Liptovská Teplička in a mountainous region of Northern Slovakia. The main site characteristics were: mean annual rainfall 900 mm (500 mm during the growing season) and mean annual temperature 4°C (9.5°C during the growing season). The soil characteristics before the establishment are given in Table 1. Our research was carried out in the secondary vegetations of a semi-natural grassland substituting a forest stand and we studied the influence of mowing on the development of three grassland types: Treatment 1 was de-intensified permanent grassland, Treatment 2 grassland abandoned for approximately 10 years, Treatment 3 the same grassland but mowed once a year, Treatment 4 weedy grassland caused by over-fertilization, and Treatment 5 the same sward, but mowed once a year. The aim of our study was to find out whether the botanical composition and dry matter production differ from each other as a result of mowing management. Before cutting, botanical composition was assessed according to Gáborčík and Javorková (1980). Consequently, the index of qualitative similarity (IS_J) and the index of quantitative similarity ($IS_{J/G}$) were calculated for each plot as follows: index of qualitative similarity $IS_J = c/(A + B - c)$; and Index of quantitative similarity $IS_{J/G} = \Sigma c_i/(a_i + b_i - c_i)$

where: A – number of species in plot A; B – number of species in plot B; *c* – number of common species in plots A and B; c_i – abundance of the *i*-th species in the compared plots; a_i – abundance of species present in plot A only; b_i – abundance of species present in plot B only (Moravec, 2000). Cutting took place in the mid of July (the peak of herbage production).

Table 1. Soil characteristics before establishment of the experiment

Grassland	$pH_{(KCl)}$	Cox	N	P	K	Mg
		(g kg^{-1})				
Semi-natural	6.52	40.60	4.60	6.54	120.87	1030.1
Abandoned	5.66	54.30	5.04	17.76	76.79	486.5
Weedy	6.67	57.17	5.55	73.68	952.55	1,009.9

Results and discussion

In 2006, at the beginning of the research, de-intensified (modification of utilisation from three cuts a year to only one cut) permanent grassland consisted of 45 grassland species. From functional groups of grasses, legumes, and other plants, *Avenula pubescens*, *Medicago lupulina* and *Alchemilla xanthochlora* dominated in this type of grassland (10, 10, and 7% dominance (*D*), respectively). At the same time, the abandoned grassland type was characterised by governance of other herbs (61% coverage), which dominated by *Alchemilla xanthochlora*, *Cruciata laevipes* and *Hypericum perforatum* (10, 7, and 7% *D*, respectively). Finally, weedy grassland (as a result of a chronic folding and subsequently sporadic mowing) was dominated by *Elytrigia repens*, *Poa pratensis* and *Cirsium arvense* (42, 16, and 9% *D*, respectively).
In the first year of investigation the qualitative similarity was higher between de-intensified and abandoned grasslands than between de-intensified and weedy grasslands (Table 2). This is a result of higher probability of occurrence of common species in species-rich treatments from the regional species pool – selection effects (e.g., Sala, 2001). We observed decreasing qualitative similarity between de-intensified and both managed and non-managed abandoned grassland, in the second year. In contrast to our expectation that determination of qualitative similarity between de-intensified and abandoned

grassland was higher in the non-managed treatment and lower in the managed one. On the contrary, the botanical composition development and subsequent qualitative similarity was just as we had expected. The comparison managed and non-managed treatments in both abandoned and weedy grasslands offered us the highest levels of the Jaccard's index. The quantitative index of similarity (Gleason's index) developed according to our expectations: convergence among both managed treatments and de-intensified grassland as a control, and divergence as a result in various management types in the same type of grassland.

Dry matter production was significantly higher in both types of non-managed grassland in comparison to de-intensified semi-natural grassland (Model: $F_{2, 6} = 18.000$; $P = 0.003$; Table 3). Dry matter production in the first year was significantly correlated to soil availability of nitrogen, phosphorus and oxidizable carbon concentration ($r = 0.9222$; $P = 0.0040$; $r = 0.8478$; $P = 0.00389$; and $r = 0.8804$; $P = 0.00173$ for N, P, and C_{ox}, respectively). Potassium concentration had a smaller effect on dry matter production, but it was still significantly correlated with it ($r = 0.7574$; $P = 0.01810$) (all degree of freedom = 7). Dry matter production was positively correlated with all of these soil characteristics.

Similarly as in the first year, production of the observed grasslands was positively correlated with soil characteristics also in the second year. However, its influence was not significantly correlated (N: $r = 0.2297$; $P = 0.41020$; P: $r = 0.3739$; $P = 0.16973$; K: $r = 0.4671$; $P = 0.07919$; and C_{ox}: $r = 0.2131$; $P = 0.44576$). These results suggest a hypothesis that different abiotic conditions but not soil characteristics significantly affected production. A certain role may have been played by an increased temperature throughout this second growing period. There is an indirect argument for this as the number of species increased (Table 3). An above-average temperature could support establishing of additional plant species in this region, where amounts of precipitation in both the growing season as well as outside of it are sufficient. As Table 3 states, there were significant differences between particular treatments in dry matter production (Model: $F_{4, 10} = 32,777$; $P < 0,001$). After having introduced one-cut-year management on grassland formerly non-managed grassland, average dry matter production decreased in comparison with unmanaged treatments (Table 3). We accept the conclusion by Tilman *et*

Table 2. Similarities in botanical composition

		1		2		3		4	
		2006	2007	2006	2007	2006	2007	2006	2007
IS_J	2	38.1^{24}	33.8^{27}						
	3	–	32.9^{24}	–	57.6^{38}				
	4	12.1^{7}	23.1^{15}	12.7^{7}	14.5^{11}	–	13.2^{9}		
	5	–	27.4^{17}	–	13.2^{10}	–	15.2^{2}	–	68.6^{24}
$IS_{J/G}$	2	63.6	62.0						
	3	–	70.5	–	87.1				
	4	49.7	58.7	26.2	31.8	–	30.0		
	5	-	74.9	-	38.2	–	35.4	–	92.0

IS_J qualitative similarity index (Jaccard's index); $IS_{J/G}$ quantitative similarity index (Gleason's index); figures in superscripts denotes number of common species between two relevés compared *al*. (2006) that this production should be sustainable with low inputs of agrichemicals. Therefore, some amount of N fertilisation may be useful in habitats without legumes (in our case weedy grassland after a predicted long-term depletion N of the soil), and P or other nutrients to replace nutrients by exports (Tilman *et al*., 2006).

Table 3. Dry matter production (Mg ha^{-1}); its coefficient of variability (%) and number of species (S)

Treatment	Year						Mean
	2006			2007			
	production	*CV*	S	production	*CV*	S	
1	1.73[b]	4.69	45	1.45[c]	0.78	50	1.59
2	2.83[a]	21.37	42	6.46[a]	105.70	57	4.65
3				1.76[c]	7.08	47	2.30
4	3.76[a]	25.94	20	6.86[a]	109.04	30	5.31
5				3.89[b]	72.55	29	3.83

The same letter in superscript denotes that it is non-significant differences at level $P < 0.05$

Conclusion

The use of grassland for biofuel production is an alternative which can help to maintain and improve diversity of vascular plants in semi-natural grasslands and provide rural residents employment.

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Alternative use of different grassland types: II. Accumulation of carbon in grassland ecosystems

Britaňák N., Hanzes Ľ. and Ilavská I.

Plant Production Research Centre, Grassland and Mountain Agriculture Research Institute, Research Station, Poprad, Slovakia
E-mail: brinor@isternet.sk

Abstract

Based on two-year results we state that the exploited both abandoned and weedy grasslands contribute to a loss of carbon from grassland ecosystems. A weedy grassland compared with an abandoned grassland (carbon loss 0.48%, annually) showed a higher loss of dynamics of carbon (decreased carbon amount of 3.11%, annually). Resumption of the grassland management with one cut a year increased the amount of carbon in both roots and sods of the abandoned grassland. These increments, however, could not sufficiently compensate for the decrement in carbon of both soil and above-ground dry matter production. In the weedy grassland, we observed carbon accumulation in a part of the sod only. This increase of carbon could not compensate for losses of carbon in the dry matter production of soil, roots and above-ground dry matter production. However, we expect the long-term management of this grassland will stabilise carbon sequestration.

Keywords: carbon, dry matter, oxidizable carbon, root, sod

Introduction

A number of perennial grasses are used increasingly in Europe and North America as renewable bioenergy sources, as they can be grown with minimal maintenance on marginal soils and harvested to produce large volumes of carbon-rich biomass. These bioenergy crops include a number of high biomass, rhizomatous bunchgrasses such as *Miscanthus*, *Panicum virgatum*, *P. coloratum*, *Bouteloua dactyloides*, *Pennisetum purpureum*, *Phalaris arundinacea*, *Andropogon gerardii*, *Arundo donax,* and *Festuca arundinacea*. Although planting grasses as biofuels have economic and environmental advantages, many of the biofuel species are invasive (Gibson, 2009). However, Tilman *et al*. (2006) state that biofuels derived from native grassland perennial mixtures can be produced on agriculturally degraded lands and thus do not need either to displace food production or cause loss of biodiversity via habitat destruction. In addition to energy for harvest, these grasslands need only application of P or other nutrients if initially limiting or to replace nutrients exports. Furthermore, biofuels from high-diversity grassland are carbon-negative because of the net ecosystem carbon dioxide sequestration in soil and roots (Tilman *et al*., 2006). In the Slovakia over 350,000 ha of land are not used and/or ca12,000 ha are weedy caused by of over-fertilisation or other incorrect management. Therefore, we have been looking for an alternative to use biofuel production for these grasslands with beneficial effects on the environment. In the presented article we have focused on three types of grassland and their ability to sequester carbon.

Material and methods

We performed the experiment in a mountainous region (Low Tatra Mts.) of the Slovak Republic, near Liptovská Teplička (of 960 to 1,005 m a.s.l.). Our research was carried out in secondary vegetation of a semi-natural grassland and we studied the influence of mowing on the ability to sequester carbon in soil, roots and sods of three grassland types: Treatment 1 was de-intensified permanent grassland, Treatment 2 grassland abandoned for approximately 10 years, Treatment 3 the same grassland, but mowed once a year, Treatment 4 was weedy grassland caused by over-fertilisation, and Treatment 5 the same sward, but mowed once a year. Both de-intensified and weedy grasslands had been developed on Mollisols, but the abandoned grassland was developed on Histosols. In all grassland types we took soil and root from within depth of 10 cm, as Mollisols are shallow. Carbon accumulation was assessed as the sum of oxidizable carbon (method by Tjurin) and carbon in roots, sods and above-ground biomass. May *et al*. (2007) state that living things are made up of H, C, O, N, P, and S in the rough proportions 3,000:1,500: 1,500:16:1.8:1, i.e., the proportion of carbon in biomass is as high as 40%. Therefore, the amounts of carbon in the biomass were calculated as follows: dry matter (for roots, sods, above-ground biomass, respectively) × factor 0.4. As these grasslands differed from each other in the bulk density of soil, we used the one-way ANOVA Kruskal-Wallis test to compare carbon accumulation and its release.

Result and discussion

In Table 1 shows the concentrations of carbon in above-ground and sod and root biomass, respectively, and carbon in soil and their totals. The results of ANOVA Kruskal-Wallis' tests for years and treatments are given in Tables 2 and 3.

Table 1. Partitioning of the amount of carbon in different types of grassland (t.ha^{-1})

Treat-ment	DM^{DM}		Sod^{S}		Root^{R}		Sum of	Soil	Totally
	(Mg ha^{-1})	(%)	(Mg ha^{-1})	(%)	(Mg ha^{-1})	(%)	DM+S+R	(Mg ha^{-1})	(Mg ha^{-1})
1	0.63	8.2	4.93	63.4	2.21	28.4	7.77	49.22	56.99
2	1.85	16.7	6.78	61.4	2.41	21.9	11.04	41.46	52.46
3	0.92	7.4	7.37	59.3	4.14	33.3	12.43	39.56	51.99
4	2.21	20.4	4.30	39.6	4.33	40.0	10.84	68.10	78.94
5	1.53	15.6	5.76	58.5	2.55	25.9	9.84	64.35	74.18

We did not observe any statistical differences in the grassland ecosystem's carbon concentrations (χ^2 = 2.27; P = 0.13) between the two years. There were no significant differences between the years in the amount of carbon in above-ground dry-matter (χ^2 = 1.47; P = 0.22) nor of carbon in soil (χ^2 = 0.07; P = 0.79). However, statistically significant differences in the carbon concentration in the sod (χ^2 = 6.39; P = 0.01) and the root biomass (χ^2 = 17.20; P < 0.01) was found between the years.

Comparing the years, the treatments rendered statistically significant results. This means that we did record no significant differences in the amounts of the carbon in sod (χ^2 = 8.78; P = 0.07) and root (χ^2 = 5.05; P = 0.28) biomass but highly significant differences in concentrations of C in soil (χ^2 = 51.69; P < 0.01), above-ground dry-matter (χ^2 =

Table 2. Rank-sums of years (Kruskal-Wallis ANOVA)

Year	n	C in Soil	C in Roots	C in Sods	C in DM	C in Ecosystem
1	30	933	1195.5[a]	1086[a]	833	1017
2	30	897	634.5[b]	744[b]	977	813

Letters in superscripts denote statistically significant differences at level P <0.05

40.94; $P < 0.01$) and of course, in the whole grassland ecosystem ($\chi^2 = 45.10$; $P < 0.01$). These differences caused by the introduction of one-cut-a-year management (critical value for a multiple pair-wise comparison [for $k = 5$; and $n = 12$] is 233.4).

Bardgett (2005) says that the above-ground production is represented by a little part of the ecosystem biomass. Our non-managed treatments, as controls of abandoned and weedy grasslands, have above-ground biomasses at levels of 16.8% and 20.5%, respectively. Various trends in grassland development before and after the introduction of management have resulted in different proportions in the dry matter production. During two years of management, an above-ground biomass of on average only 7.4% in abandoned grassland and up to 15.5% in weedy grassland was found. The dry-matter production of de-intensified grassland represents 8.1% of the total biomass of the ecosystem.

Comparison between the first and the second year of research shows that these three types of grassland are different in accumulation/release of carbon (except for carbon concentration in dry-matter production). Only the abandoned grassland accumulates carbon in its ecosystem (non-managed1.97% and managed 4.92%).The other ones release carbon from their ecosystem (de-intensified grassland –6.50%; weedy grassland non-managed –11.79%, and managed –10.43%).

However, when including dry-matter production into our analysis and comparing the non-managed and managed treatments in the grasslands, we found the average loss of carbon from the abandoned grassland to be 0.48% and from the weedy grassland 3.11%, annually. Although mowing once a year is a simple type of management, the impact on the abandoned grassland was different from the weedy grassland. Both applied treatments lowered their dry-matter production, as a result of the change in the management. Moreover, lower carbon concentrations in the soil of both grasslands were recorded as well. We observed an increased amount of carbon sod biomasses, both the abandoned and the weedy grassland. However, a mowing had different effects on the root part of these ecosystems. Whereas this type of management promoted the root systems of the abandoned grassland, its effect on the weedy grassland was negative (Table 1). Totally, after two years of research, the resumption

Table 3. Rank-sums of treatments (Kruskal-Wallis ANOVA)

Treatment	n	C in Soil	C in Root	C in Sod	C in DM	C in Ecosystem
1	12	366[ab]	276.5	319.5	98[b]	295[b]
2	12	186[bc]	331.5	490	472[a]	192[b]
3	12	114[c]	429	430	232[b]	179[b]
4	12	582[a]	438	279.5	564[a]	609[a]
5	12	582[a]	355	311	464[a]	555[a]

Letters in superscripts denote there are statistically significant differences at level $P < 0.05$

of mowing in the abandoned grassland and introduction of biofuel production in the weedy grassland decreased the carbon concentrations in these ecosystems as a whole. Before the start of this experiment, we had expected an improvement in botanical composition along with an increase in sequestering carbon in grassland ecosystems.
After the two years of the experiment our results do not agree with the results by Tilman *et al*. (2006) on carbon sequestration as the ecosystem's service.

Conclusion

In the long-term we expect that the experiment will change the grasslands from carbon positive (carbon release into the atmosphere) to carbon negative (sequestration of carbon).

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Effects of different establishment techniques on pasture improvements for wild animals in the Italian Apennine Mountains

Cervasio F.[1], Ponzetta M.P.[2], Argenti G.[3], Messeri A.[1], Crocetti C.[2] and Staglianò N.[3]

[1]*University of Florence, Department of Agronomy and Land Management (CIRSeMAF), Firenze, Italy*
[2]*University of Florence, Department of Animal Science, Firenze, Italy*
[3]*University of Florence, Department of Agronomy and Land Management, Firenze, Italy*
E-mail: mariapaola.ponzetta@unifit.it

Abstract

The propagation of invasive species and their impact on land use pose difficult research questions as a result of the complex relationship between the ecological nature of the infestation and the animal responses to it. Infestation is often a result of land abandonment, which encourages progressive plant growth over green areas, with a consequent reduction in biodiversity. Bracken fern (*Pteridium aquilinum*) is one of the most invasive weeds whose presence reduces the qualitative value of the pastures it encroaches on. This study, carried out in a Regional Park in the central Apennine mountains (Italy), examined the effectiveness of different agronomical management systems against bracken fern infestation and their effects on botanical biodiversity and on the potential reutilisation of open areas as pastures for wild animals. The results highlighted interesting differences between areas managed with different environmental improvements, in particular concerning the specific contribution of the most important botanical families, the pastoral value of the canopies, and their floristic richness.

Keywords: ungulates, pastoral value, biodiversity, botanical composition

Introduction

The constant and remarkable reduction of pastoral activity and agricultural practices has caused deep changes in the natural herbaceous vegetation, concerning both floristic composition and the proportion among different species. From a macroscopic point of view this causes a quick colonisation of areas once used as pastures by invasive vegetation and a reduction of floristic richness and biodiversity (Tucker and Evans, 1997). *Pteridium aquilinum* is certainly a species with high competitive skills and which is able to colonise abandoned areas. This invasive species has a high covering action (Pakeman and Marrs, 1992; Le Duc *et al.,* 2000) which inhibits the establishment and growth of herbaceous vegetation, particularly of species with high forage values, causing a reduction of the pastoral value. The aim of this study is to test the real efficacy of some agronomical practices on areas once grazed and now utilised only by wild animals and thus initially characterised by a massive invasion of bracken fern. The defence of such open areas, especially inside parks, is necessary for the preservation of botanical and landscape biodiversity, besides playing an attractive role for wild animals.

Material and methods

The area of study is located inside the Regional Park of 'Laghi di Suviana e Brasimone', in the northern Italian Apennines, at about 1,100 m a.s.l. The area is 2.5 ha wide, with a massive presence of invasive vegetation (41% *Pteridium aquilinum*) and it was divided into two distinct sectors that were treated with two types of agronomical management. Inside the first area (P), all invasive vegetation was cut up with mechanical intervention by means of a tractor, then ploughing to a minimum depth of 15 cm was performed, whereas the second area (H) was treated only with superficial harrowing. In both cases agronomical interventions were followed by the sowing of the following mixture: *Bromus inermis* (30%), *Dactylis glomerata* (30%), *Festuca ovina* (25%), *Trifolium pratense* (10%), and *Lotus corniculatus* (5%). In the two following years the sward was cut once a year to maintain the new vegetation. Data collection concerned botanical composition recorded in the summer months from 2006 to 2008 (8 samples per year), using linear analysis according to Daget and Poissonet (1969). This survey permitted the determination of the specific contribution (SC) of each species within the total of recognised vegetation, by means of which the pastoral value (PV) was calculated (Cavallero *et al.,* 2002). Furthermore, biodiversity was estimated by the Shannon-Wiener index (Maugurran, 2004) in order to identify possible differences between treatments. The data were analysed with ANOVA, using Tukey's test to compare the averages.

Results and discussion

The comparison between the two areas highlights, in each annual survey, a smaller specific contribution of bracken fern in the ploughed area in comparison to harrowed plots, pointing out the greater efficacy of deeper soil tillage in containing invasive vegetation (Table 1). Moreover, the smaller shading action of *Pteridium aquilinum* favours the growth of heliophilous species in these areas, which is usually characterised by a higher forage value, in particular those belonging to the *Leguminosae* family. Grasses and other species are not affected in any remarkable way by the establishment technique.

Table 1. Specific contribution for grasses, legumes, other species and bracken fern in each area for years of trial

Family or species	2006			2007			2008		
	H	P	sign.	H	P	sign.	H	P	sign.
Gramineae	15.7	24.3	ns	33.9	34.0	ns	24.0	25.5	ns
Leguminosae	19.0	39.6	*	0.0	27.3	*	1.7	18.3	*
Other families	43.5	35.7	ns	42.5	38.2	ns	36.8	56.2	*
Pteridium aquilinum	21.8	0.4	*	23.6	0.5	*	37.5	0.0	*

Significantly different *$P < 0.01$; ns – not significant

The better qualitative and quantitative characteristics of the canopies present in the P areas produced a remarkable effect on the pastoral value observed in each year (Figure 1). Furthermore, a decreasing trend in the quality of the canopy is observed in both areas after sowing. This is especially due to the colonisation of spontaneous vegetation belonging to botanical families with poor or no pastoral value interest.
With regard to biodiversity, the ploughed area during the whole period of assessment definitely has a higher Shannon-Wiener index (H') value and it is characterised by an increasing trend (Figure 2). On the contrary, the harrowed area shows a reduction of the same index with time. Such a tendency is certainly due to the different capacity for suc-

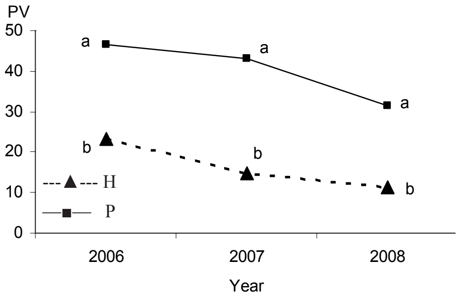

Figure 1. Trend of pastoral value under the two treatments for each year of trial. Values in the same year characterised by the same letter are not significantly different ($P < 0.01$)

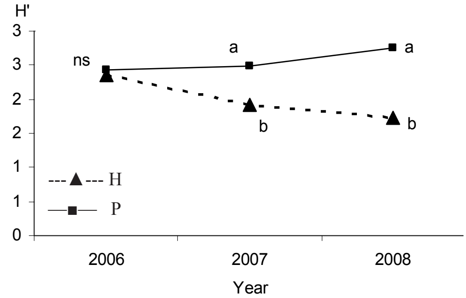

Figure 2. Trend of H' under the two treatments for each year of trial. Values in the same year characterised by the same letter are not significantly different ($P < 0.01$, ns = not significant).

cess of the forage species mixture, which tends to have a decreasing importance in the coenoses in the harrowed sector, and to the high occurrence of bracken fern, which is still the dominant species in the H plot.

Conclusions

The results highlight the importance and efficacy of the sward establishment methods used to reduce *Pteridium aquilinum*, even if deeper soil tillage seems to be more effective in terms of the reduction of this invasive species, and it allows a more proper establishment and growth of other species, with a consequent improvement in the biodiversity and forage quality of the canopy. Harrowing could be employed in the event of the reduced availability of money, as it produces improvement effects in comparison to no interventions at all, as reported by Cervasion *et al.* (2008), even if these effects have a reduced time duration and need continued cuts to maintain and preserve the results obtained. This work confirms the importance of the restoration of open areas to maintain biodiversity and to play an attractive role for wild animals.

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Peculiarities of transition of unused grasslands and other abandoned areas in Lithuania

Daugėlienė N., Žekonienė V. and Bartkevičius E.

Lithuanian University of Agriculture, Ecological Department, Kaunas, Lithuania
E-mail: ndaugelen@takas.lt

Abstract

Unused grassland areas, the majority of which are situated in the south-eastern and western parts of Lithuania, were formed during the land reform as a result of the changes in the ratio between perennial vegetation and arable land. Various factors were responsible for the appearance of unused grasslands: land reform peculiarities, inappropriate exploitation of land amelioration equipment, soil erosion and acidification, and inadequate use of grassland areas. A large part of the unused grasslands is composed of cultivated meadows and pastures that have not been fertilised and renovated for the last decade. Parts of such areas are fallows, and the other parts are being conserved. The areas of cultivated meadows and pastures are being conserved first, then former cereal fields, and last row crop fields. The main criterion for grassland conservation is the soil texture. Of the total amount of unused meadows and grasslands 54% is left for spontaneous overgrowth with various plants, trees, and shrubs, while 64% is afforested. Meadows and pastures most commonly overgrow spontaneously with white alder and birch, swamps and peatlands with birch, and quarries and sands with white alder, pine, and birch. Fir is commonly used for the afforestation of meadows, pastures, swamps, and peatlands, while pine is most commonly used for quarries and sands.

Keywords: abandoned grasslands, conservation, spontaneous growth, afforestation

Introduction

The national strategy of Lithuania for sustainable development points out that with spontaneous renaturalisation the areas of forest and other natural territories increase, as does biological and landscape diversity, and during the last decade the afforestation of unproductive land has resulted in a 1% increase in the total woodland area, which will consequently enhance the ecological stability of the territories. There are several reasons for the appearance of unused grasslands 1. Nearly 15% of arable land is exposed to erosion, which destroys the valuable topsoil layer and reduces its productivity 2. The poor condition of land reclamation installations. Currently, 57% of the land reclamation constructions are obsolete. The condition of land reclamation constructions is especially poor in west Lithuania, which receives a large amount of precipitation 3. In Lithuania, there are 30% of acid soils that rapidly acidify if not limed (Mažvila *et al*., 2004). Soil acidification promotes negative changes in soil properties and limits the diversity and productivity of legumes 4. Inadequate utilisation of semi-natural and natural flooded grasslands. Improper management of these areas results in sward destruction, lesser biological diversity, and poorer soil properties (Daugėlienė, 2002). The consideration of various ecological and economic factors on the basis of experimental results is necessary for the planning of the management of low-productive soils. This study shows the trends in the transition of unused grasslands and other abandoned land areas.

Materials and methods

Experiments were performed on various soils of Lithuania: sandy clay loam *Dystric Albeluvisols,* light loam *Haply-Endohypogleic Luvisol* and *Orthieutric Albeluvisols*, on sandy *Skeleti-Calcaric Arenosols*, loamy sand, and clay loam *Eutric Albeluvisols.* The soils differ in their acidity and nutrient status. The research on the transformation of grasslands and other unused areas was conducted at the Lithuanian Institute of Agriculture, Vokė Branch. The analysis of the abandoned land afforestation was carried out using inventory data from 15 forestry farms.

Results and discussion

Conservation of grasslands and other abandonment areas. The process of the conversion of agrocenoses into long-term unused grassland takes many years. Humus variation in the soil suggests that early in the summer (June 25) in grassland not used for 10 years the humus content at the 0–15-cm and 15–30-cm depths differed by a factor of more than two (Table 1). At the end of the growing season (August 3) the content of humus at the above-mentioned depths differed only inappreciably. In grassland not used for 10 years the humus content was similar to that in arable soil, and therefore such grassland can be considered as organic matter stabiliser, inhibiting its leaching into deeper soil layers.

Table 1. The variation in the humus content during the warm period of the year in soil under perennial grasses and in abandoned land

Treatment	Sampling depth (cm)	Humus content % at different dates of the growing season		
		June 25	July 13	August 3
Perennial grasses of the 1st year of use	0–15	1.94	1.90	1.91
	15–30	1.88	1.80	1.80
Perennial grasses of the 2nd year of use	0–15	2.03	2.11	2.00
	15–30	2.02	1.98	1.80
Grassland not used for 10 years	0–15	2.50	1.86	1.98
	15–30	1.17	0.81	1.70
LSD_{05}		0.18	0.19	0.06

Other abandoned land areas (former fields of cereals or row crops) are conserved by sowing with perennial grasses, which is done with the soil texture being taken into account. The species well-suited for sowing on hilly loam soils high in lime or on gravelly soils are lucerne, bird's foot trefoil, and common sainfoin, and on acid hilly soils white and red clover mixtures with grasses. On acid light loamy soils where legumes perform poorly, the best-suited grasses are red fescue and bent grass. They form a firm turf and low herbage yield (Daugėlienė, 2002). Research conducted in various natural zones of Lithuania indicates that grasslands not used for an extensive period of time have to be cut once or twice per growing season. The cut herbage can be used as forage or can be left to rot in the field. When the cut is taken once per growing season, when perennial grasses have ripened seed, this provides an opportunity to conserve grasslands cheaply for many years (Zableckienė and Butkutė, 2003). Differences in soil class explain a large part of the land abandonment pattern and the associated transition paths, as well as transition rates (Sluiter and de Jong, 2007).

Spontaneous growth of shrubs and afforestation on grasslands. Grasslands that are not cut and not grazed, especially those situated near forests, are prone to spontaneous overgrowth with shrubs and trees. Unused meadows and grasslands are most subject to this kind of overgrowth (53% of the total overgrown area). Swamps and peat bogs account for 41%. Unused grasslands and pastures are most frequently overgrown with birch, white alder, and other tree species; pine, aspen, and ash are less frequent, and the least frequent tree species is fir (Table 2). In temporarily waterlogged habitats' grasslands and pastures the most frequent tree species are birch (76%) and conifers (17%). The more productive the habitat, the more dominant white alder and aspen are. Unused swamps and peat bogs are most frequently overgrown with birch, while black alder is less frequent. Used peat bogs in which the depth of the peat layer does not exceed 30 cm tend to overgrow rapidly with birch and pine. Later, birches suppress pines and low-productivity birch groves form. Sandy soils are overgrown with white alder, pine, and birch. On sandy soils precipitation infiltration is intensive, and high contents of major biogenic elements are leached; therefore fertiliser action is poor, as is its utilisation, which results in severe ecological harm. Consequently, part of low-productivity sandy and gravelly soils should be left for spontaneous overgrowth, since economically it does not pay to cultivate field crops there (Riepšas, 2001).

Table 2. Spontaneous afforestation of unused grasslands

Land category	Afforested area (ha^{-1})		Dominant tree species (area %)							
	total	up to 10 years	pine	fir	ash	birch	black alder	aspen	white alder and others	LSD_{05}
Grasslands and pastures	3,173	1,708	7	0.8	1.2	31	5	2	54	4.74
Swamps, peat bogs	2,471	760	6	0	–	66	21	–	7	9.06
Quarries, sands	108	66	40	2	–	38	–	–	50	8.62

Afforestation of grasslands. The areas that should be afforested first are those in which forest plantings would perform anti-erosive functions, as well as sands or other environmentally sensitive lands. On light-textured eroded soils, slopes with an inclination of more than 10° are afforested first and on heavy-textured soils slopes with an inclination of 15°. The largest areas that are afforested are those of meadows and pastures; sands are afforested on a smaller scale and swamps and peat bogs are the least afforested. The

Table 3. Afforestation of unused grasslands

Land category	Afforested area (ha^{-1})		Dominant tree species (area %)				
	total	up to 10 years	pine	fir	birch	black alder	LSD_{05}
Grasslands and pastures	1,454	926	22	76	–	1	17.8
Swamps, peat bogs	112	96	13	79	6	2	18.1
Quarries, sands	221	153	83	11	6	-	19.4

most frequent tree species used for afforestation are fir and pine, while birch and black alder and other species are much less frequent (Riepšas, 2001).

Conclusions

In Lithuania, grasslands and pastures account for the largest share of the total unused land. Part of such areas are fallowed or conserved by sowing with perennial grasses. Of the total unused meadows and grasslands 54% is left for spontaneous overgrowth with various plants, trees, and shrubs, while 64% is afforested. Unused grasslands overgrow with birch and white alder, and quarries and sands with pine. The dominant species of planted trees are fir and pine.

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Lolium multiflorum as a catch crop in maize

De Vliegher A.[1], Latré J.[2] and Carlier L.[1]

[1]Institute for Agricultural and Fisheries Research ILVO, Merelbeke, Belgium
[2]University College Ghent, Faculty of Biosciences and Landscape Architecture, Ghent, Belgium
E-mail: alex.devliegher@ilvo.vlaanderen.be

Abstract

This study is focussed on the effect of Italian ryegrass (*Lolium multiflorum* Lam) (Lm) sown in a maize crop or after the maize harvest on the residual nitrate content in the soil before the winter period. In this experiment emergence and development of Italian ryegrass was significantly influenced by the sowing period ($P < 0.001$). The best development was realised by sowing after harvest of the maize. The results of sowing Lm at the 2–4 leaf-stage of maize were disappointing and sowing in the 6–8 leaf stage – on average 2 weeks later – was better but still inadequate. Despite significant differences in ground cover between sowing periods, no significant effects on residual nitrate in the soil in November were measured. Sowing a maize variety with an earlier maturity stage and a corresponding earlier harvest date resulted in a significant higher residual nitrate content in the soil in November.

Keywords: *Lolium multiflorum* Lam, residual nitrate, ground cover

Introduction

According the EU Nitrate Directive, the nitrate content in groundwater may not exceed 50 mg l^{-1}. Maize is a widely used forage crop with a relatively short growing season and a restricted period of N-uptake and is therefore a crop with a reasonable risk for nitrate leaching. In Flanders, the nitrate content in the soil layer 0–90 cm, measured in the period 1 October–15 November, is used as a criterion for the risk of N leaching and as a measure for the application of a good agricultural practice. Exceeding the 90 kg NO_3-N ha^{-1} $year^{-1}$ limit has substantial finacial consequences for the farmer. The goal of sowing catch crops is to reduce the residual nitrate content before the winter, to maintain the organic matter content in the soil and to prevent soil erosion.
Grasses used as a catch crop can be undersown in maize or sown after the harvest of the maize. Undersown catch crops should be more effective in reducing nitrogen leaching because the time for growth is maximised and it does not require cultivation of the soil in autumn, which itself increases N mineralisation. This study is focussed on the effect of Italian ryegrass (*Lolium multiflorum* Lam) (Lm) sown in a maize crop or after the maize harvest on the residual nitrate content in the soil before the winter period.

Materials and methods

The experiment was established on a sandy soil in Bottelare (2004) (B04), Hoogstraten (2004, 2005) (H04 and H05) and Melle (2004, 2005) (M04 and M05) as a complete block design with 3 replicates and with plots of 10 × 6 m^2. Treatments included 2 maize

varieties with a different maturing and harvest date: cv. Aurelia, maturing class early–half early and cv. Anjou 304, maturing date half late–late. Italian ryegrass was sown at the 2–4 and the 6–8 leaf-stage of maize and after the harvest of the maize in September (cv. Aurelia) and October (cv. Anjou 304).
Maize was planted at the beginning of May with an established crop density of 10 plants m^{-2}. Cattle slurry (40–50 Mg ha^{-1}) was spread just before ploughing. No other fertiliser was applied and there was mechanical weed control with harrow and hoe between the rows in combination with chemical weed control in the rows.
Italian ryegrass (tetraploid, cv. Meroa RvP) was broadcast undersown between the maize rows at a rate of 20 kg ha^{-1} or sown at 40 kg ha^{-1} after the maize harvest. The 2 silage maize varieties were harvested in accordance with their maturity class (dry matter content of about 32%). Ground cover was determined by estimation (scale 1–9) in 15 ad random squares of 25 × 25 cm in each plot in November. The residual nitrate content was measured in the soil profile 0–90 cm at the end of the official sampling period (10–15 November). The replicates of the soil samples per experimental plot were mixed before the analysis.

Results and discussion

In this experiment emergence and development of Italian ryegrass was significantly influenced by the sowing period ($P < 0.001$) (Table 1). The best development was realised by sowing after harvest of the maize. The results of sowing Lm at the 2–4 leaf-stage of maize were disappointing and sowing in the 6–8 leaf stage – on average 2 weeks later – was better but still inadequate. In many cases in this experiment, the undersown grass emerged unsufficiently and was seriously damaged by the machinery during the harvest of the maize. Undersowing was not susseccesful here but sometimes failures are mentioned in literature too (Jovanic *et al.,* 2000). Contrary to these results, other studies in Belgium indicate that ryegrass sown before the 5–8 leaf stage of the maize can grow too fast and compete with maize for water and nutrients and therefore *Festuca arundinacea*, *Festuca rubra* and *Dactylis glomerata* are more adapted to early sowing in maize (Mouraux *et al*., 1993; Verbruggen and Carlier, 1993).
Cv. Aurelia and cv. Anjou 304 were harvested on average on 25 September and 15 October respectively (an interval of 20 days). An early harvest of maize had a minor positive but non significant effect on the ground cover of the undersown catch crop.
The difference in sowing date after harvest resulted in a reasonable better development of the earliest sowing: a ground cover of 7.8 versus 6.5 for sowing after harvest in September and October, respectively.
Despite significant differences in ground cover between sowing periods, no significant effects on residual nitrate in the soil in November were measured (Table 1). The use of Italian ryegrass as a catch crop had no effect on the residual nitrate content in comparison with a reference without a catch crop in this experiment. The average residual nitrate content per experimental site was 90, 157, 128, 84 and 78 kg N ha^{-1} for B04, H04, H05, M04 and M05, respectively. In H04 and H05 the residual nitrate content exceeded considerably the limit of 90 kg N ha^{-1}. This means that there is a substantial risk of N leaching in these sandy soils. The success of undersowing grass in maize depends mainly on weather and soil conditions and N-uptake is very variable e.g. 1–36 kg ha^{-1} in experiments of Vandendriessche *et al.* (1993). Whitmore and Schröder (2007) conclude that a successful undersowing of maize with grasses can reduce nitrate concentra-

Table 1. Ground cover of Italian ryegrass (Lm), sown at different moments in the growing season of two maize varieties with a different maturity class (scale 1–9) and residual nitrate in the soil under this catch crop (average 5 experimental sites). The effects of sowing period of Italian ryegrass and maturity class of the maize varieties (difference in harvest period) were tested with two-way ANOVA analysis

Sowing period Italian ryegrass	Maize variety (harvest date maize)	Ground cover	Residual nitrate in the soil (kg NO_3-N ha^{-1} in the soil layer 0–90 cm)
	early (cv. Aurelia) late (cv. Anjou 304)	(1–9)[1]	
2–4 leaf stage	early	1.9	121
	late	1.3	93
6–8 leaf stage	early	3.7	121
	late	2.8	94
After harvest	early	7.8	122
	late	6.5	107
No	early	–	113
	late	–	106
Sowing period		***	NS
Maize variety (harvest date maize)		NS	*
Sowing period × maize variety		NS	NS

***$P < 0.001$, **$P < 0.01$, *$P < 0.05$ and NS – non significant
[1]scale 1–9: 1 = very bad and 9 = very good

tions in the water draining from soils in winter by 15 mg l^{-1} compared to a conventional catch crop and by more than 20 mg l^{-1} compared to a fallow soil.
Sowing a variety with an earlier maturity stage and a corresponding earlier harvest date resulted in a significant higher residual nitrate content in the soil in November. This can be partly explained by differences in soil conditions – temperature, humidity, soil disturbance by machinery – in the period after the first harvest and in differences in N-uptake by the 2 varieties. There is genotypic variation in DM production, N uptake and N utilisation (Wiesler and Horst, 1994).

Conclusion

In this study, undersowing Italian ryegrass in maize was not very successful in terms of ground cover in November. Emergence and vigour of Italian ryegrass sown after harvest of the maize was better and explained the better score for ground cover. In both situations the application of a catch crop did not significantly influence the residual nitrate content in the soil in November.
An early harvest of the maize, corresponding with the use of a variety with an earlier maturity stage resulted in an significant increase of the residual nitrate content of the soil despite a slightly better ground cover of the catch crop.

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Multifunctionality and sustainability of the utilisation of permanent pastures in Romania, under conditions of alternative utilisation

Dragomir N.[1], Pet I.[1], Dragomir C.[1], Pet E.[1], Cristea C.[2], Rechitean D.[2], Toth S.[1] and Fratila I.[1]

[1]Banat University of Agricultural Sciences and Veterinary Medicine, Faculty of Animal Husbandry and Biotechnologies, Timişoara, Romania
[2]Grass Research Development Station, Timişoara, Romania
E-mail: dragomir_ne@yahoo.com

Abstract

Permanent pastures are part of a rural area, together with all the other social and economic activities specific to it. The Romanian rural area comprises over 90% of the country, compared to only 75% in the EU. The Romanian pasture area is 4.9 million hectares, representing 33% of the arable land or 21% of the country's surface. This area could provide, under extensive growing conditions, the necessary food for at least 1.6 million cattle or 12 million sheep, with an animal production value of more than 2,100 mill €/year. The drastic reduction in livestock encourages the alternative utilisation of pastures for other activities, too: a source of biological nitrogen, an area for CO_2 capture, the achievement of agricultural production, the development of landscape tourism, and others.

Keywords: permanent pasture, alternative utilisation, biological nitrogen, animal-based products, agricultural products

Introduction

Among all agricultural structures, pastures are real "cover crop"-type systems, long-term in nature, that cover the soil with characteristic vegetation all through one agricultural year, contributing directly to the improvement of soil fertility, to the reduction of the negative effects caused by soil erosion, to the diversification of animal feed, and to the permanent regulation of natural factors (Wytrzens *et al*., 1999; Dzalbe and Busmains, 2002; Hervien, 2002; Peco, 2002).
The work presents some possibilities for the alternative utilisation of the permanent pastures in Romania in the context of the multifunctionality of these areas.

Method of research

The initial data necessary to perform this study (evolution of pasture area, livestock evolution, floristic structure of permanent pastures, pasture yield, and quality) relied on the results obtained by this work's authors during a period of research over 30 years long in the field of pastures (Dragomir *et al.*, 2001, 2002, 2008).
In order to estimate the amount of nitrogen fixed (BNF), we considered the results of the research performed by Kristensen *et al.* (1995) and Watson and Gross (1997), who established a proportionality between the amount of nitrogen fixed, the proportion of legumes in the pasture, the dry matter yield, and the method of utilisation (cutting or grazing).

Results and discussion

The multifunctionality of the permanent pastures in Romania is given by the complexity of utilisation of this unique land patrimony: a food source and living environment for animals, a great diversity of plant species that can be introduced into the genetic germ plasm fund, the soil protection and CO_2 capture functions, landscape and energy importance, and the performance of related economic activities (apiculture, herb provider). To maintain and to keep the continuous functioning of these areas, it is necessary to assure the equilibrium of the entire pasture ecosystem (Table 1).

Table 1. Multifunctional structure of permanent pastures in Romania

Main functions	Function characteristics
Feed for animals	It provides the necessary forage for at least 60% of the cattle livestock and 80% of the sheep livestock.
Economic aspects	Connected activities resulted from the utilisation and capitalisation of pastures (animal product processing, gathering of herbs, apiculture, etc.).
Habitat for animals	Among the 783 types of habitats in Romania, almost 60% may be found in permanent pastures. Among the animal species, 5 have disappeared, and more than 30 are threatened with disappearance.
Biodiversity and preservation of plant species	On the territory of our country, more than 3,700 species of plants have been identified, of which more than 70% belong to the permanent pasture vegetation. 74 species have disappeared, 485 are threatened with disappearance, 200 species are vulnerable, 23 are declared monuments of nature, and 1,253 are rare species. The biodiversity indices of pasture vegetation in Romania are higher than in many European countries. Romanian pastures comprise an important genetic fund of germ plasm and a very rich melliferous and medicinal flora.
Ecological function	Soil protection against erosion and preservation of natural area.
Landscape function	Plant diversity ennobles and beautifies the environment.
Energy function	A large part of the biomass could be transformed into non-conventional energy products.

The floristic structure and the productive potential of at least 70% of the total pasture area (3.5 mill ha) can provide animal-based products (meat, milk) with an annual value of over 2,000 mill € under extensive utilisation (Table 2).

Table 2. Estimated efficiency of animal production on the permanent pastures of Romania (under extensive utilisation)[1]

Animal category	Maximal capacity (no. of animals)	Potential yields		Value, (mill € $year^{-1}$)
		structure	(thousand t $year^{-1}$)	
Cattle	1,600,000	meat	885	1,300
Sheep and goats	12,000,000	milk	2,500	800
Total	–	–	–	2,100

[1]Usable area: 3.5 mill ha (70% of the total area of permanent pastures)

Table 3. Estimative amount of biologically-fixed nitrogen (BNF) in the pasture agro-ecosystems and legume crops in Romania

Structure	Area (mill ha)	Mean BNF amount (kg ha^{-1} year^{-1})	Total BNF amount (thousand t)	Value (mill € year^{-1})
Permanent pastures[1]	3	30	90 (28%)	97
Temporary pastures	0.6	80	48[2] (15%)	52
Perennial legumes	0.7	160	112[2] (35%)	120
Annual legumes	0.5	140	70[2] (22%)	75
Total	4.8	–	320 (100%)	344

[1]Permanent pastures with legume proportion > 10%

[2]The amount of nitrogen fixed in the temporary pasture and legume crops could assure the necessary nitrogen for rotation crops on an area of at least 0.5 mill ha

Pasture crops (permanent and temporary) and legume crops (annual and perennial) totalling an area of almost 5 mil. ha may constitute an important source of biologically-fixed nitrogen (BNF). If at least 25% of this amount remained in the soil, then the nitrogen necessary for the next crops (cereals) in rotation would be assured for an area of over 0.5 mil. ha (Table 3).

Table 4. Estimative honey production balance in Romania, under conditions of pasture crops and other agricultural crops

Structure	Area (mill ha)	Mean honey amount (kg ha^{-1} year^{-1})	Total honey amount (thousand Mg year^{-1})	Value (mill € year^{-1})
Permanent pastures	3.5	70	245 (33%)	735
Temporary pastures	0.6	120	72 (10%)	216
Legume crops (annual and perennial)	1.2	140	168 (23%)	504
Other agricultural crops	2.5	100	250 (34%)	75
Total	7.8	107	735 (100%)	2,205

An alternative utilisation system of pastures is represented by the development of apiculture activities (gathering, processing, capitalisation), with an important role for the Romanian natural and social conditions. So the estimative results presented in Table 4 show that the melliferous flora present in the floristic structure of the permanent pastures, too, may contribute with at least 33% to the achievement of the entire honey potential of our country. To this, we may add 33% more from the contribution of temporary pasture and legume crops (annual and perennial). The economic importance of this alternative function of pastures consists in an annual estimated agricultural product value of more than 1,500 mill €.

Conclusions

Under the conditions prevailing in Romania, the multifunctional character of permanent pastures allows the alternative utilisation of these areas, with important economic and social effects.

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The use of salt for managing unguarded mixed livestock on Atlantic mountain heathlands

Eliceits P.[1], Aldezabal A.[2], Ruiz R.[1] and Mandaluniz N.[1]

[1]*NEIKER-Tecnalia, Vitoria-Gasteiz, Spain*
[2]*University of the Basque Country, Bilbao, Spain*
E-mail: nmandaluniz@neiker.net

Abstract

Western European heathlands are located in mountain areas where livestock has traditionally ranged. It has been demonstrated that livestock exert an important effect upon these natural resources. Thus, management alternatives are sought to attract them in order to improve habitat use. In this sense, the provision of different nutrients such as salt is expected to attract animals and consequently, control the expansion of dense heathlands. Therefore, a study was carried out to assess the effect of different salt doses on soil and vegetation parameters and on animal use. According to the results obtained, livestock were strongly attracted by salt and their trampling resulted in an increase in the amount of grass. Finally, plots treated with salt showed a higher content of sodium in soil samples but no differences were found in the nutritive value of the pasture.

Keywords: grazing, management, tools, vegetal mosaics

Introduction

Western European countries own huge extensions dominated by open heathlands (Alonso *et al.*, 2003), protected by the European Habitat Directive (97/62/EU). Most of these communities are located in mountain areas where, traditionally, livestock has played a determinant role in modelling the ecosystem (San Miguel, 2003).
However, the current trends observed in livestock systems in Europe demonstrate that the decline in livestock pressure (effect of grazing, trampling, or even the faecal accumulation) on these areas has caused a non-uniform use of the ranges, with a tendency towards shrub invasion in certain areas. Thus, management alternatives (non-invasive, easy to carry out and cheap) are sought to attract livestock and improve the pasture utilisation of these mosaics. The provision of nutrients such as salt (Pfister and Manners, 1991) is expected to attract animals and, consequently, control the expansion of dense heathlands and preserve open ones. Because of all these considerations, a study was carried out to assess the effect of different salt doses on vegetation parameters and animal use.

Materials and methods

The study was carried out in the Natural Park of Gorbeia (43ºN'2.5ºW), an Atlantic region of the Basque Country, Northern Spain. In this area, grassland is combined with heathlands at altitudes above 800 m, shaping a particular environment that has traditionally been ranged by mixed and unguarded livestock (Casasus *et al.*, 2005). In September 2007, different salt doses (0, 50, and 100 kg ha^{-1}) were spread (put directly onto the soil) on plots 20 × 100 m using 3 replicates. The plots were located in dense heathlands composed mainly of the following shrubs: heather (mainly *Erica vagans,* and to a lesser extent *E. cinerea, E. ciliaris*, and *E. tetralix*), gorse (*Ulex europaeus*), and fern (*Pteridium aquilinum*). Three transects were monitored in each plot, before (D-10) and one month after (D-30) the application of the salt. Soil, vegetation, and livestock were monitored in order to assess the effect of the application of the salt.

(1) Upon soil: one representative sample was taken in each plot from a depth of 7 cm, dried 30ºC per 48 h, and sent to the laboratory to determine the pH and organic matter (OM), macronutrients (N, P and K), and sodium (Na) content.

(2) On vegetation: (*i*) the pasture height was measured by means of a manual stick (H.F.R.O., 1979), with a precision of 0.5 cm; (*ii*) the vegetation structure (%) was determined by the point intercept method on 3 transects of each plot, giving 100 contacts per transect. Plants were grouped into the following botanical groups: 'swards' including graminoids and non-graminoids; 'shrubs' including heather species and gorse, and 'others' including ferns and litter, dead material, bare ground, dung, etc; (*iii*) sward samples were taken by 'hand plucking' (Wallis de Vries, 1995) and nutritive value was estimated in terms of crude protein (CP) determined by Kjeldahl (A.O.A.C., 1999) and fibres (neutral and acid detergent fibres: NDF and ADF) (Van Soest, 1982). Finally, the content of Na in the sward was estimated.

(3) On animal behaviour: livestock pressure was estimated as faecal accumulation (Lange and Willcocks, 1978), that of cattle and mares by counting faeces numbers/plot (standardised to no. faeces ha^{-1}) while that of sheep and goats was collected by plot, dried in an oven (40ºC per 48 h) and weighed (standardised to kg dry matter (DM) ha^{-1}). Measurements were taken before the application of the salt (D-0) and 10, 20, and 30 days latter (D-10, D-20, and D-30).

(4) Data were analysed by a general lineal model (S.A.S., 2003) considering the following fixed effects: day in relation to the application (D-0 vs. D-30 for soil and vegetal parameters and D-0, D-10, D-20, and D-30 for livestock use), salt application (yes vs. no), salt dose (0, 50, or 100 kg ha^{-1}).

Results and discussion

(1) Soil. Average values for pH, OM, N, P, K, and Na were 4.1 ± 0.1, 28% ± 2, 1.15% ± 0.13, 12.3 ppm ± 4.9, 283 ppm ± 44, and 0.28 meq 100 g ± 0.06, respectively. According to the statistics, there was a tendency for there to be a higher Na content after the application of the salt and on plots spread with salt with no differences between the salt doses (Table 1).

(2) Vegetation. The average sward height was 4.2 ± 1.6 cm, increasing significantly in D-30; this was probably related to the autumn regrowth pattern. The area studied was composed of 29% ± 17 sward and 43% ± 14 shrubs, and a tendency for there to be higher grass cover was observed after the application of the salt (Table 1), which could be due to the effect of trampling.

The average CP, NDF, and ADF values and the Na content of the pasture were 13.3% ± 2.9, 71% ± 3, 40% ± 3, and 0.42 g kg^{-1} ± 0.14, respectively. A higher CP and lower fibre content were observed after the application of the salt, which could also be linked to the autumn regrowth (Fuentes-Yague, 2003). Moreover, a higher content of Na was observed after the application, but there were no effects resulting from the salt doses (Table 1), which could be due to the ingestion of salt by livestock on high-salt plots.

(3) Livestock use. The average faecal accumulation during the monitoring period was 0.97 ± 1.5 kg DM small ruminant per ha; 12 ± 17 cow per ha and 59 ± 61 mare per ha. Salt plots attracted livestock, as cited in the literature (Mandaluniz *et al*., 2005; Phillips

Table 1. The effect of the day, salt application, and salt dose upon soil Na content (mq 100 g^{-1}), vegetal parameters as height (cm), structure (%), nutritive value (%), and faecal accumulation (kg DM ha^{-1} or no. faeces ha^{-1})

		Day			Salt application			Salt dose (kg ha^{-1})			
		D-0	D-30	*P*	yes	no	*P*	0	50	100	*P*
Soil	Na	0.25	0.30	0.06	0.30	0.25	0.06	0.25	0.31	0.29	ns
Sward	height	4.2^{a}	5.8^{b}	***	5.0	4.9	ns	4.9	5.0	5.0	ns
Vegetation structure	sward	29	36	0.06	33	32	ns	32^{a}	38^{b}	28^{a}	0.07
	shrubs	43	40	ns	43	40	ns	40	42	44	ns
	others	28	24	ns	24	28	ns	28	20	28	ns
Pasture nutritive value	cp	12.1^{a}	14.6^{b}	**	13.2	13.6	ns	13.6	13.4	13.0	ns
	fnd	72^{a}	70^{b}	**	71	71	ns	71	71	72	ns
	fad	41^{a}	39^{b}	*	40	39	ns	39	40	41	ns
	na	0.36^{a}	0.47^{b}	*	0.43	0.40	ns	0.39	0.42	0.45	ns
Faecal accumulation	small rum.	9.2^{a}	2.7^{b}	**	6.1	3.5	ns	3.5^{a}	5.4^{ab}	6.8^{b}	0.11
	cattle	66^{a}	8^{b}	**	36	31	ns	31	30	42	ns
	mares	210^{a}	32^{b}	***	137	95	0.09	95^{a}	146^{ab}	129^{b}	0.07

*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$

et al., 2000) with an exponential accumulation in D-10 (more details in Eliceits and Mandaluniz, 2008). Finally, a tendency for there to be a higher presence of small ruminants and mares on high-salt plots was observed (Table 1).

Conclusions

In the short term, livestock were attracted to the plots treated with salt, resulting in higher grass cover and a greater sodium content in the soil, probably because of the effect of trampling. There was no significant effect of the salt dose, which could be due to the ingestion of the salt by livestock just after its application. A longer monitoring approach is necessary to assess the effect on soil, vegetal, and livestock parameters, in order to adjust the use of these tools to conduct livestock and improve pasture conservation.

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Silvopastoral systems: effects on alpha and beta biodiversity eleven years after establishment

Fernández-Núñez E., Mosquera-Losada M.R. and Rigueiro-Rodríguez A.

University of Santiago de Compostela, High Polytechnic School, Crop Production Department, Lugo Campus, Lugo, Spain
E-mail: mrosa.mosquera.losada@usc.es

Abstract

The European Union has agreed to reduce biodiversity losses by 2010. Land use change can cause important modifications in biodiversity. Biodiversity is an important issue in promoting agricultural sustainability, and it depends on vegetation management. The objective of this work is to evaluate the effect of two tree species, *Pinus radiata* D. Don and *Betula alba* L. (2,500 tree ha^{-1}) and three types of fertilisation (none, dairy sewage sludge fertilisation, and mineral fertilisation) on the alpha (Species Richness (SR) and Pielou Index) and beta biodiversity (Index of Complementarity C_{AB}) after 11 years. The results show that SR was drastically reduced under the plantation of *Pinus radiata* D. Don compared to *Betula alba* L. (SR_{pine}=2 *vs* SR_{birch}= 14) after eleven years of tree establishment. SR reduction was also more important when fertilisation was applied (either organic or inorganic).

Keywords: *Pinus radiata*, *Betula alba*, fertilisation, ryegrass

Introduction

Since the middle of the 20th century policies of afforestation and increasing timber production have been promoted by the EU. One major characteristic of these policies has been the planting of large areas of productive coniferous tree species because of their higher productivity. The promotion of afforestation and agroforestry systems can affect biodiversity in a positive or negative way. Within the Lugo province (north-west Spain), *Pinus radiata* is currently one of the most widely used afforestation trees (Rigueiro-Rodríguez *et al.,* 2005). Most of these afforested areas have been established on former farmland and on abandoned and degraded scrublands and, normally, they have been established at a high density. These land use changes can cause important modifications to microclimatic conditions (soil, interior temperature of the system …) and this can affect biodiversity in the short and medium term. The best way to conserve biodiversity is through a knowledge of the effect of different land management techniques on the alpha and beta biodiversity (Mosquera-Losada *et al*., 2009).

Materials and methods

The study was initiated in Lugo (NW of Spain) in 1995 over a soil classified as Umbrisol (FAO, 1998), with a sandy-silty texture (61% sand, 34% silt, and 5% clay) that was previously used for potato cultivation. The design was established using random blocks with three replicas. The treatments consisted of the evaluation of two forest species: *Pinus radiata* D. Don (from container plants) and *Betula alba* L. (from bare roots) established at

2,500 trees ha^{-1}. Each replica has an area of 64 m^2 and 25 trees were planted with an arrangement of 5 × 5 stems, forming a perfect square. At the end of the winter of 1995, after the preparation of the soil, the plots were sown with *Lolium perenne* L. var. Brigantia (25 kg ha^{-1}) + *Trifolium repens* L. var. Ladino (4 kg ha^{-1}) + *Trifolium pratense* L. var. Marino (1 kg ha^{-1}). Three types of fertilisation were applied: *NF* = No fertilisation, *D* = Dairy sewage sludge fertilisation (154 m^3 ha^{-1}) at the establishment, and *M* = Mineral fertilisation (500 kg 8:24:16) at the beginning of every year plus 40 kg N ha^{-1} after the first harvest (May). *D* treatment received the same treatment as *M* after 1997. Every year pasture production was estimated by harvesting an area between six inner trees in the plots three times during the spring and once in the autumn, with the exception of the first year, when two harvests, one per season, were performed. The samples were transported to the laboratory, where species were hand separated and the botanical composition was estimated on the basis of the percentage of dry matter. The alpha biodiversity, Species Richness (SR) and Pielou Index (Magurran, 1988) and beta biodiversity were estimated according to the Index of Complementarity (C_{AB}) (Colwell and Coddington, 1994) in the first, fifth, and tenth years of the experiment. In this work we show the results during three periods of the development of the system, corresponding to the year of establishment (1995), intermediate development of the system (2000), and the final situation (2005). The ANOVA and LSD tests were used for the statistical analyses.

Results and discussion

After 11 years of study, the results show a different effect of the two types of tree canopy and the three fertilisation treatments established in alpha and beta biodiversity. On the one hand, the alpha biodiversity was similar in the first five years (1995–2000) in both systems (pine and birch) and decreased significantly in the last year ($P_{SR} < 0.001$ and $P_{Pielou} < 0.01$) under pine and fertilisation treatments (*D* and *M*) (Figure 1). On the other hand, the species are very similar in both tree canopies ($C_{AB} < 50\%$) in 1995 and 2000,

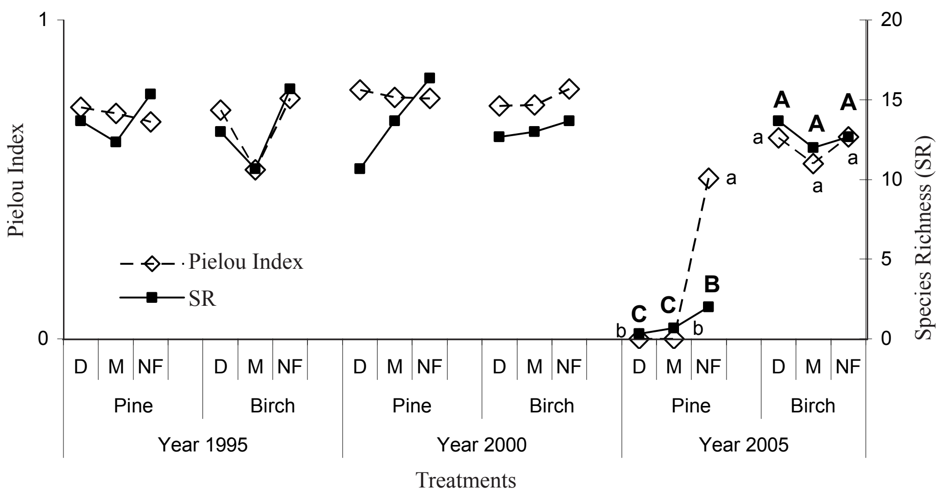

Figure 1. Alpha biodiversity (Species Richness (SR) and Pielou Index) over the three years of study and two tree species where: *D*: dairy sewage sludge fertilisation; *M*: inorganic fertilisation; *NF*: no fertilisation. Different letters indicate significant differences between treatments in the same year

Table 1. Index of Complementarity (C_{AB}) between the plots established under pine trees and birch trees in the three years of the study where: a = species present in the plots of pine trees, b = species presents in the plots of birch trees, c = common species between the plots established under the two canopies, S_{ab} = total richness of species for both plots, U_{ab} = number of unique species in each type of plot

Year	a	b	c	S_{ab}	U_{AB}	C_{AB}
1995	31	29	27	33	6	0.18
2000	25	21	19	27	8	0.30
2005	5	17	4	18	14	0.78

while in the last year the understory composition is very different (Table 1). In our case, canopy closure caused an important decrease in the amount of light within the pine trees plots and favoured the presence of litter, especially during the last year of the study (2005). In this situation, the seeds under the litter are deprived of light and the seeds on top cannot root easily (Ellsworth *et al*., 2004). This causes a considerable decrease in the Species Richness and floristic diversity of the systems. This effect was increased when fertilisation (*D* or *M*) was applied because these treatments favoured the presence of sown species (Mosquera and González, 2000; Rajaniemi, 2002).

Conclusions

Forest tree species choice and initial fertilisation are very important to preserve biodiversity in silvopastoral systems. Pine at high density caused faster biodiversity reduction at a species and landscape level than broad-leaved *Betula alba*. Inorganic or organic fertilisation causes a faster reduction in biodiversity.

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Nutritive value at ear emergence of four timothy varieties

Frankow-Lindberg B.E.

Swedish University of Agricultural Sciences, Department of Crop Production Ecology, Uppsala, Sweden
E-mail: bodil.frankow-lindberg@vpe.slu.se

Abstract

Four timothy (*Phleum pratense* L.) varieties of different earliness, namely Jarl, Grindstad, Alexander, and Ragnar, were sampled at the same phenological stage. The plants were grown in Perlite in a controlled environment, and a complete mineral solution was supplied daily. The established plants were kept under conditions simulating the autumn and winter climate, and after that at temperatures and day-lengths corresponding to spring and early summer in Sweden. The plants were cut at ground level and were separated into leaves, stems, stubble, and spikes. The samples were dried at 60°C for 48 h, then weighed, milled, and analysed for organic matter digestibility, crude protein, neutral detergent fibre (NDF), and insoluble detergent fibre (iNDF). There were no significant differences in any of the variables between the four varieties. The differences in phenological development among the respective varieties were four days between the earliest (Jarl) and the latest (Ragnar) variety.

Keywords: digestibility, ear emergence, fibre, *Phleum pratense*, timothy, varieties

Introduction

If feeding rations to high-yielding ruminants are to contain a large amount of forage it must have a high level of digestibility. Since the average dairy herd yield in Sweden is > 8,000 kg ECM milk, the demand for highly nutritious forage is of prime importance. This emphasis on the nutritive value of forage is a stimulus for plant breeders to create varieties with improved feeding qualities. It is widely accepted that the nutritive value is mainly determined by the phenological stage of the crop. At a given stage it may also be affected by the digestibility of the different parts of the plant and their relative proportion in the crop, since leaves generally have greater digestibility than stems (Bélanger *et al.*, 2001). Recently, a new timothy variety (Ragnar) has been released in Sweden, which is said to have an improved nutritive value. Whether this improvement is a function of the slow phenological development of Ragnar, or changes in its chemical composition, has not been confirmed. It is thus of interest to compare the nutritive value of varieties differing in maturity when harvested at a pre-determined phenological stage. The varieties examined belong to the same maturity group as that suggested by Míka (1983) as the relevant basis for nutritive value comparisons between varieties.

Materials and methods

Four timothy (*Phleum pratense* L.) varieties displaying distinct field variation in earliness, namely Jarl (early), Grindstad (early), Alexander (in between), and Ragnar (late), were used in the experiment. To eliminate the effects of fluctuations in weather variables on nutritive variables (Thorvaldsson, 1988), the plants were grown in a controlled environment. The plants were grown in boxes (27 × 17 × 14 cm) in Perlite, with 21 plants per box. The boxes were placed close to each other to simulate sward conditions, and were moved around every week. The plants received a complete mineral solution daily. The plants were established in early autumn and thereafter, during a period of three months, were subjected to climatic changes in temperature and day-length that simulated autumn and winter conditions. During this period the plants were trimmed three times to a stubble height of 8 cm to encourage tillering. During the experimental period the plants were kept in a constant climate with a temperature of 15/10°C (day/night), and a day-length of 18 h. This corresponds to normal spring/early summer weather in Sweden. The varieties were harvested at the two-node stage (data not presented) and at ear emergence (the target developmental stage for practical farmers) in the following order: Jarl > Grindstad > Alexander > Ragnar. The plants were cut at ground level, the number of fertile and vegetative shoots was counted, and thereafter they were sorted into four fractions: leaves + sheaths, stems, stubble, and spikes. Dead material was discarded. The samples were dried at 60°C for 48 h, and were then weighed, milled, and analysed for organic matter digestibility (OMD), crude protein (CP), neutral detergent fibre (NDF), and insoluble detergent fibre (iNDF). Organic matter digestibility was used to calculate metabolisable energy (ME) according to the formula: ME = 0.9 × OMD – 2.0 (Fodertabeller för idisslare, 2003). The whole-crop nutritive value was calculated from the weights and quality variables of the individual fractions combined. The experimental design was a completely randomised design with four replicates. The stubble (bottom 8 cm) and spike data are not reported since stubble is not of interest for practical conditions and the spikes contributed little to the yield.

Results and discussion

The differences in phenological development among the respective varieties were four days between the earliest (Jarl) and the latest (Ragnar) variety. This is consistent with the results from the official variety testing (Halling, 2008), but, in particular, temperature variations in the field may increase or reduce these differences (Jefferson, 2005).

Table 1. Stem CP, NDF, iNDF (g kg DM^{-1}), and ME content (MJ kg DM^{-1})

Variety	CP	NDF	iNDF	ME
Grindstad	158	602	185	10.8
Alexander	144	611	191	10.8
Jarl	149	612	187	10.8
Ragnar	151	619	194	10.9
Significance	NS	NS	NS	NS

Jarl yielded significantly less than the other varieties ($P < 0.05$), which did not differ significantly from each other. This is consistent with the results obtained in the official variety testing (Halling, 2008) performed in the field. The negative relationship between yield and nutritive value reported by Bélanger *et al.* (2001) was thus not confirmed by this study.

Table 2. Leaf CP, NDF, iNDF (g kg DM^{-1}), and ME content (MJ kg DM^{-1})

Variety	CP	NDF	iNDF	ME
Grindstad	264	409	48	13.0
Alexander	255	397	50	13.0
Jarl	256	416	53	13.0
Ragnar	252	421	56	13.0
Significance	NS	NS	NS	NS

The leaves had, as expected, a greater ME concentration and a smaller fibre concentration than the stems. There were no differences in any of the nutritive variables of the stems (Table 1) or the leaves (Table 2) among the varieties. The calculations of the quality of the whole crop showed no significant differences among the varieties. This is in contrast to the results reported by Jefferson (2005). However, in his experiment all the varieties were harvested on the same day. It is also in contrast to the suggestions by Bélanger *et al.* (2001) that when early- and late-maturing varieties are compared at the same stage of development, early-maturing varieties have a greater DM digestibility and a lower concentration of NDF. Jarl had the significantly smallest proportion of leaves in the crop ($P < 0.05$), while there was no difference among the other varieties (0.50 vs. 0.56). Since leaves are more digestible than stems, the leaf proportion of the crop could theoretically affect the nutritive value of the crop, but other factors are also involved (Bélanger and McQueen, 1996; Gustavsson and Martinsson, 2004). The total number of vegetative shoots was largest for Grindstad. However, some of these shoots were very small and contributed infinitesimally to the yield, and are more an indication of the regrowth potential of Grindstad. The majority of the shoots were fertile (no significant differences in numbers between varieties) at the time of harvesting and they constituted more than 50% of the total shoot numbers. This may explain why no differences in nutritive value were found, since the stem is the main determinant of the nutritive value of the crop (Durand and Surprenant, 1993). Harvesting at a later stage would probably not have yielded more information, since the rate of change in digestibility and NDF followed a similar response curve, irrespective of differences in maturity among the four timothy varieties grown in the field (Bélanger and McQueen, 1997).

It is concluded that there were no differences in nutritive value among the varieties studied when they were harvested at the same phenological stage. The leaf proportion of the crop did not affect the nutritive value of the whole crop.

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Annual and seasonal effects on micro-mineral concentrations in four grassland species

Frankow-Lindberg B.E., Lindström B. and Öborn I.

Swedish University of Agricultural Sciences, Department of Crop Production Ecology, Uppsala, Sweden
E-mail: bodil.frankow-lindberg@vpe.slu.se

Abstract

The micro-mineral (B, Cd, Co, Cr, Cu, Fe, Mn, Mo, Ni, Pb, Se, and Zn) concentrations in four grassland species, namely perennial ryegrass (*Lolium perenne* L. cv. Helmer), cocksfoot (*Dactylis glomerata* L. cv. Dactus), red clover (*Trifolium pratense* L. cv. Fanny), and white clover (*Trifolium repens* L. cv. Ramona) were analysed. The plants were grown in southern Sweden (56°55'N, 13°07'E, 55 m a.s.l.) as pure stands and were fertilised with 180 kg nitrogen ha^{-1} year^{-1}. The soil at the site was a sandy clay loam with a pH of 6.9, an organic matter content of 2.1%, and a CEC of 23 cmol$_c$ kg^{-1}. The plots were harvested three times year^{-1} for three consecutive years. Analyses of the plants showed that in perennial ryegrass there was a significant seasonal effect on the concentrations of several micro-minerals. White clover and cocksfoot showed few seasonal effects and red clover none. Annual trends in micro-mineral concentrations were few.

Keywords: annual effects, cocksfoot, micro-minerals, perennial ryegrass, red clover, seasonal effects, white clover

Introduction

The micro-minerals boron (B), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), nickel (Ni), selenium (Se), and zinc (Zn) are essential to plants and/or animals and play an important role in the animal diet as they may cause malfunctions as a result of either deficiency or of toxicity (Whitehead, 2000). Other trace elements, such as cadmium (Cd) and lead (Pb), are potentially toxic metals without any known essential function. Significant differences between plant species in their concentrations of micro- (Forbes and Gelman, 1981; Ylaranta and Sillanpää, 1984) and macro-minerals have been reported (Wilman and Derrick, 1994), but there are few studies on annual and seasonal variation in micro-mineral concentrations in herbage. The aim of this study was to investigate possible annual and seasonal effects on B, Cd, Co, Cr, Cu, Fe, Mn, Mo, Ni, Pb, Se, and Zn concentrations in four common forage species.

Materials and methods

Four grassland species, perennial ryegrass (*Lolium perenne* L. cv. Helmer), cocksfoot (*Dactylis glomerata* L. cv. Dactus), red clover (*Trifolium pratense* L. cv. Fanny), and white clover (*Trifolium repens* L. cv. Ramona), were grown in pure stands and mixtures for three consecutive years. The experiment was carried out under the auspices of EU COST Action 852 ('Quality legume-based forage systems for contrasting environments'), and more details about the experiment can be found in Frankow-Lindberg *et* *al.* (2009). The experimental site was located at Svalöv (56°55'N, 13°07'E, 55 m a.s.l.) in southern Sweden. The soil was a sandy clay loam with a pH of 6.9, an organic matter content of 2.1%, and a cation exchange capacity (CEC) of 23 $cmol_c$ kg^{-1}. The plots were fertilised with 180 kg nitrogen ha^{-1} $year^{-1}$. After an establishment year, whole plots were harvested for three years (2003–2005) with an experimental plot harvester three times per year (late May–early June, the second half of July, late August–early September) with a stubble height of ca. 5 cm (normal practice within this climate zone). At each harvest the biomass yield was determined and samples for the analysis of dry matter (DM) and mineral analysis were taken from the pure stand plots. The samples were dried and wet-digested with 10 + 5 ml HNO_3 at 135°C for 17 h using a digestion block and diluted with ultrapure water before being analysed for mineral concentrations on an ICP-MS (Perkin Elmer ELAN 6100). Since the experimental layout followed a simplex design, which does not contain any true replicates, an analysis of variance was therefore performed with two factors (years and harvest numbers) on the mineral concentration data.

Results and discussion

Significant annual trends in micro-mineral concentrations were few. In perennial ryegrass the Cr concentration ($P < 0.05$) and in white clover the Mo concentration ($P < 0.05$) decreased over the years. In cocksfoot the Mn concentration ($P < 0.05$) increased over the years. A few micro-minerals showed significant increases in their concentrations over the season (Table 1), and there were also differences between species. The seasonal effects were strongest in perennial ryegrass (significantly so for six elements), while there were few micro-minerals that showed a significant seasonal effect in cocksfoot and white clover. In red clover, there was no significant seasonal effect in any element. However, for a range of elements in all species, significances between $0.05 < P < 0.1$ were found, suggesting that seasonal variations in more mineral concentrations could have been common in this experiment. These results are in contrast to data presented by Anke *et al.* (1994), who found a general decline in concentrations of micro-minerals over the season.

Table 1. Average plant concentration in the different harvest (cuts), across years, of micro-minerals with significant seasonal effects, mg kg DM^{-1} ($n = 3$). The respective levels of significance shown are related to seasonal effects, and not to individual figures

	Harvest within year								
	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
	perennial ryegrass			cocksfoot			white clover		
Cd	0.02	0.03	0.05**	0.08	0.12	0.12**			
Cu	5.0	5.0	7.7*						
Fe	78	103	134*						
Mn				66	120	152*	37	39	56***
Mo	1.1	1.4	1.9*						
Pb	0.08	0.09	0.22**						
Se	0.03	0.05	0.08*						

* $P < 0.05$, ** $P < 0.01$ and *** $P < 0.001$

The recorded concentrations (Tables 1 and 2) are more or less within the range of previously published data (Forbes and Gelman, 1981; Ylaranta and Sillanpää, 1984). The exceptions are that the two clover species had slightly lower concentrations of Mn, but higher concentrations of B and Cu.
The two clover species had higher concentrations of B and Cu compared to the two grasses, and also of Fe compared to cocksfoot, while the two grasses had a higher concentration of Cr and Mn than the two clover species. For all other elements (Co, Mo, Ni, Pb, Se, and Zn), the concentrations were similar among the species.

Table 2. Average concentrations of micro-minerals by evaluated species with no significant seasonal effect, mg kg DM^{-1} (n = 9, except for white clover where n = 8)

Species	B	Cd	Co	Cr	Cu	Fe	Mn	Mo	Ni	Pb	Se	Zn
Perennial ryegrass	20		0.05	0.68			103		1.88			23
Cocksfoot	16		0.03	0.81	5.4	71		1.19	1.81	0.14	0.05	23
Red clover	52	0.05	0.07	0.18	13.7	102	39	0.84	2.19	0.09	0.06	30
White clover	52	0.01	0.12	0.22	10.6	132		1.26	1.62	0.10	0.06	27

It is important to bear in mind that mineral concentrations may vary with seasonal trends in DM production (Pelletier *et al.,* 2008). In this case, the DM yield generally declined over time (data not shown), both between years and within seasons (less so for red clover). This might be an explanation for the seasonal effects found.

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Cultivated and wild growing forage crops – reservoirs of viruses and phytoplasmas

Fránová J.[1], Petrzik K.[1], Jakešová H.[2], Bečková M.[1] and Sarkisova T.[1]

[1]*Biology Centre ASCR, Institute of Plant Molecular Biology, Department Plant Virology, České Budějovice, Czech Republic*
[2]*Breeding Firm Ing. Hana Jakešová, CSc., Hladké Životice, Czech Republic*
E-mail: jana@umbr.cas.cz

Abstract

Several symptoms of mosaic, yellowing/reddening, phyllody, necrosis and dwarf have been observed in cultivated as well as wild growing forage crops. To detect and identify the pathogens, plants were subjected to biological assays, electron microscopy, PCR/RFLP DNA analysis, RT-PCR, cloning and sequencing. *Red clover mottle virus* (RCMV, *Comovirus*), *Clover yellow vein virus* (*Potyvirus*), *Potato virus X*, *White clover mosaic virus* (WClMV, *Potexvirus*), *Alfalfa latent* and *pea streak viruses* (*Carlavirus*), new members of genus *Cytorhabdovirus* and *Carlavirus* were identified by sequencing. Bacilliform particles (ca 213–533 nm by 44–58 nm) of the genus *Cytorhabdovirus*, WClMV, *Alfalfa mosaic virus* (*Alfamovirus*) and particles resembling members of the genus *Badnavirus* (ca 35 by 220–330 nm) were observed on negatively stained preparations and ultrathin sections by electron microscopy and mechanically transmitted to various host plants. WClMV, RCMV, *Bean yellow mosaic virus* and new member of *Potyviridae* family were determined in wild growing plants. The occurrence of phytoplasmas belonging to different 16S ribosomal subgroups was confirmed (16SrI-B, 16SrI-C, 16SrX-A, 16SrXII-A).

Keywords: symptoms, electron microscopy, biological and molecular identification

Introduction

In the European agriculture, as well as in the Czech Republic, the alternative functions of grassland play an important role with the improving tendency. Forage crops are susceptible to virus and phytoplasma diseases that decrease yield by reducing foliar growth, reduce longevity of stands and productivity of plants, increase susceptibility to root organisms and other plant pathogens, cause plants to produce fewer and less efficient root nodules. More than 100 viruses and phytoplasmas affecting forage crops are now described and it is probable that further diseases will be found. With regard to a relatively high occurrence of ill plants from several locations, *Trifolium* species are considered to be one of the most important natural reservoirs of phytoplasmas and viruses within the Czech Republic.

Plants showing especially dwarf growth habit alone or together with curl, diverse leaf drawing, mosaic, leaf fragility symptoms has been repeatedly found in clover breeding nurseries as well as in wild growing plants. Biological experiments, transmission electron microscopy (TEM) and molecular methods were applied to identify the pathogens.

Materials and methods

Samples originated from 200 of cultivated plants [*Trifolium pratense* (number of plants:141), *T. hybridum* 4n (15), *T. repens* (9), *T. resupinatum* (11), *Medicago sativa* (24)/ and of 25 wild growing /*Trifolium pratense* (10), *T. repens* (4), *T. dubium* (2), *Vicia cracca* (4), *Lupinus polyphyllus* (5)] were examined during 2007–2008. Crude sap from leaf samples were examined by mechanical inoculation of host plants (especially *Nicotiana occidentalis* Wheeler, accession 37B and *Physalis floridana* Rybd.). Virus purification from infected differential host plants was also performed. Ultrathin sections from symptomatic leaves of forage crops as well as experimental host plants and negatively stained crude and partially purified preparations, were examined in a JEM 1010 TEM. RNA was isolated using the RNeasy Plant Mini Kit (Qiagen), cDNA was synthesised using the iScript cDNA Synthesis Kit (Bio-Rad) according to the manufacturer's recommendations. Genus-specific primers were designed for detection of *Alphacryptoviruses*, *Carmoviruses*, *Carlaviruses*, *Closteroviruses*, *Comoviruses*, *Cryptoviruses*, *Luteoviruses*, *Potyviruses*, *Potexviruses*, *Rhabdoviruses*. Specific detection of RCMV and WClMV was performed with primers derived from sequences NC_003741 and NC_003820 deposited in GenBank. Amplification up to 35 cycles was used in all experiments. Products visible after separation on agarose gels were verified by sequencing: bands of expected size were excised from gel, purified and cloned to pJET vector (Fermentas). Clones containing the correct insert were sequenced and the nucleotide sequence evaluated.

For phytoplasma detection, nucleic acid samples from symptomatic forage crops, positive and healthy controls, were extracted. The universal primer pairs R16P1/P7 was used in direct PCR while the R16F1/B6 was employed in nested assay. For increasing of the detection sensitivity, further nested PCR by primers R16/F2/R2 were employed. The phytoplasma identification was performed by the restriction fragment length polymorphism analyses.

Results

Phytoplasma-like bodies, bacilliform, filamentous and rod-shaped virions were observed singly or in different combination in all symptomatic clover and lucerne plants examined by TEM.

Viruses were sap-transmitted from symptomatic lucerne, red and white clover plants by mechanical inoculation to herbaceous hosts. Usually, five days after inoculation, a few chlorotic/necrotic lesions developed on the inoculated leaves of *N. occidentalis* 37B. Subsequently, plants produced systemic mosaic and necrosis. The presence of viruses in experimental hosts was also confirmed by TEM. According to the shape and size, three kinds of bacilliform particles were observed. Those, measuring ca 213–533 nm by 44 to 58 nm and localised within the cytoplasm, were assigned to the *Cytorhabdovirus* genus. Partially purified bacilliform particles, measuring approximately 18 nm by 30–56 nm were preliminarily identified as *Alfalfa mosaic virus*. Particles with the size ca 35 by 220–330 nm and distributed individually in the cytoplasm resembled members of the *Badnavirus* genus. Aggregates of flexuous filaments typical for *Potexviruses*, cytoplasmic cylindrical inclusions resembling those produced by members of the *Potyviridae* family and unusual spiral-like structures were also observed.

RCMV, *Clover yellow vein virus*, *Potato virus X*, WClMV, *Alfalfa latent* and *Pea streak viruses* were detected individually or in mixed infections and identified by sequencing.

Moreover, new members of *Cytorhabdovirus* and *Carlavirus* genus were also identified by sequencing in clover and lucerne breeding nurseries. WClMV, RCMV, *Bean yellows mosaic virus* and a new member of *Potyviridae* family were identified in wild growing plants. Phytoplasmas belonging to different 16S ribosomal subgroup (aster yellows – 16SrI-B, clover phyllody – 16SrI-C, apple proliferation – 16SrX-A, stolbur – 16SrXII-A) were identified in some cultivated as well as wild growing forage crops during 2007–2008 only sporadically. One exception was epidemic occurrence of clover phyllody phytoplasma in one breeding station in the Czech Republic in 2007.

Discussion

In the former Czechoslovakia, virus and phytopasma diseases of different clover species and legumes have been studied (Musil *et al*., 1981; Valenta and Musil, 1963). However, the current situation of virus and phytoplasma occurrence is poorly understood. To our knowledge, association of phytoplasma and viruses with malformed clovers was studied recently in a limited area of the Czech Republic (Fránová *et al.,* 2004), including molecular characterisation stolbur phytoplasma from red clover plants (Fránová *et al.,* 2009), as well as *Trifolium* species were considered to be one of the most important natural reservoirs of aster yellows phytoplasma within the Czech Republic. Our investigation confirmed previous reports, moreover, new viruses were identified by sequencing and TEM. Using RT-PCR by designed genus and species specific primers it is possible to detect about 450 different viruses. However, from some symptomatic clover samples, which reacted negative in RT-PCR, virus(es) with filamentous particles were mechanically transmitted to differential host plants. Development of molecular methods with higher sensitivity as well as identification and characterisation of new viruses is in progress.

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Arthropod biodiversity in a landscape with grass and leguminous vegetation cover

Frydrych J.[1], Barták M.[2], Lošák M.[1], Cagaš B.[1], Rotrekl J.[3] and Kolařík P.[3]

[1]*OSEVA PRO Ltd., Grassland Research Station, Rožnov-Zubří, Czech Republic*
[2]*Czech University of Life Sciences Prague, Faculty of Agrobiology, Food, and Natural Resources, Prague, Czech Republic*
[3]*Research Institute for Fodder Crops, Ltd., Troubsko, Czech Republic*
E-mail: frydrych@oseva.cz

Abstract

Hemiedaphic arthropod biodiversity was studied in the following 5 grassland agroecosystems in North Moravia: Kelč (intensive seed production system), Horní Lideč (organic seed production system), Střítež (organic hay production system), Střítež (mulched meadow without biomass harvesting), and Zubří (spontaneous fallow). The highest number of both (morpho)species and specimens and simultaneously the highest Margalef's species richness index was found in the organic hay production system (Střítež); on the contrary, the lowest numbers in corresponding characters were found in intensive systems or systems without biomass harvesting (mulch and fallow). Both the diversity and equitability indices were more equally spread among the various agricultural systems.

Keywords: arthropods, grassy agroecosystems, agriculture, biodiversity

Introduction

In addition to its primary production function (of food and fibres) and contribution to food safety, agriculture fulfils important environmental, economic, and social functions. OSEVA PRO Ltd., Grassland Research Station, Rožnov-Zubří, Czech University of Life Sciences Prague, and the Research Institute for Fodder Crops, Ltd., Troubsko have set up a project *Impact on insect biodiversity in the landscape through various methods of farmland exploitation and agricultural technologies with respect to grass and leguminous pests and their bio-regulators*. The project focuses on the monitoring of the variability of insects under different systems of farmland exploitation and agricultural technologies with respect to the variability of pests and their bioregulators under grassland and leguminous vegetation cover. As a part of the research, the variability of insects in grassland and leguminous vegetation cover in systems of organic and conventional farming will be compared. This aim fulfils the recommendation of the decision IV/6 of the 1998 Conference of Parties to the Convention of Biological Diversity: 'evaluate the effect of different agricultural practices on wild biodiversity'.

Materials and methods

Collecting method – to catch only autochthonous species and simultaneously to reach a high taxonomic resolution, we used emergence traps. The traps (1 trap per locality) with a quadrangular pyramid shape (effective capture area = bottom of the trap = 1 m^2) were made of fine polyamide fabric (mesh less than 0.1 mm). The sides of the traps were shallowly buried in the soil to prevent allochthonous immigrants from entering the trap. The collecting head was filled with 70% ethyl alcohol. Approximately each month trapped material was collected by simply inserting a new collecting bottle, the sample being stored in a freeze box (–20°C).

Brief description of localities under study. Kelč: seed production system, *Festuca pratensis*, cv. Rožnovská. Intensive system with pesticides and synthetic fertilisers for more than 5 years. **Horní Lideč**: seed production system, *Festuca pratensis*, cv. Rožnovská. Organic system without pesticides and synthetic fertilisers (with organic fertilisers only) for more than 3 years. **Střítež nad Bečvou (hay)**: meadow used for hay production, the dominant species: *Agrostis stolonifera*. Organic system without pesticides and synthetic fertilisers, 2–3 cuttings per year, this system has prevailed for more than 10 years. **Střítež nad Bečvou (mulch)**: meadow without harvesting, cut biomass (2 cuts per year) left on the surface as mulch, the dominant species: *Agrostis stolonifera*. Organic system without pesticides and synthetic fertilisers, 2–3 cuttings per year, this system has prevailed for more than 3 years. **Zubří**: spontaneous fallow, without any agricultural management for more than 5 years (formerly used as a meadow for hay production), the dominant species: *Agrostis stolonifera*.

Material processing

First, each sample was sorted into the following taxonomic groups: *Araneae, Collembola* (they were omitted for the purpose of this article), *Dermaptera, Psocoptera, Heteroptera*, *Auchenorrhyncha, Sternorrhyncha, Thysanoptera, Neuroptera, Coleoptera, Diptera*, *Hymenoptera,* and *Lepidoptera. Heteroptera, Coleoptera*, and *Diptera* were further subdivided into families, and *Hymenoptera* were sorted into superfamilies. Then all the groups were separately divided into morphospecies or true species according to our knowledge and similarity in appearance and counted.

Synecological analyses

For the purpose of analyses, each sample was considered as a separate unit because it is hardly possible to homologise 'morphospecies' between individual samples even in the same locality. The following community characters were used: Simpson's index of diversity: $D = 1/\sum p_i^2$ and equitability: $E = D/Nd$, where $p_i = N_i/N$. Nd = number of species found in a given locality, N = number of specimens of the locality, N_i = number of specimens of i-*th* species in the locality. Shannon's index of diversity: $H = -\Sigma\, p_i \ln p_i$ and equitability: $J = H/\ln Nd$, where symbols are the same as in Simpson's indices. Margalef's index of species richness: $P = (Nd - 1)/\log N$, where the symbols are the same as in Simpson's indices. For details consult Begon *et al*. (1997).

The characters N, Nd, D, E, H, and J were averaged to obtain the mean value for each locality under study.

Results and discussion

The number of specimens – the mean number of specimens per sample – ranged from 2,632 to 863 (specimens m^{-2} $month^{-1}$). The highest number of specimens was found in Střítež (hay), under an organic field management regime. On the contrary, the lowest numbers of specimens were found in Zubří and Kelč.

The number of species – the mean number of species per sample – ranged from 97.5 to 130.3 (species m^{-2} $month^{-1}$). The highest number of species was found in the Střítež locality (hay), exactly as in the case of the number of specimens. Zubří displayed the lowest number of species (spontaneous fallow without harvesting biomass).
Margalef's species richness index – the highest Margalef's index was in the Střítež locality (hay); on the contrary, the lowest was in Střítež (mulch).
Shannon's index of diversity – the highest value of the Simpson's diversity index was observed in Střítež (hay) and Horní Lideč. Střítež (mulch) and Zubří displayed the lowest diversity, the first locality being under organic management and the latter being spontaneous fallow without biomass harvesting. The highest Shannon's diversity was observed in Kelč and Horní Lideč. Střítež (hay) displayed the lowest diversity
Simpson's and Shannon's indices of equitability – Simpson's equitability is the highest in Horní Lideč and Shannon's equitability is the highest in Kelč. On the contrary, the lowest Simpson's equitability was in Střítež (mulch) and Zubří. The lowest Shannon's equitability was in Střítež (hay).

Table 1. The values of synecological indices are summarised in the following table – Statistics ANOVA

	Index			No. species statistic	No. specimens statistic
	Simpson's	Shannon's	Margalef's		
Kelč	26.22 [a]	1.61 [a]	35.34 [a]	107 [a]	1,035 [a]
Horní Lideč	32.35 [a]	1.55 [a]	36.34 [a]	103 [a]	1,624 [a]
Střítež nad Bečvou (hay)	34.16 [a]	1.28 [a]	41.27 [a]	130 [a]	2,632 [a]
Střítež nad Bečvou (mulch)	21.34 [a]	1.44 [a]	32.90 [a]	102 [a]	1,544 [a]
Zubří (fallow)	23.76 [a]	1.47 [a]	34.02 [a]	98 [a]	863 [a]

Conclusions and discussion

The highest number of specimens was found in Střítež (hay), an organic system. On the contrary, the lowest amount of specimens was found in Zubří (fallow) and Kelč (intensive agricultural system). The highest number of species was found in the Střítež locality (hay), exactly as in the case of the number of specimens. Zubří displayed the lowest number of species. The highest Margalef's index was in the Střítež locality (hay); on the contrary, the lowest was in Střítež (mulch). The highest Simpson's diversity was observed in Střítež (hay) and Horní Lideč, an organic system. Střítež (mulch) and Zubří (fallow) displayed the lowest diversity. The highest Shannon's diversity was observed in Kelč and Horní Lideč. Střítež (hay) displayed the lowest diversity. The Simpson's equitability is the highest in Horní Lideč (an organic system) and the Shannon's equitability is the highest in Kelč (intensive agricultural system). On the contrary, the lowest Simpson's equitability was in Střítež (mulch) and Zubří (fallow). The lowest Shannon's equitability was in Střítež (hay). The differences between the localities are not inconclusive (Table 1).

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Utilization of *Lolium multiflorum* on arable land in the context of non-production functions of an agriculture system

Fuksa P., Brant V., Venclová V. and Hakl J.

Czech University of Life Sciences Prague, Department of Forage Crops and Grassland Management, Prague, Czech Republic
E-mail: fuksa@af.czu.cz

Abstract

Stands of *Lolium multiflorum* seeded in autumn and spring terms, the stand of spontaneous fallow and subsequent crop (*Triticum aestivum*) were compared in the years 2001–2004. Production of aboveground phytomass, calorific value, and total energy production of the vegetative covers and impact of variant on subsequent crop were determined. Total energy production ranged 189.9–225.0 GJ ha^{-1} depending on vegetative cover. The highest total production of phytomass and energy production were determined in a stand of *L. multiflorum* seeded on autumn. Total yield of aboveground phytomass of *T. aestivum* was in the range 6.64–8.55 Mg ha^{-1} and grain yield represented 3.32–4.82 Mg ha^{-1} depending on variant. Significantly higher total yield (P = 0.0190) and energy production (P = 0.0193) were determined in the variant after spring seeding of *L. multiflorum*. Spontaneous fallow had the lowest preceding crop value.

Keywords: *Lolium multiflorum*, fallow, biomass production, energy production

Introduction

An imbalanced cycle of nutrients and organic matter occurs in agricultural enterprises that are focused on plant production because a considerable part of the production is sold off the farm. Utilization of crop residues can also contribute to negative balance, e.g. utilization for energy purposes instead of the plant biomass incorporation into the soil. Utilization of green fallows for conservation of soil fertility has been investigated for a long time. Fallow use is affected by plant selection, method of land management (Smith *et al.*, 2000), development of the plant species spectrum, intensity of weed infestation (Brant *et al.*, 2004), and other factors. Fallows can significantly enhance stability of energy balance on arable land, because the biomass produced usually stays on the planted site (Brant *et al.*, 2008). The aim of our research was to determine total energy production of aboveground phytomass of different vegetative covers and subsequent crop on arable land, and to evaluate the preceding crop value of the covers investigated.

Materials and methods

Field experiments were carried out at the Research Station of Czech University of Life Sciences in Prague (Červený Újezd locality). The experimental stand was located in a sugar-beet growing region at 405 m above sea level. Average annual temperature is 7.9°C and average total precipitations 525.8 mm. The locality falls into Class III according to the climatic regionalization of the Czech Republic (Moravec and Votýpka, 2003). The soil is classified as clay loam. Experiments were carried out during 2001–2004.

Wheat (*Triticum aestivum* L.) was the preceding crop. Spontaneous fallow and stand with *Lolium multiflorum* Lam. based on 28 August 2001, and a variant with *L. multiflorum* seeded on 5 April 2002, were investigated. The seeding rate of *L. multiflorum* (cv. Prolog) was 40 kg ha^{-1}. Experimentation was based on randomized blocks with four replicates of each variant. The plot size was 60 m^2. Evaluated plots were mulched twice during the vegetation periods in 2002 and 2003 (17 June 2002, 26 August 2002, 9 June 2003 and 10 September 2003). Ploughing was practised after the second mulching in 2003 with the subsequent seeding of *T. aestivum* (cv. Alana, seeding rate 230 kg ha^{-1}). *Triticum aestivum* was harvested on 4 August 2004. Production of aboveground biomass and species spectrum of vegetative covers were evaluated always in the day of mulching. Calorific measurement was used to determine calorific value and total energy production (Fuksa *et al.*, 2006). Statistical analysis was carried out with Statistica 8.0 (ANOVA, Tukey HSD test, $\alpha = 0.05$).

Results and discussion

Production of aboveground phytomass of plant cover and the proportions of seeded plant species, weeds, and volunteers of preceding crop to the total production are summarized in Table 1. Statistically significant differences ($P = 0.0006$) in total biomass production were found in 2002 in the first mulching term. In the following terms of mulching no significant differences in biomass production were found. However, there were important differences in the competitiveness of *L. multiflorum* to weed infestation, depending on the seeding term. The weed spectrum mainly comprised annual species and volunteers of *T. aestivum* in the first year of vegetation. An important decrease of species diversity and progress of perennial weeds were determined in the second year. A detailed evaluation of investigated stands in relation to weed infestation was published by Brant *et al.* (2004).

Table 1. Dry matter production (Mg ha^{-1}) and share (%) of *Lolium multiflorum*, weeds and volunteers of *Triticum aestivum* in the years 2002–2003 (1 = *L. multiflorum* – autumn seeding, 2 = *L. multiflorum* – spring seeding, 3 – fallow)

Treatment	Variant	Total (Mg ha^{-1})	Cultivated crop		Weeds		Volunteers	
			(Mg ha^{-1})	(%)	(Mg ha^{-1})	(%)	(Mg ha^{-1})	(%)
1st mulching 2002	1	5.96	4.88	82.0	0.23	3.9	0.84	14.2
	2	2.84	1.36	47.7	1.31	46.2	0.17	6.1
	3	4.99	–	–	0.48	9.6	4.51	90.4
2nd mulching 2002	1	2.38	2.15	90.3	0.23	9.7	0.00	0.0
	2	3.67	3.25	88.5	0.42	11.5	0.00	0.0
	3	2.62	–	–	2.07	78.9	0.55	21.1
1st mulching 2003	1	3.51	1.95	55.5	1.56	44.4	0.00	0.1
	2	3.48	0.81	23.3	2.67	76.7	0.00	0.0
	3	3.06	0.00	–	2.99	97.6	0.07	2.4
2nd mulching 2003	1	0.90	0.42	46.5	0.48	53.5	0.00	0.0
	2	0.84	0.12	14.6	0.72	85.4	0.00	0.0
	3	0.54	–	–	0.54	100.0	0.00	0.0

Calorific value of the aboveground phytomass of vegetative covers ranged from 17,206 J g^{-1} (*L. multiflorum* from spring seeding) to 18,193 J g^{-1} (spontaneous fallow) with significant difference ($P = 0.0001$) in the year 2002. Values measured in the year 2003 ranged 17,685–17,930 J g^{-1} without significant differences among variants. Term of mulching was not important for the calorific value of phytomass. Statistically significantly higher ($P = 0.0112$) calorific value of wheat grain (18,190 J g^{-1}) than value of straw (17,867 J g^{-1}) was measured. Differences among variants were not statistically significant. The highest values of total energy production in the sum of both years were determined in variant of *L. multiflorum* from autumn seeding (Table 2). Spring seeding of this species produced the lowest energy production. Spontaneous fallows also showed relative potential from the energy balance perspectives. Kocourková *et al.* (2007) published annual energy production (60.5–92.7 GJ ha^{-1}) of some grass species growing on arable land. Total phytomass production of subsequent crop (grain and straw) ranged 6.64–8.55 Mg ha^{-1} and grain yield represented 3.32–4.82 Mg ha^{-1} depending on variant. Significantly highest total phytomass ($P = 0.0190$) and energy production ($P = 0.0193$) of *T. aestivum* were determined in the variant after spring seeding of *L. multiflorum*. Spontaneous fallows had the lowest preceding crop value. Retention of straw on the field is important from the perspectives of energy balance. In our experiment, the energy values of straw represented 43.2–49.4% from total energy production of *T. aestivum* aboveground phytomass.

Conclusion

Values of total energy production of investigated vegetative covers were not significantly different. Higher preceding crop value of *L. multiflorum* in comparison with spontaneous fallow was determined. Higher competitive ability to weed infestation in variant of autumn seeding of *L. multiflorum* was found. Vegetative cover in stand provides effective utilization of solar radiation and to improve total energy balance and organic matter circulation in agricultural system. Fallow utilization can be important mainly in areas with lower rate of animal production, for example in the context of agro-environmental practices.

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Effect of different mulching regimes on rate of decomposition of above-ground biomass

Gaisler J. and Pavlů V.

Crop Research Institute, Prague, Department of Plant Ecology and Herbology, Liberec, Czech Republic
E-mail: gaisler@vurv.cz

Abstract

The effect of different frequency and terms of mulching on the rate of biomass decomposition was studied on an upland meadow in the Jizerské hory Mts. The following treatments were applied on grassland with a dominance of *Festuca rubra*: mulching once per year in July, mulching once in September, mulching twice per year (June and August) and three times per year (May, July, and September). Litter-bags with dry above-ground mulched *in situ* biomass were installed on the soil surface in sward after each mulching. After 3, 6, and 12 months the litter-bags were collected and the undecomposed biomass was dried and weighed and the rate of decomposition was quantified. The highest rate of decomposition was found during the first three months (more than 4 mg g^{-1} day^{-1}) and after that it subsequently decreased to 0.1 mg g^{-1} day^{-1}. The highest total biomass losses during 12 months were found in the three-times- mulched treatment in the first period of mulching (91%) and in the second period (88%). On the other hand, the decomposition process was slow in the treatment mulched once in September (60% decomposed biomass per year). Because of the decomposition process, mulching at least twice per year could be recommended as an alternative method for grassland management.

Keywords: upland meadow, mulching, decomposition, litter-bags

Introduction

In the last decade of the 20^{th} century the importance of semi-natural grasslands for forage production decreased as a result of the decrease in the cattle population in marginal areas of the Czech Republic. A lot of meadows and pastures were abandoned. Tall dicotyledonous species, such as *Cirsium* spp. or *Rumex* spp. spread on mesic unmanaged grassland.
Mulching is a simple and low-cost procedure that can help maintain many grassland locations and fallow farm land (Prochnow *et al.*, 2000). However, the rapid decomposition of the mulch is important, because a long cover and shading of the sward will cause undesirable changes in grassland composition. After 25 years of management mowing and mulching resulted in a species composition similar to that resulting from grazing by sheep (Kahmen *et al.*, 2002). After the mulching a large amount of crushed biomass remains on the sward surface. The rate of decomposition of the dead biomass is affected by some key factors: the date of mulching, weather conditions, and the quality of the biomass. Many authors have studied the decomposition of aboveground or underground litter in varying conditions (e.g. Oliver *et al.*, 2002; Koukora *et al.*, 2003); however, there is a lack of studies focused on the decomposition rate of mulched biomass.
Therefore the aim of our work was to study the effect of mulching with different frequencies and terms on the rate of decomposition of mulched material.

Materials and methods

The experiment was carried out in the Jizerské hory Mts. (50°51'N, 15°02'E) 12 km north-west of the town of Liberec, Czech Republic, from 2002 to 2003. The altitude of the study site is 420 m a.s.l., the mean annual temperature is 7.2°C, and average annual precipitation is 803 mm (Liberec meteorological station). The geological substratum is granite. The mean forage yield of the meadow ranged from 2 to 4 t ha^{-1} of dry matter per year, and no fertilisers have been used on the site. The plant community of the study site was classified as *Arrhenatherion*, with *Festuca rubra* being dominant. The observed treatments were:

U Unmanaged control
1MJ Mulching once per year in July
1MS Mulching once per year in September
2M Mulching twice per year in June (2MJn) and August (2MA)
3M Mulching three times per year in May (3MM), July (3MJl), and September (3MS).

Before the date of each mulching, aboveground biomass was collected and adjusted to 10 cm in length (simulation of mulching) and dried and 10-g samples of the dry matter were placed in 1-mm mesh-bags on the soil surface of the sward. In unmanaged treatments undecomposed dead material was collected and installed at the end of May.
After 3, 6, and 12 months the bags were sampled and the mass losses were measured. The rate of the decomposition was calculated from biomass losses. ANOVA was used for the data analyses.

Results and discussion

During the first three months of decomposition we found significant differences ($P < 0.001$) among the treatments (Figure 1). The lowest biomass losses were recorded in the U and 1MS treatments, where only about 40% of the biomass was decomposed. On the other hand, on the first and second mulching dates of the 3M treatments it was over 80% of the mass after mulching. Higher losses of mass were found in the spring months than in the summer and/or autumn.

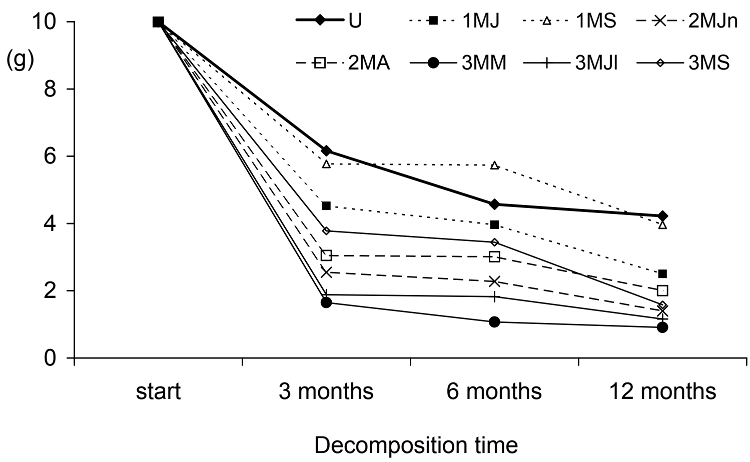

Figure 1. Losses of biomass during decomposition test

Regardless of the treatments, the highest rate of decomposition (RD) was found during the first three months of decomposition and after that it was reduced dramatically (Figure 2). The highest RD was revealed in 3MM treatment (9.08 mg g^{-1} day^{-1}) and also in 3MJl treatment (8.82 mg g^{-1} day^{-1}). A slightly lower RD was found in both 2MJn and 2MS treatments (8.10 mg g^{-1} day^{-1} and 7.56 mg g^{-1} day^{-1}, respectively), whereas the lowest RD was recorded in unmanaged control U (4.17 mg g^{-1} day^{-1}) and also in 1MS treatment (4.60 mg g^{-1} day^{-1}). The RD was very strongly affected by the species composition of the forage and the dates of mulching. The biomass from forbs and legumes decomposed faster than that from grass. The biomass from the intensively managed treatments (3MM and 3MJl) decomposed faster than that from the extensive ones, because of the younger biomass involved, which was predominantly in the vegetative stage, with a higher content of degradable nitrogen and sugars. On the other hand the mulch biomass in the summertime had a higher proportion of less degradable mature reproductive plants. The frequency of mulching affected not only the maturity of the grassland, but also the botanical composition. In particular, the different rate of legumes, forbs, and grasses can affect the decomposition process significantly (Koukora *et al.*, 2003; Zhong HuaPing and Du ZhanChi, 1997). It is also necessary to take climatic factors into account. For example, Prochnow's *et al.* (2000) study on mulched grasslands revealed that mulch decomposition is more dependent on weather conditions than on vegetation structure.

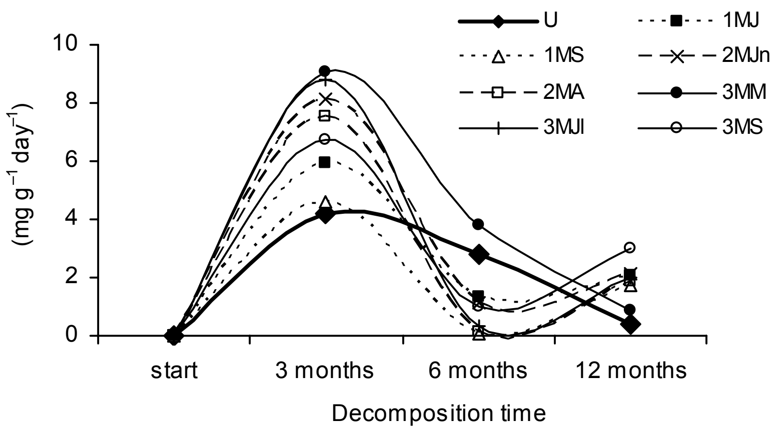

Figure 2. Rate of decomposition under different treatments

Conclusions

The rate of biomass decomposition was strongly affected by the dates and frequency of mulching. Young plant material from frequent and early mulching decomposed faster than that from infrequent and later ones. More than 80% of the biomass decomposed during the first three months after mulching in May or June. As a result of the decomposition process, mulching at least two times per year could be recommended as an alternative method for grassland management.

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Effects of harvesting methods on seed yield and quality of *Scorpiurus muricatus* L.

Giambalvo D., Amato G., Di Miceli G. and Frenda A.S.

University of Palermo, Faculty of Agriculture, Palermo, Italy
E-mail: giardo@unipa.it

Abstract

Scorpiurus muricatus L. is an annual legume, widely distributed in Mediterranean pastures, that is appreciated by farmers for its productivity, forage quality, and palatability. It is characterised by long flowering and ripening periods and by pod shedding. These characteristics cause high seed losses, which could reduce its seed harvest efficiency in terms of seed yield and quality. In this study, we investigated the effects on seed yield and quality of different harvesting methods (windrowing at different times with subsequent combining was compared with direct combining). Our results show that direct combining when the pods were fully ripened reduced pod losses compared with swathing methods, producing the highest yield of seed actually harvested. However, in this study, the unique climatic conditions during the pod development stage (extremely high temperatures) accelerated the ripening process, presumably limiting pod shedding.

Keywords: prickly scorpion's tail, seed production, *Scorpiurus muricatus*

Introduction

Prickly scorpion's tail (*Scorpiurus muricatus*) is a self-seeding annual legume widely distributed in the natural pastures of the Mediterranean area and appreciated by farmers for its productivity (Le Houérou, 2001), forage quality (Licitra *et al*., 1997), and palatability.

Although *S. muricatus* represents a very interesting species for Mediterranean areas, the use of this annual legume as a forage crop in agricultural cropping systems is not well documented. In particular, information on seed production is almost completely lacking. *Scorpiurus muricatus* is characterised by long periods of flowering and ripening (Di Giorgio *et al*., 2007a) and it is possible to observe flowers and green and mature pods on the plant and shed pods on the soil surface at the same time during the reproductive stage. These characteristics cause high seed losses, and could reduce seed harvest efficiency in terms of seed yield and quality.

Materials and methods

A field study was conducted at the Pietranera farm about 30 km north of Agrigento, Italy (37°30'N; 13°31′E; 178 m a.s.l.) on a deep, well-structured soil, classified as a vertic haploxerert. The seeds of a Sicilian ecotype of *S. muricatus* were sown in early January 2007 at a rate of 500 viable seeds per m^2, a soil depth of 3 cm, and a row spacing of 18 cm. The field was kept free of weeds by hand weeding. The plants were swathed when the first pods were mature (T1) or when 50% of the pods were mature (T2), and the swaths of both treatments were then combined when dry. A standing crop treatment (T3)

was also directly combined when all the pods were mature. The swaths were laid with a plot swather and left to dry in the field. A plot combine was used for both direct and windrow combining. The experimental design was a randomised complete block with three replications. The dimensions of each plot were 20 × 1.44 m and each contained eight rows. At each swathing time and during the direct harvest, an above-ground biomass sample was collected from an area of 1.44 × 0.50 m in each plot. The pods were separated suddenly from the plants and divided into two fractions on the basis of pod colour: green and green-brown (immature pods) or brown and yellow-brown (mature pods).
A sample from each fraction was weighed before and after drying at 60°C for 48 h. In a subsample of 100 pods from each fraction, the number of seeds per pod and the seed weights were determined. At harvest, the total pod production was calculated by summing the following fractions: (1) pods harvested by combine; (2) separation losses (pods lost because of threshing inefficiency) – all the pods were collected together with the straw on a plastic sheet placed behind the straw walkers, and (3) shed pods (naturally or as a result of mechanical operations); this fraction was determined after combining by manual pod recovery in five sample areas of 1.44 × 0.50 m each. A sample of 200 pods from each fraction was hand-threshed to determine the seed weights. The seeds were stored for the germination test. The remaining pods were threshed with a laboratory hulling machine to assess seed production. The germination test was carried out in November 2007 using 400 seeds (100 seeds × 4 replicates; 20°C in the dark). The germinated seeds were counted daily for 21 days and the mean germination time (MGT) was computed.

Results and discussion

At the stage of the first mature pods (T1), the plants were still green and the moisture of the standing biomass (stems, leaves, flowers, and pods) was about 650 g kg^{-1}. At the subsequent swathing date (T2), the moisture content had decreased to 350 g kg^{-1}, and when all the pods were mature, it was about 90 g kg^{-1}. Drying was more rapid than that observed by Di Giorgio *et al*. (2007b) because in this experiment the temperatures after the first pods had matured were particularly high (on average, a maximum daily temperature of 38.0°C; Figure 1).

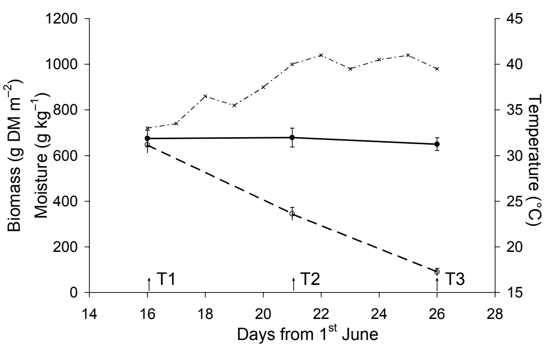

Figure 1. Above-ground biomass (solid line), biomass moisture content (dotted line), and maximum daily air temperature (dash-dotted line). The bars indicate standard errors (n = 4)

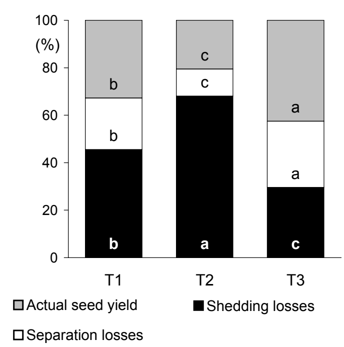

Figure 2. Rate of shedding losses, separation losses, and actual seed yield on total seed production according to the harvest methods studied. Within each seed fraction, a different letter indicates a different value (P < 0.05)

The total above-ground biomass (Figure 1) and total seed production (Table 1) were not significantly affected by the harvest date. The rate of seed production from immature pods decreased rapidly from T1 to T3 (88%, 36%, and 0%, respectively).
When the crop was swathed at the beginning of pod ripening (T1), pod shedding (both natural and that resulting from mechanical operations) led to a 46% loss in seed production. The losses were greater (about 70%) when the swathing was delayed (T2), whereas direct combining reduced the fraction of seed left on the ground to 30% (Figure 2). The separation losses varied significantly, from 11% (T2) to 28% (T3) of the total seed yield. However, the seed losses resulting from threshing inefficiency were about 40% of the total yield picked up by the combine, with no differences among the treatments. The seed yield actually harvested with direct combining (596 kg ha^{-1}) was significantly higher than that harvested with either swathing treatment. Early swathing (T1) gave a significantly higher seed yield than did swathing five days later (T2; 459 versus 288 kg ha^{-1}, respectively).

Table 1. Seed characteristics from mature and immature pods at different harvest dates

	Immature pods			Mature pods			Total or average		
	T1	T2	T3	T1	T2	T3	T1	T2	T3
Seed production (g m^{-2})	115^{a}	51^{b}	0c	15^{c}	92^{b}	142^{a}	130	143	142
Seed moisture (g kg^{-1})	550^{a}	272^{b}	–	257^{a}	101^{b}	82^{b}	514^{a}	154^{b}	82^{c}
Seeds/pod (N)	6.4^{a}	5.6^{b}	–	7.0	6.8	6.8	6.5	6.3	6.8
1,000 seed weight (g)	7.5	7.4	–	8.5	8.2	8.1	7.7	7.9	8.1

Means followed by a different letter are significantly different ($P < 0.05$)

The seed quality (seed weight, germination, hard seed content, and MGT) of the different pod fractions was not significantly affected by the harvest method.
The seeds from pods collected on the soil surface (fraction lost as a result of shedding) showed, on the whole, better seed quality (Table 2) than those from pods picked up by the combine (including both the harvested fraction and the fraction lost during separation). This result can be explained by the fact that most of the pods in the fraction 'lost as a result of shedding' were the first pods formed, which therefore developed under more favourable environmental conditions (higher soil moisture and lower temperatures) than the pods that formed and developed later.

Table 2. Seed quality traits of the different fractions of pod yields (mean values of the three treatments studied)

	Pods		
	harvested	lost during separation	lost as a result of shedding^{+}
1,000 seed weight (g)	7.68^{b}	7.71^{b}	8.02^{a}
Germinated seed (%)	17.3^{b}	19.7^{b}	68.1^{a}
Hard seed (%)	81.6^{b}	79.2^{b}	29.3^{a}
MGT (day)	4.5^{b}	4.7^{b}	3.4^{a}

$^{+}$includes pods shed naturally and as a consequence of mechanical operations; MGT – mean germination time
Means followed by a different letter are significantly different ($P < 0.05$)

Conclusion

In conclusion, the direct combining of Prickly scorpion's tail when the pods are fully ripe reduced pod losses compared with swathing methods and produced the highest seed yield actually harvested. However, the unique climatic conditions during the pod development stage (extremely high temperatures) in this study accelerated the ripening process, presumably limiting pod shedding. Under less stressful conditions, Di Giorgio *et al*. (2007b) observed levels of pod shedding much higher than ours.

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Phytocenological characteristics of two pasture swards with different management histories

Hakrová P., Sýkorová Z., Novotná K., Frelich J. and Šlachta M.

University of South Bohemia, Faculty of Agriculture, České Budějovice, Czech Republic
E-mail: zsykor@zf.cju.cz

Abstract

The phytocenological characteristics of pasture sward were monitored at two mountain sites. One site (Farm-1) was covered by *Lolio-Cynosuretum* vegetation and it had been grazed in rotation by dairy cattle for more than forty years. The other site (Farm-2) was a newly established pasture grazed by sheep. The species richness, abundance, and Shannon index of diversity were examined at each site three times a year from 2006 to 2008. At the beginning of the experiment the species richness, total abundance (plant cover), and the diversity were higher at the Farm-1 site (34; 2.00 and 89% on average, respectively) than at the Farm-2 site (15; 1.15 and 64% on average, respectively). During the three-year study significantly higher values of the three characteristics were found at the Farm-2 site (37 species; 1.86 Shannon index; 87% total abundance). However, the undesirable species *Bromus hordeaceus*, *Rumex obtusifolius,* and *Urtica dioica* made a substantial contribution to this trend. They were present at a high level of abundance (5–25%) in the sward in 2008.

Keywords: grazing, plant diversity, Shannon index, mountain pasture, cattle

Introduction

Permanent grasslands represent one quarter of the total agricultural land in the Czech Republic. Grazing management has become more frequent in the last two decades as a result of the development of beef husbandry in mountain areas. The transition from arable land to permanent grassland was used by farmers in order to provide their animals with a sufficient grazing area. Although the choice of a suitable seed mixture is the basis of the successful development of the sward, the management and the environmental conditions also affect the species composition substantially. In this study the development of a newly established pasture in the mountain region of South Bohemia was examined during the three years following the sowing. Simultaneously, a well-preserved pasture in the same region was surveyed in order to compare the temporal changes in both the swards.

Material and methods

The experiment was carried out in the south of the Czech Republic at an altitude of 575 m a.s.l. Two pasture sites 22 km apart and located at the same altitude were selected for the examination. One site (Farm-1) was a 57-ha pasture grazed in rotation by a herd of approximately 101 cows of the Czech Fleckvieh and Holstein breeds for more than 40 years. The pasture sward belonged to the *Lolio-Cynosuretum* association (Frelich *et al*., 2006). It was cut for ensilage in late May or June and grazed subsequently in 3 cycles till October. Mineral fertilisation was provided each year to the amount of 20 kg N ha^{-1}.

No resowing had taken place there. The other site (Farm-2) was originally arable land sown in 2005 with a mixture of plant species in the following weight ratios of the seeds: *Lolium multiflorum* (30%), *Lolium perenne* (20%), *Phleum pratense* (20%), *Festuca pratensis* (10%), *Trifolium hybridum* (10%), *Trifolium repens* (7%), and *Poa pratensis* (3%). The sward was cut in 2006 and it had been grazed since 2007 by a flock of sheep. A line of 5 (Farm-1) or 4 (Farm-2) stands at a 50-metre distance was established in both the pastures. The number of vascular plants (species richness) and the species abundance according to the Braun-Blanquet scale (Moravec, 1994) were measured at each stand over an area of 16 m^2 3 times a year (in May, July, and September). The Shannon index of diversity H' (Magurran, 1988) and the total abundance (sum of species abundances, i.e. total plant cover) were calculated for each stand. The differences between the years and between the localities were evaluated separately by a one-way ANOVA and Tukey's post-hoc test (Statistica, StatSoft, Inc., 2005).

Results and discussion

In the first year of the study 34 species and 15 species of vascular plants were identified at the Farm-1 and Farm-2 sites, respectively. In the last year of the study seven species more at Farm-1 site and twenty-two species more at Farm-2 were recorded (41 and 37 species, respectively). Both the species diversity (Shannon index) and the total abundance were higher at Farm-1 in comparison to Farm-2 at the beginning of study (Table 1). The diversity, however, increased significantly at Farm-2 from 1.15 to 1.86 ($P < 0.001$) between 2006 and 2008 and the originally low total abundance grew from 64% to 87% in the same period ($P < 0.001$). These changes indicated a positive change in the sward structure and composition towards a more persistent plant cover. The species composition differed markedly between the localities, however. A list of species with a greater abundance than 5% in some of the stands is given in Table 2. In the long-term pasture (Farm-1) a species composition typical for the *Lolium-Cynosuretum* association was identified in all three years. At Farm-2 only four species of the original sown mixture (*Lolium perenne*, *Lolium multiflorum*, *Trifolium repens*, *Trifolium hybridum*) were identified in greater abundance one year after the sowing. The reason why the other species sown (and mainly *Phleum pratense*) were not present in greater abundance is not clear. The low quality of the seeds seems to be the most probable reason. The four species persisted in the site in greater abundance until the end of the observation

Table 1. Diversity and abundance at Farm-1 and Farm-2 sites during the three years of the study

		2006		2007		2008		Year
		mean	S.D.	mean	S.D.	mean	S.D.	
Farm-1	Shannon index	2.00	0.17	2.11	0.23	1.93	0.32	n.s.
	Total abundance	89	10	83	7	94	6	**
Farm-2	Shannon index	1.15	0.19	1.64	0.28	1.86	0.16	***
	Total abundance	64	8	68	17	87	6	***
Farm	Shannon index	***		***		n.s.		
	Total abundance	***		**		**		

S.D. – standard deviation; n.s. – not significant *$P > 0.05$; significant difference: **$P < 0.01$; ***$P < 0.001$

Table 2. List of species with a greater abundance (> 5%) recorded in some of the stands in a particular year. *species with an abundance greater than 25%

Farm-1		Farm-2	
2006	2008	2006	2008
*Lolium perenne**	*Lolium perenne*	*Lolium perenne*	*Lolium perenne**
*Festuca rubra**	*Festuca rubra**	*Lolium multiflorum**	*Lolium multiflorum**
*Agrostis capillaris**	*Agrostis capillaris**	*Trifolium repens*	*Trifolium repens**
*Trifolium repens**	*Trifolium repens*	*Trifolium hybridum**	*Trifolium hybridum*
Dactylis glomerata	*Dactylis glomerata**		*Poa annua*
Trifolium pratense	*Trifolium pratense*		*Taraxacum* sect. *Ruderalia*
Taraxacum sect. *Ruderalia*	*Taraxacum* sect. *Ruderalia*		*Rumex obtusifolius*
Achillea millefolium	*Achillea millefolium*		*Urtica dioica*
Plantago lanceolata	*Plantago lanceolata*		*Bromus hordeaceus*
Trisetum flavescens	*Poa pratensis*		
	Veronica chamaedris		
	Alchemilla monticola		
	Anthriscus sylvestris		

in 2008. Seven other species emerged in the sward in an abundance of more than 5% in 2008. Three of them (*Bromus hordeaceus*, *Rumex obtusifolius*, and *Urtica dioica*) were of poor nutritional value, however, and they became an undesirable part of the intended pasture sward.

Conclusions

The species abundance and diversity increased significantly in the newly established sward during the three years of the study and they reached similar values to those of the well-preserved pasture. Undesirable species regarding nutritional quality (*Bromus hordeaceus*, *Rumex obtusifolius* and *Urtica dioica*) contributed to this trend, however, and they were present in an abundance of more than 5% in the sward at the end of the study.

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Botanical monitoring of grasslands after the adoption of agro-environmental arrangements

Holubec V.[1] and Vymyslický T.[2]

[1]*Crop Research Institute, Gene Bank Department, Prague, Czech Republic*
[2]*Agricultural Research, Ltd., Troubsko, Czech Republic*
E-mail: holubec@vurv.cz

Abstract

The effect of the agro-environmental arrangements adopted by farmers was monitored by means of the investigation of biotic changes. The botanical part was based on 47 localities within different regions of the Czech Republic selected for monitoring during 2005–2008. Plant checklists were elaborated for each locality. Phytosociological relevés were noted on permanent plots 9 m^2 using a standard Braun-Blanquet scale. Biological diversity was evaluated using the Shannon and Evenness indices. Analyses of variance of evenness and species numbers appeared not to be significant, but the evaluation of the dynamics of typical meadow species and weedy/ruderal species showed positive trends towards a decrease in weeds in connection with reduced fertilisation levels. Rare weeds were found and suggested for conservation in the gene bank.

Keywords**:** meadows, pastures, monitoring, plant recording, phytosociological relevés, agro-environmental treatments

Introduction

The landscape character of the Czech Republic has been slowly changing since the political changes in 1989. The amount of agricultural land has decreased by 1,640 km^2 and the area of meadows and pastures has increased by 1,390 km^2 (Nevělík, 2006). The Convention on Biological Diversity (CBD, 1992) fundamentally changed the practice of plant conservation by placing much greater emphasis on *in situ* conservation. It also stressed the direct link between conservation and use (Maxted *et al.*, 2008). The Ministry of Agriculture of the Czech Republic subsidises projects supporting the sustainable development of the countryside. Among such projects there are agro-environmental arrangements, by means of which aspects of nature conservation are integrated into agricultural policy. It was desirable to assess whether such support programmes really achieve the aims of agro-environmental arrangements. The botanical part of this assessment deals with the monitoring of expected changes in vegetation. This submitted monitoring is aimed at investigating qualitative and quantitative changes in the biodiversity of selected agricultural tracts over time. The monitoring of vegetation can also reveal threats to some plants and their need for *in situ* conservation.

Material and methods

47 tracts with grassland vegetation were selected within various regions of the Czech Republic. Each of the selected tracts was visited from May to June and in October every year from 2004 up to 2008. All plant species on the tract were determined and recorded.

The nomenclature of plant names in the paper was unified according to Kubát *et al.* (2002) and vegetation according to Chytrý *et al.* (2007). A plot of a size 3 × 3 m was permanently marked and phytosociological relevés were elaborated using the Braun-Blanquet combined scale (Prach, 1994). The data collected were used to calculate botanical diversity by means of the following characteristics: Shannon index H and its standardised version Evenness Eh. Botanical diversity was also evaluated statistically using analysis of variance (ANOVA). Species numbers and evenness indices for each plot were tested. All species present were roughly divided into groups labelled 'l' – typical for meadows and pasture and desirable from both the botanical and agricultural points of view – and 'p' – a ruderal group – and their share was monitored over the years. The results are presented within prevailing subsidy titles (A, ecological agriculture, B1, grassland treatments, C1, grassing of arable land, C4, wet and peaty meadows, and C5A, bird localities on grasslands – nesting place of *Crex crex*). Each subsidy title has its own requirements for treatment by farmers, especially dealing with prato-technical terms. Fertilising is allowed up to 60 kg ha^{-1} of N, including cattle grazing, and no fertilising on C4. Two cuts are requested on dates before the stated deadlines with no mulching.

Results and discussion

The richest plots, with the highest species numbers, were found in the Jeseníky Mts., in the Drákov (29 spp. per plot), and Rejvíz (26 spp. per plot) localities. The highest

Table 1. Shannon indices and species numbers on permanent plots according to agro-environmental treatments (*n* = number of plots)

Title	Year	Shannon diversity index					Species number				
		average	at. dev.	median	min	max	average	st. dev.	median	min	max
A *n* = 16	2005	2.123	0.479	2.170	1.187	2.940	15.375	4.365	15	9	23
	2006	2.100	0.422	2.053	1.287	2.945	16.875	4.349	17	10	25
	2007	2.038	0.410	2.131	1.054	2.588	17.313	4.586	19	9	22
	2008	1.993	0.425	1.988	1.376	2.726	17.667	5.038	19	9	25
B1 *n* = 9	2005	1.794	0.506	1.809	1.187	2.713	12.333	5.657	11	6	22
	2006	1.818	0.450	1.722	1.278	2.649	13.000	5.477	12	5	22
	2007	1.803	0.476	1.878	1.054	2.588	13.333	4.899	13	6	22
	2008	1.807	0.425	1.789	1.343	2.415	14.375	5.208	14	8	24
C4 *n* = 9	2005	1.995	0.399	1.864	1.392	2.713	13.556	5.126	13	6	22
	2006	2.035	0.366	1.872	1.631	2.649	14.556	4.419	14	9	22
	2007	2.040	0.412	1.882	1.415	2.683	14.778	3.993	14	10	22
	2008	1.912	0.413	1.954	1.376	2.470	14.500	4.751	14	9	24
C5A *n* = 12	2005	2.212	0.409	2.281	1.613	2.940	15.833	3.512	16	11	23
	2006	2.182	0.370	2.166	1.721	2.945	17.917	3.315	18	13	25
	2007	2.187	0.307	2.176	1.666	2.782	19.417	3.528	20	14	26
	2008	2.150	0.348	2.164	1.671	2.726	19.750	3.696	20	14	26

Shannon index levels were found for the Polom and Orlické Záhoří localities, both in the Orlické hory Mts. The localities in the Krušné hory Mts., Humpolec, and Vítonín showed increasing Shannon indexes, while the localities in the Votice region showed a decreasing tendency over the years of the study. But the latter may not be a negative result, if it is caused by a decreasing number of annual, segetal, or nitrophilous species. There is a small difference in the mean number of species per plot, but in fact it varies from 5 to 26 (Table 1). It is obvious that the lowest numbers are in the variant B1 and especially C1 (grassing of a field), where only 5 species were noted. Surprisingly, plot 88 in Velký Rybník still keeps rows of the former sowing of *Lolium perenne* and *Festuca pratensis*. For these mentioned localities the Shannon indices are very low.

The changes in botanical diversity were not always caused by adopting agro-environmental arrangements. In the case of the Sněžník locality, the permanent plot was marked near a large patch of *Carex brizoides*. The sedge expanded to the plot and took it over. The number of species decreased by 3, the dominance of *Carex* went to 4, and the Shannon index decreased from 0.76 to 0.67.

There were fluctuations in the appearance of ephemeral plants in locality 84 – Bykoš. *Erophila verna* was noted twice and found in May 2009 again. During the past 2 years *Erophila* was replaced by a mass occurrence of *Vicia tetrasperma*. Locality 85 – Bykoš – is receiving more attention as a result of another rare weed – *Adonis aestivalis*. It occurs in large numbers along the field road. Both *Erophila* and *Adonis* are worthy of the attention of the Czech Gene Bank, because as rare weeds they are the subjects of conservation.

Because of a high variation, the differences between the mean Shannon index values were not significant over the years and treatments. Treatment A (ecological agriculture) appeared to be near a significant level (0.92). To evaluate positive or negative trends in

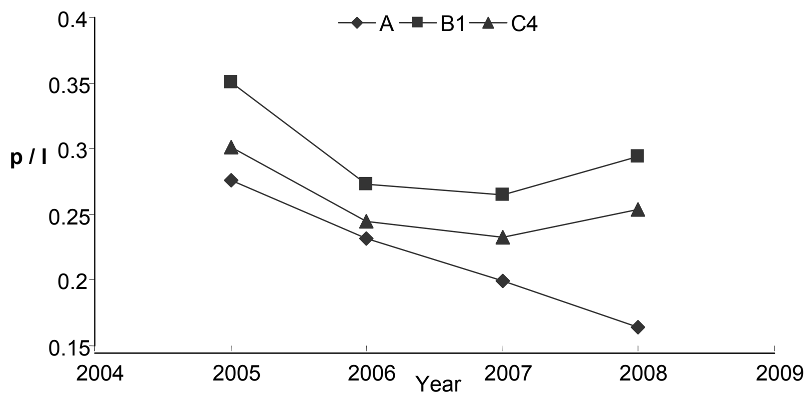

Figure 1. Changes in species numbers of weedy/meadow (p/l) species per plot

changes of vegetation, a ratio p/l was used (Figure 1). The Rejvíz and Šišovka localities used to have a large share of nitrophilous ruderal species such as *Urtica dioica, Rumex obtusifolius, Heracleum sphondilium*, etc. Applying agro-environmental arrangements, they have been slowly decreasing and in 2008 an orchid species was found (*Dactylorhiza majalis*). Similarly, there is a significant increase in the number of dicots (especially *Achillea millefolium*) in the nearby Ve Lhotkách locality.

Conclusions

With the adoption of agro-environmental treatments, some positive trends in vegetation changes have been found after 5 years of monitoring. Botanical diversity calculated in terms of numbers of species and Shannon index are slightly higher, but as yet with no statistical significance. There is a significant decrease in ruderal, nitrophilous, and segetal species and increase in dicotyledonous species, including fluctuation in ephemeral species. However, some observed changes were not caused by agro-environmental arrangements, but by spontaneous succession.

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Effect of mulching on phytomass structure and grassland succession

Hrabě F. and Krausová A.

Mendel University of Agriculture and Forestry in Brno, Department of Animal Nutrition and Fodder Production, Brno, Czech Republic
E-mail: hrabě@mendelu.cz

Abstract

The results present differences in the succession and structure of permanent grassland (PG), newly sown grass stand (conversion of arable land to a set-aside), and two variants of spontaneous grassing (with and without Glyphosate herbicide) after their mulching three times and one time a year. Mulching 3 times a year is connected with the lower accumulation of dead phytomass (11.8% of the total phytomass). This intensity of mulching also exhibits significant differences in sward variants, with the exception of spontaneously grassed stands. The share of the grass component is entirely dominant in permanent grassland (> 90%). In the sown variant of clover grasses, the dominant *Lolium* sp. and *Poa pratensis* suppress the dominance of *Elytrigia repens* considerably to 10.8% (3× mulch) and 21.7% (1× mulch). Spontaneously grassed stands show a visible succession phase of dominance of *Elytrigia repens*, with the species' cover being 50–70%. Mulching once a year reduces the number of species, particularly in the group of forbs. In comparison with newly established grass stands (15–21 species), permanent grassland shows a lower number (9–12).

Keywords: grasslands, mulching, succession, stand structure

Introduction

The conversion of arable land to set-aside via grassing has been, until recently, one of the steps advocated by the programmes of the CAP of the EU. In the paper, the attention is focused on various systems of grassland establishment (controlled, spontaneous grassing) in relation to different management styles, i.e. mulching 3 times and 1 time a year. An assessment is made of the differences in the stand structure expressed by the share of dead phytomass, as well as by the share of grasses, legumes, and forbs in the dry phytomass. Other characteristics assessed included the stand's species diversity and the phase of the succession changes as compared with permanent grassland. The issue of mulching pure stands of selected grasses and legumes was studied by Šantrůček *et al*. (2002) and, in permanent grassland, by Fiala and Gaisler (1999).

Material and methods

The trial was established at the Research Forage Station of Mendel University of Agriculture and Forestry in Brno in Vatín. The average annual temperature is 6.9°C and the average annual precipitation is 617.5 mm. The experiment was established on a plot with a permanent sward (9 years old). Part of the plot was treated with Glyphosate herbicide and ploughed in the autumn of 2004. In the spring of 2005, experimental stands were established with the following variants: A – original permanent grassland; B – controlled grassing (Glyphosate + sown clover-grass mixture: *Festuca rubra* 30%, *Poa pratensis* 20%, *Lolium perenne* 20%, *Lolium multiflorum* 20%, *Trifolium repens* 10%); C – spontaneous grassing with, and D without the application of Glyphosate. All the variants of the experiment were treated by two management methods – mulching once a year and mulching three times a year. In the course of the trial, the experimental plot was not fertilised with mineral fertilisers. The plant species were detected in the phytomass by botanical analysis – sampled from 1 m^2. The statistical evaluation was performed in the STATISTICA program by using the analysis of variance (ANOVA) with the subsequent Tukey test.

Results and discussion

Live and dead phytomass

The effect of mulching intensity (3× and 1× per year) is significantly reflected in the different share of dead phytomass in the total harvested herbage weight, with 11.8% in the variants mulched 3 times a year, as compared with 15.1% in the stands mulched 1 time a year – on average in all four variants (Table 1). A higher intensity of mulching facilitates the representation of finer rhizomatous grasses, legumes, and possibly other dicotyledon species (Figure 1) with a lower concentration of fibre in the phytomass and its more rapid decomposition. In the average of three experimental years (2006–2008), the sward that was mulched 3 times a year showed a significant difference between all the variants of cultivation, with the exception of variants with spontaneous grassing, with shares of 9.4% and 15% as compared with 5.4% in controlled grassing. A high proportion of 'old tissues' was observed in the permanent grassland – Variant A (17.9%). With mulching once a year, a significant difference was observed in the share of dead herbage between Variant B (16.4%) and D (10.7%).

Table 1. The share of dead phytomass (in %) in dry matter yield, Vatín, average 2006–2008

	A	B	C	D
Mulching 3 times a year	17.6	5.5	9.4	15.0
Mulching once a year	21.6	16.4	11.8	10.7

Stand composition structure

Mulching three times a year significantly increases the dominance of legumes (14.3%), as compared with mulching once a year (6.2%). The expansion of legumes reduced the proportion of grasses, i.e. 70.7% (3× mulching) as compared with 83.0 % (1× mulching) – see Figure 1.

The differences in the structure of the individual variants of cultivation following on from the different phases of succession are statistically significant. Velich (1986) claims that after multiple years of mulching of permanent grassland it is possible to speak about a stabilisation phase of succession, with the dominance of grasses. The stability is also corroborated by the equable values of the Shannon and Simpson indices of species diversity and its equability. The controlled grassing shows a dominance of bunch (*Lolium perenne* – 64.9% – 3× mulching and 43.2% – 1× mulching) and rhizomatous grasses (*Poa pratensis* – ca 10% – 3× mulching and 21.6% – 1× mulching). The coverage of *Elytrigia repens* is limited by competition to about 10.8% (3× mulching) and 21.7% (1× mulching). According to Velich (1986), the succession of spontaneously grassed

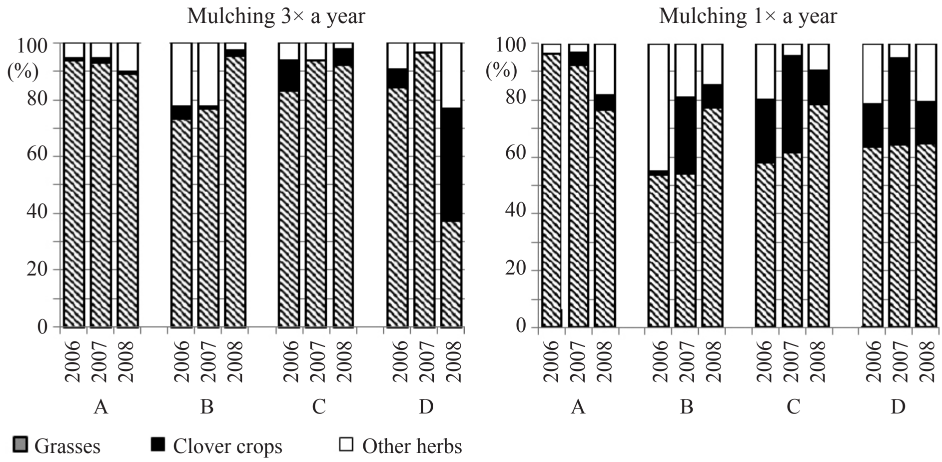

Figure 1. The share of botanical groups (in %) in the yield of phytomass, Vatín 2006–2008

stands with the dominance of grasses, i.e. 60.8–64.3% (3× mulching) and 88.3–93.4% (1× mulching) can be called a couch-grass stage in the fourth year of cultivation. The dominance of *Elytrigia repens* in the sward reaches 50–70% and, of cultured species, *Poa pratensis* has a dominance of max. 8.0%. The dominance of the legume component in the spontaneously grassed stands is 23.9–21.4% with 3× mulching and 4.3–17.7% with 1× mulching per year. Fiala and Gaisler (1999) consider the high production of underground phytomass to be an asset in mulching once a year; the undesirable course of succession is, however, a disadvantage.

Species diversity

The general trend is a lower number of species in stabilised permanent grassland, as compared with the newly established stands at both mulching intensities (Table 2). These stands exhibit a higher number of forb species (8–12), as compared with 3–5 in the permanent grassland. Mulching once a year slightly reduces the total number of species (13–14) in the newly established stands, as compared with the stand mulched three times a year (17–21), and particularly the number of other herb species up to 7–8, as compared with 8–12 in the stand mulched 3 times a year. This is in agreement with Šantrůček *et al.* (2002). The persistence of species in the stands according to the Gleason and Jaccard

Table 2. Total average and maximum number of species and numbers by agrobotanical groups in the mulched grass stands, Vatín, average 2006–2008

Variant	Mulching 3× per year			Mulching 1× per year		
	average	max	G-L-H	average	max	G-L-H
A	9	12	5-1-3	12	14	6-1-5
B	16	18	7-1-8	15	21	5-2-8
C	19	21	6-1-12	14	17	5-1-8
D	15	17	4-1-10	13	15	5-1-7

G – grasses; L – legumes; H – other dicotyledon herbs index of similarity can be evaluated positively only in the permanent grassland and in the stands with mulching 3× per year.

Conclusion

As compared with mulching three times a year, the mulching of grasslands once a year increases the share of dead herbage. In permanent grasslands it reduces the species diversity, suppressing forbs and also the proportion of legumes. In terms of succession and structure, the permanent grassland is already in the stabilisation phase (proportion of grasses > 90%). After 4 years the spontaneously grassed stands were in the coach-grass stage, with the coverage of *Elytrigia repens* ranging from 50–70%. The dominance of *Elytrigia repens* can be significantly reduced by the sowing of a clover-grass mixture.

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The implementation of an indicator method for eligible grassland within an agri-environmental programme in the German Federal State of Brandenburg

Kaiser T.[1], Lorenz J.[1] and Hoffmann E.[2]

[1]*Leibniz-Centre for Agricultural Landscape Research (ZALF), Müncheberg, Germany*
[2]*The Brandenburg State Office for Environment, Potsdam, Germany*
E-mail: mkaiser@zalt.de

Abstract

Regionally specific indicator species and groups can be used to design agri-environmental schemes for extensively used grasslands. In 2007 a preliminary list of indicator species was tested on 122 parcels representing the characteristic spectrum of Brandenburg's grassland site conditions. Finally, 27 indicator species and groups were selected whose occurrences were positively correlated with species diversity. A method for the indicator species' recording was fitted to the different area size of the parcels. Grassland is eligible for remuneration if at least four indicator species occur in all of the required test sections of a single parcel. The method is used in an actually introduced agri-environmental programme in Brandenburg for the targeted promotion of biodiversity outside Natura 2000 areas.

Keywords: plant indicator, biodiversity, species-area relationship, extensification

Introduction

Research into the effectiveness of agri-environmental schemes (AES) has shown that the restoration of botanically diverse grasslands previously used intensively for agricultural purposes is frequently difficult to achieve simply by a reduction in the intensity of cultivation (Berendse *et al.*, 1992; Kleijn *et al.*, 2004; Herzog *et al.*, 2005; Pywell *et al.*, 2007). An approach to improving such programmes is the so-called result-oriented remuneration. The first experiences arose from some AES in Switzerland and Germany (Oppermann and Gujer 2003; Wittig *et al.*, 2006). Farmers qualify for a result-oriented premium in the event of the presence of a minimum number of indicator species. On behalf of the Ministry for Rural Development, Environment, and Consumer Protection of the German Federal State of Brandenburg, a floristic indicator approach was validated. The method was implemented within an agri-environmental measure in the framework of the cultural landscape programme of Brandenburg. We give an overview of the methodological approach and results in this paper.

Material and methods

The Federal State of Brandenburg is located in the north-eastern part of Germany. A list of indicator species for the species-rich grasslands of Brandenburg was developed in a two-stage procedure. In the first stage, potentially suitable plant species were selected in 2005 on the basis of available vegetation data and specialist knowledge (Matzdorf *et al.*, 2008). The validity of this list of indicators was tested in a second stage of the procedure in 2007. For that purpose, 122 grassland parcels representing Brandenburg's grassland habitats were examined from mid-May to the end of June. As this approach aims at agriculturally useable grasslands, extremely dry or wet sites were excluded from the investigation. The plant species were recorded alongside transect sections of 50 m × 2 m (100 m²) divided along the diagonal across the parcel. The quality of the pre-selected indicator species was assessed on the basis of these criteria: number of plant species and number of plant species indicating extensive use. The presence or absence of every potential indicator species was tested for its influence on the total number of species and the number of species indicating extensive use in a given vegetation record. The results were depicted as box plot graphs. Differences between groups were assessed for statistical significance using the Mann-Whitney *U*-test. Besides the indicator testing, a method for the recording of the indicator species was developed that took into consideration the great variation in grassland parcels in Brandenburg.

Results

Selection of indicator species. The vegetation surveys of all 50-m sections were the basis of the validation test for indicator suitability. A separation according to the main factors influencing grassland vegetation was required in order to allow an assessment of the effect of a single species. In the north-eastern lowlands of the German Plain, the moisture gradient is the determining factor for vegetation in extensively used grasslands (Kaiser *et al.*, 2005). The classification into moisture groups was performed using Ellenberg's mean moisture values (Ellenberg *et al.*, 1991). Separated into the respective main group of occurrence, the crucial test criterion was a significantly higher diversity (species number and number of species indicating extensive use) when the species tested was present, compared to cases of its absence. Using the Mann-Whitney *U*-test, most of the pre-selected species revealed significant differences. For special river corridor species such as *Cnidium dubium,* a differentiation exclusively by moisture group was insufficient. It was appropriate to include only floodplain sites in the comparison for these species. The results of all potentially suitable indicator species are depicted in box-and-whisker diagrams. The added case numbers allow the main groups of occurrence to be determined. An example is presented in Figure 1.

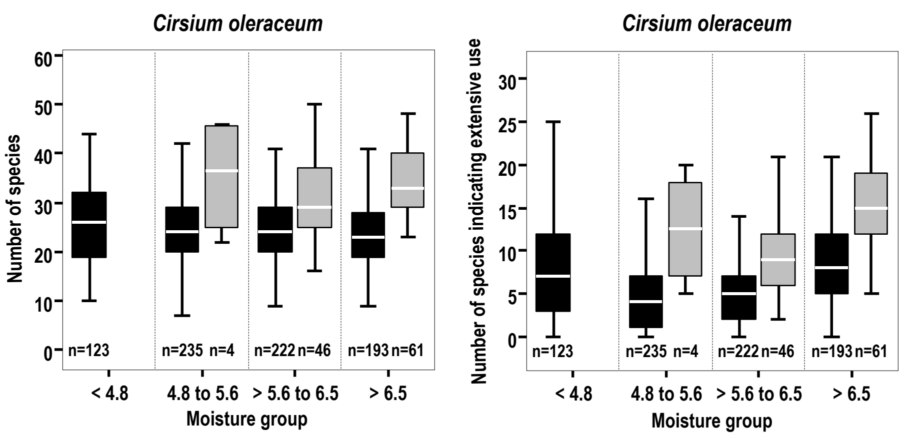

Figure 1. The effect of the absence (black) and presence (grey) of a potential indicator species on species diversity

Indicator species that are hard to distinguish were pooled into species groups in order to make the remuneration approach practicable for farmers. Finally, 27 species and species groups representing the main grassland biotopes in an even balance with each other were included in the indicator list for Brandenburg.

Test method for quality evaluation of grassland. Hitherto existing methods of plant species evaluation for result-oriented remuneration in Germany are based on the transect method. In this approach, a 2 m-broad transect is established along the longest diagonal of a grassland parcel. The transect is divided into equal thirds. Farmers get a premium if at least four indicator species from a given list are present in all of the three transect sections (see Oppermann and Gujer, 2003). The problem with this method lies in the different transect lengths caused by the different sizes and spatial geometries of grassland parcels. The greater the differences between the diagonal lengths, the greater the impact of the well-known species-area relationship (Rosenzweig, 1995) on the assessment results. Figure 2 illustrates the pairwise comparison between numbers of indicator species found on a 50-m section and on a 200-m section, respectively, each combination within the same parcel. The linear trend function in Figure 2 demonstrates that the threshold value of 4 indicator species found on a 200-m section is consistent with the value of 2 indicator species found on a 50-m section.

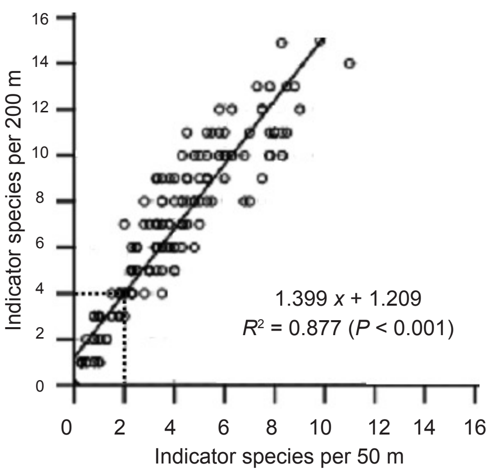

Figure 2. Indicator species-area relationship – 50-m compared to 200-m transect section

In regard to the variation in size of Brandenburg's grasslands, a method with unitary transect sections was established (see Figure 3). The definition of 100-m units resulted from the average parcel size in Brandenburg. In the case of diagonals less than 300 m, the test is restricted to 2 × 100-m sections. For parcels smaller than 1 ha, 2 × 50-m sections

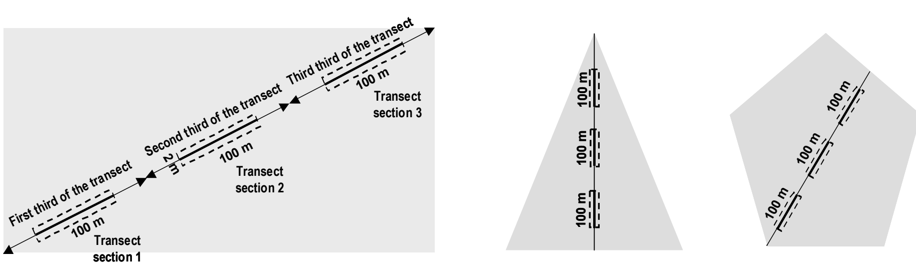

Figure 3. Arrangement of test sections for different parcel geometries

are adequate. The threshold value of 4 indicator species has been retained unchanged. The method presented was implemented into the agri-environmental measure:
"Single area-related extensive management of particular grassland sites" within the cultural landscape programme in Brandenburg. In this the indicator criterion acts as entrance requirement for a traditionally established agri-environmental programme.

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Botanical diversity and nitrate leaching with different styles of grassland management

Kobes M., Frelich J., Šlachta M., Voženílková B. and Suchý K.

University of South Bohemia, Faculty of Agriculture, České Budějovice,
Czech Republic
E-mail: kobes@zf.jcu.cz

Abstract

In 2005–2007 the influence of cattle grazing and the combination of mowing and grazing and the absence of management (leaving fallow) was studied in grasslands in the Šumava foothills, Czech Republic. The development of the sward composition (species richness and diversity) and ecological functions (nitrate contents in ground water, soil cementation) were assessed in experimental areas established at two altitudes (Rojov, 850 m a.s.l., Velký Chuchelec, 650 m a.s.l.). The results of botanical composition analyses show that leaving the grasslands fallow leads to the degradation of the sward composition. Grazed and mowed + grazed stands had a better sward composition, with *Poa pratensis, Festuca pratensis, Dactylis glomerata, Lolium perenne*, and *Trifolium repens* being dominant, while the plots left fallow were overgrown with *Festuca rubra, Agropyron repens*, and *Urtica dioica*. The Simpson's index values were significantly higher in the grazed stands than in the fallow stands. From the viewpoint of underground water protection against nitrate pollution, grazing in 3–4 pasture cycles may be optimal, when mean (x = 1.62 mg l^{-1}) and maximum ($x_{max.}$ = 4.48 mg l^{-1}) nitrate concentrations were lower then normative concentrations for drinking water. However, higher soil cementation values were measured in the grazed plots (penetrometrical resistance 2.65–4.34 MPa at a soil depth of 0.1 m) than in the other treatments.

Keywords: permanent grasslands, management, grazing, botanical composition, species diversity, nitrate leaching

Introduction

The area of permanent grasslands, which have potentially positive ecological functions in an agricultural landscape, has kept increasing in the Czech Republic since the 1990s. The positive ecological functioning of grasslands is associated especially with their botanical composition and the amount and dynamics of biomass production and its quality (Klimeš *et al*., 2007). Species composition and the diversity of grass swards and their ecological functions are influenced, in addition to the ecological conditions, by the type and intensity of management (Klimeš *et al*., 2006). The suitable management of grasslands can therefore ameliorate their ecological functioning.

Material and methods

In 2005–2007 the influence of different styles of management of grasslands on their ecological characteristics and functions was studied in two localities (Rojov, 850 m a.s.l., Velký Chuchelec, 650 m a.s.l.) in the Šumava foothills (South Bohemia, Czech

Republic). Experimental areas grazed by cattle, mown once a year + grazed once a year and an unharvested (fallow) area were evaluated (Table 1). Not only the same breed of cattle, but the same herd of cattle was used at both localities. All the experimental areas were grazed by cattle until 2000, while they received the respective types of management from 2000 to 2007. Four replicate 30 m^2 plots were established within each treatment and site. The number of species (species richness – *S*), species diversity (Simpson's index – *D*), concentrations of nitrates in ground waters, and soil cementation (penetrometrical resistance) were evaluated. In addition, lyzimetric waters were taken in Velký Chuchelec 5 times per year from lyzimeters installed at a depth of 0.5 m in the soil. The probabilities of elevated nitrate concentrations in ground waters were evaluated using empirical models (Klimeš and Kužel, 2004).

Results and discussion

The effect of management on the number of species differed between the two localities, which also differed in their altitude and stand (sward) type. The localities were evaluated separately. The highest number of vascular plant species was found in the grazing treatment in Rojov (850 m a.s.l.) with the stand type *Festucetum rubrae*. By contrast, the highest number of species was found in the fallow stand in Velký Chuchelec (650 m a.s.l.) with the stand type *Triseteto-Dactylidetum* (Table 1). In the fallow stands some species had a solitary character. It increases the values of the number of species richness (S), but not the values of species diversity (D). The Simpson's index (D) values were higher in the grazed and mown + grazed stands than in the fallow stands in both localities (Table 2). The differences between the grassland management types were significant ($P < 0.01$) at both localities. Higher values for Simpson's index (and the index of equitability) were found for the grazed plots and the mown + grazed plots than in the fallow plots in the stand type *Triseteto-Dactylidetum* in Velký Chuchelec. The values of these parameters were equal to, or lower, in the managed stands than in the fallow stands within the stand type *Festucetum rubrae* in the Rojov locality. Not only the management, but also the stand type, influences the S and D values.
The mean nitrate concentrations in the ground water (NO_3^- mg l^{-1}) were low (Table 3). The maximum values of nitrate concentrations were higher in the fallow stands and mown + grazed stands. Higher probabilities of elevated nitrate concentrations in ground water were found in the grasslands mown and grazed once a year. The grazed grasslands had higher soil cementation values (penetrometric resistance 2.65–4.34 MPa at a soil

Table 1. Experimental localities, variants, and mean values of total number of vascular plant species (S)

Locality, variant		Year (mean value of S)			
		2005	2006	2007	$\bar{x}$
Velký Chuchelec, 650 m a.s.l.	mowing (1×) + grazing (1×)	21	21	21	*21.0*
	grazing II (3× in year)	20	20	20	*20.0*
	continuous grazing	23	23	23	*23.0*
	fallow land II	26	28	28	*27.3*
Rojov, 850 m a.s.l.	grazing I (3× in year)	25	26	27	*26.0*
	fallow land I	21	22	22	*21.7*

Table 2. Simpson's index of species diversity (D) in experimental variants (separately in each locality)

Locality, variant		Year, mean value of D		
		2005	2006	2007
Rojov	grazing	12.31	12.690	13.477
	fallow land	11.62	10.917	9.046
Velký Chuchelec	mowing + grazing	10.81	13.351	12.821
	grazing	14.33	14.684	12.198
	continuous grazing	10.53	11.013	11.737
	fallow land	8.13	8.787	11.211

		$\bar{x}$ D	Homogenous groups at level $P_{0.05}$				
Rojov	grazing	13.01	****				
	fallow land	9.78		****			
Velký Chuchelec	mowing + grazing	12.09	****	****			
	grazing	11.84		****	****		
	continuous grazing	11.11			****	****	
	fallow land	9.95				****	****

Variants: Locality V. Chuchelec – $F = 11.28$**, $P < 0.01$; locality Rojov – $F = 18.31$**, $P < 0.01$
Years: Locality V. Chuchelec – $F = 2.61$, $P > 0.05$; locality Rojov – $F = 2.23$, $P > 0.05$

Table 3. Mean values of NO_3^- concentrations (mg l^{-1}) in ground waters in the Velký Chuchelec locality under different management of grass stands (x) with mentioned minima (x_{min}) and maxima (x_{max}) of the obtained values, coefficients of variation [$V(x)$], probabilities of unexceeding critical values [$F(x)$], and values of 95% 100% P fractiles ($x_{0.95}$)

Velký Chuchelec locality, variant	$\bar{x}$	$x_{min.}$	$x_{max.}$	$V(x)$	$F(x)$ (mg l^{-1})		$X_{0.95}$
					$x \leq 15$	$x \leq 50$	
Fallow land	2.195	0.000	8.480	*5.646*	*0.978*	*0.994*	*11.718*
Continuous grazing	1.644	0.000	5.780	*3.449*	*0.958*	*0.993*	*13.224*
Grazing	1.625	0.030	4.480	*4.330*	*0.966*	*0.999*	*11.078*
Mowing + grazing	2.136	1.130	6.530	*1.660*	*0.814*	*0.974*	*15.552*

depth of 0.1 m) than in the other treatments (penetrometric resistance 1.77–2.39 MPa). Higher soil cementation can promote the development of rhizomatous grasses (especially *Poa pratensis*) and white clover (*Trifolium repens*; Klimeš, 1999; Klimeš *et al*., 2006), which results in an increase in the particular species' cover (Weyermann *et al*., 2008).

Conclusion

Grazed swards have better values for some parameters (species diversity – D, nitrate leaching) in polycriterial evaluations of their non-productive functions than fallow areas. A rotation system of grazing by 3 or 4 pasture cycles per year can be recommended in submontane regions. The use of grassland with mowing once a year + grazing once a year represents low-intensity management. Mowing once a year + grazing twice a year is theoretically more suitable and sustainable there. Leaving the stands fallow leads to a poorer plant species composition and is therefore justified only in waterlogged areas (lower soil cementation in fallow stands). The exploitation of grasslands by cattle grazing can promote their favourable ecological functions, provided there is a suitable grazing technique and animal concentration.

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Soil aggregate stability (SAS) of grassland in comparison with arable land

Kohoutek A., Němcová P., Odstrčilová V., Nerušil P. and Komárek P.

Crop Research Institute, Prague, Research Station in Jevíčko, Czech Republic
E-mail: vste@seznam.cz

Abstract

The positive effect of grasses on stability of soil structure has been known and used in agriculture since the 19th century. However, little attention has been devoted to permanent grasslands where it has special significance with respect to water and air regime of soil, water infiltration and other non-productive functions. The results of the submitted paper indicate that the SAS method can be applied in agronomical evaluation of soil quality with respect to soil aggregates structure as a standard method and they confirm competence of positive expertise of previous authors.

Keywords: grassland, soil structure, non-productive functions of grasslands

Introduction

The determination of SAS was carried out with a modified method by Kemper (adjusted translation DIN 19683 – 16). It is an update of the original norm of the same symbol from 1973, which was proposed as a modification of the method by Kemper and Koch (1966). It is mainly used in Germany and Austria. This method is intended primarily for determination of soil susceptibility to encrustation formation and relative comparison of stability of soil aggregates under different management of grasslands. Aggregate stability is defined here as soil resistance against changes in their cohesive arrangement.

Materials and methods

The trials were established on a fluvisoil at the Jevíčko site, the Czech Republic, in a mild climatic region (average annual temperature 7.4°C, annual rainfall 545 mm, altitude 342 m). The samples were collected on 13th October 2008 from grassland and arable land from the layer at the depth of 5–10 cm in the following alternatives presented in Table 1.

The method description. During sample collection and processing its compression is prevented, the period between collection and processing cannot exceed three weeks. By sifting we will get intact soil aggregates 1–2 mm in size. For one measurement 4 g are weighed out, poured on the sifter and covered by approximately 80 ml of distilled water at the temperature of 22–25°C. Sifting under the water is carried out for 5 min in a sifting submergible apparatus developed by an Austrian group for soil physics (BAL Gumpenstein). After 5 min sifters with remaining aggregates are taken out and dried at the temperature of 105 ± 5°C. To determine the sand proportion a solution of $Na_4P_2O_7 \cdot 10\ H_2O$ is added to the remaining sample for about 2 h. This suspension is poured onto sifters and is sifted (even manually) until only sand is left on the sifter. The aggregate stability is then calculated with a following equation:

Table 1. Soil samples for SAS determination

Sample No.	Crop
1J	permanent grassland (PG)
2J	temporary grassland (TG)
3J	reseeded (strip seeding) grassland (RG)
4J	grassland renewal (spring 2008), monoculture of *Trifolium hybridum*
5J	grassland (sowing 1986), monoculture of *Dactylis glomerata*
6J	grassland (sowing 1986), monoculture of *Arrhenatherum elatius*
7J	grassland (sowing 1986), monoculture of *Festulolium* hybrid
8J	grassland (sowing 1986), monoculture of *Festuca arundinacea*
9J	maize
10J	potatoes
11J	wheat
12J	mangel

$$A_s = \frac{m_{A.S} - m_S}{m_P - m_S}$$

where: $m_{A,S}$ – weight of stable soil aggregates and sand (g)
m_S – weight of sand (g)
m_P – weight of the material weighted out (g)

Analyses were carried out in 3 parallel replications. Analytical results were statistically evaluated with Tukey method and presented in Figure 1.

Results and discussion

The SAS method showed (a) a significant difference between stability of soil aggregates of grassland and field crops and (b) it sensitively indicated differences inside both groups (Figure 1). Technically, SAS provides significant information about the resistance level of soil aggregates against levigation, erosion, and creation of soil encrustation. Soil aggregates with high stability significantly improve water and air regime of soils. The results demonstrate that SAS is significantly influenced by genetic soil types, cultures, resp. crops sowing procedure and agricultural management. Poorly structured soils cause surface instability, soil solidification and creation of anaerobic zones that lead to erosion, bad water and nutrients accessibility for plants and by that increase of their susceptibility to diseases and yield decrease.
Similar differences were found by Míka (1973): the highest values of soil aggregates stability were demonstrated by meadow soil and followed in decreasing order by hotbed soil, clover field, potato field and wheat field. Stabilizing effect of grasses on stability of soil aggregates is obviously higher than effect of legumes while grass species with high production of root matter affect stability particularly intensively. Stability positively correlated ($P_{0,01}$) with dry matter weight of root matter (Míka, 1975) and with C_{ox} content in the soil, especially in top soil layers (≤ 0.1 m). And mechanical effect of roots for soil structure (aggregates binding) seems to be less important in heavy soils than in light (sandy) soils as a result of strong binding forces in heavy soils (Boekel and Peerlkamp,

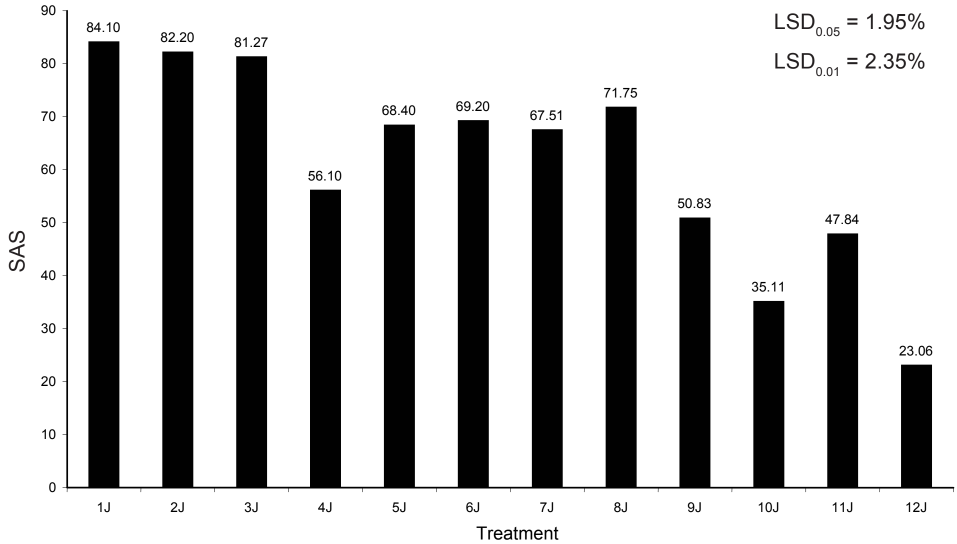

Figure 1. SAS (in %) of soil samples

1966). Fertilized grassland on heavy soils demonstrated higher aggregates stability and better water infiltration than non-fertilized control (Míka, 1973). The SAS method appears to be highly sufficiently accurate, sensitive, well reproducible and suitable for standard soil quality evaluation of a wide range of samples (Buchgraber *et al*., 2003).

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The measurement of soil protection capacity from erosion by means of a mobile rainfall simulator in grasslands

Kohoutek A.[1], Komárek P.[1], Tippl M.[2], Bohuslávek J.[2] and Janeček M.[2]

[1]*Crop Research Institute, Prague, Research Station of Grassland Ecosystems in Jevíčko, Czech Republic*
[2]*Research Institute for Soil and Water Conservation, Prague, Czech Republic*
E-mail: vste@seznam.cz

Abstract

The soil protection capacity from erosion of (1) renewed grassland, or (2) strip seeded grassland in comparison to (3) intact seminatural stand using mobile field rain simulator has been evaluated. A high protection capacity of grassland has been determined, only limited surface soil wash away occured in case of (1) in amount of 0.050 t ha^{-1} and (2) 0.008 t ha^{-1} when the strips were directed slope downwards.

Keywords: grassland, conservation technologies, erosion, rainfall simulator

Introduction

Water erosion is the activity of water which causes disintegration of the soil surface and displacement of loose matter (Janeček *et al*., 2002). The agricultural management of tilled soil brings along with it an increased risk of soil erosion. The intensity of erosion processes can be significantly limited and thus soil utilisation for field crop production can be improved.

Material and methods

The anti-erosion efficiency of strip seeding technology in grassland was investigated in comparison with grassland renovation at the Cetkovice site in the CR (location 49°34'24.508"N, 16°44'16.062"E) in 1995 and 1996. The percent proportion of soil fractions at the Cetkovice site is presented in Table 1. Strip seeding into original permanent grassland was carried out on a pasture at Cetkovice in alternations of strip seeding with a width and depth of 100 and 150 mm along the surface contour and down the slope in comparison with slot seeding with a sowing drill SE-2-024, renovation with a rotary tiller, and original grassland (Kohoutek *et al*., 1998). The strip span of the strip seeding was 0.45 m. We applied a simple legume-grass mixture of perennial clover Mustang and red clover Vesna in the amount of 25 kg.ha^{-1}. The observation was conducted immediately after seeding and renovation in 1995.
A rain simulator, designed at RISWC (Janeček *et al*., 1995), was used to measure the anti-erosion efficiency of different grassland management systems. The principal parts of a field rain simulator are FULLJET – wide-angle (104°) jets by Spraying Systems Co., which produce raindrops similar in size to natural torrential rain. Four jets with their feed hosepipes are hung on a simple frame made of duralumin pipes at a height of 3 m above the ground. One jet covers an area of 3 × 3 m. The jets are controlled by electromagnetic valves which allow the intensity of the rainfall to be set gradually up to 1 mm per minute, which is the intensity of torrential rain. We evaluated the capacity of erosion surface

wash, soil runoff, and of the hydrological and hydraulic properties of soil surfaces (humidity characteristics before and after rainfall, infiltration speed, run-off conditions).

Table 1. Percent proportion of fractions – the Cetkovice site

I. < 0.01		II. 0.01–0.05	III. 0.05–0.25	IV. > 0.25
Clay	0.001–0.01			
9.5	15.6	39.0	15.9	20.0

Results and discussion

The results attained, which demonstrated the high anti-erosion efficiency of grasslands, are presented in Table 2. The erosion wash only occurred in the renewed grassland in

Table 2. The results of the measurements of the anti-erosion efficiency of renovation, strip, and slot seeding of permanent grassland (site Cetkovice)

Alternation: Year	Sowing direction	treatment: renovation	strip* and slot** seeding (mm): depth	strip* and slot** seeding (mm): width	Slope declination (°)	Soil humidity before and after rainfall (% vol.)	Time of measurement (min)	Beginning of surface runoff (min)	Rainfall intensity (mm min^{-1})	Total rainfall height (mm)	Total height of surface runoff (mm)	Total soil loss (Mg ha^{-1})
1995	downwards	renovation	.	.	8.5	24.60 41.65	20.0	6.0	0.60	13.90	0.60	0.050
1996	downwards	renovation	.	.	8.5	18.87 43.40	20.0	0.0	0.73	14.60	0.10	0.000
1995	downwards	.	100*	100*	8.5	15.42 24.05	20.0	16.5	0.74	18.80	0.20	0.008
1995	downwards	.	150*	100*	8.5	26.50 46.25	20.0	12.0	0.82	14.80	0.00	0.000
1995	downwards	.	150*	150*	8.5	17.38 50.07	20.0	0.0	0.74	14.8	0.00	0.000
1995	along contour	.	150*	100*	8.5	25.60 46.32	20.0	0.0	0.61	12.1	0.00	0.000
1996	along contour	.	150*	150*	8.5	20.29 39.11	20.0	0.0	0.77	15.4	0.00	0.000
1996	along contour	.	30**	60**	8.5	29.84 62.43	20.0	0.0	0.78	15.6	0.00	0.000
1996	along contour	.	30**	60**	8.5	29.46 44.43	20.0	0.0	0.78	15.6	0.00	0.000
1995	original grassland	.	.	.	8.5	18.79 53.25	20.0	0.0	0.60	12.0	0.00	0.000

1995 with a total soil loss of 0.050 t ha^{-1} and in the strip-seeded grassland down the slope in 1995 with a total soil loss of 0.008 t ha^{-1}. All the other methods of strip seeding managed to infiltrate all the rainfall into the soil and prevented surface erosion wash. The technologies of strip seeding and slot seeding with the SE-2-024 seeding drill are considerate of the grass ecosystem and the results suggest that they fundamentally eliminate the risk of soil erosion immediately after treatment, whereas there is a potential risk of soil erosion after traditional grassland renovation. Strip seeding along the surface contour line can completely eliminate possible soil erosion. It was confirmed that the infiltration and anti-erosion capacity of grassland is high, which is one of the main functions of grasslands in the landscape (Janeček *et al*., 2002).

The production of voluminous feedstuff based on grasslands minimises the risk of soil erosion and the technologies of strip seeding procedures used for the introduction of new species into grasslands can practically eliminate the risk of soil erosion. In the climatic conditions of the CR it is therefore desirable to choose a suitable structure of grown voluminous feedstuff, also with respect to its anti-erosion capacity, and apply and develop new minimisation technologies which significantly reduce the risks of soil erosion.

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Aesthetic values of chosen herbs occurring in grasslands

Kolczarek R., Jankowska J., Ciepiela G.A., Sosnowski J. and Jankowski K.

University of Podlasie, Agronomy Department, Siedlce, Poland
E-mail: laki@ap.siedlce.pl

Abstract

Grasslands are terrains with a very large usage, natural, and landscape significance. Generally, landscapes not very drastically transformed by man are very beautiful and attractive places. It can be affirmed that if the proportion of floral plants is larger in the botanical composition of grasslands, their influence on the beauty created in this landscape is greater. These terrains provide unusual aesthetic impressions, especially in the period of the flowers' blooming; they provide a fascinating wealth of colours and shapes. Blooming meadows are places that characterise the unusual wealth of colours changing according to the period of the blooming of some species. The grasslands are also a special kind of "drugstore", where we can find herbs which can be used in phytotherapy and the pharmaceutical industry. The herbs coming from grasslands are more valuable than those from cultivated sources. For mental equilibrium and human health the intercourse between rich plants and the animals found in meadows is exceptionally profitable. If there is greater biodiversity in meadows, their influence on the surrounding environment is more profitable.

Keywords: permanent meadow, colour, herbs, landscape, blooming

Introduction

Grasslands belong among the areas with a very large usage, natural, and landscape significance (Kozłowski and Swędrzyński, 1996; Sawicki, 2006). Generally, landscapes not very strongly transformed by human activity are very beautiful and attractive (Warda and Stamirowska-Krzaczek, 2007). If the proportion of floral plants in the botanical composition of grasslands is larger, then their influence on the beauty of landscapes created by them is also larger. These terrains provide unusual aesthetic impressions, especially in the period when the flowers are blooming; they delight with their wealth of colours and shapes (Trzaskoś *et al*., 2006). On the grasslands in our climatic zone we can find many species of grasses and at least twice as many dicotyledonous plants, usually differing in their persistence and in the form of their growth.

Materials and methods

The aim of this work was to present the values of the floristic biodiversity of grasslands via the example of the descriptive profile of some dicotyledonous plants found on a permanent meadow in the region of Siedlce, in the valley of the Muchawka River, from the point of view of their aesthetics and colour, as well as their potential medicinal properties, in the 2007 vegetative season. The most colourful species in the individual months of the vegetative season were found and marked on ten randomly chosen small plots (5 m^2). The ecological indicator values of the vascular plants of Poland published by Zarzycki *et al.* (2002) were used. The estimation of natural values was carried out according to the valorised numbers and elaborated by Oświt (2000).

Results and discussion

In the analysed region many species of permanent meadows create interesting and colourful surfaces, changing with time. The undeniable beauty of the landscape in the period of blooming was created by many species (Table 1). The seasonal rhythms of phenological changes displayed themselves in the blooming of distinguished plant species, deciding about decorative values of landscapes (Table 1). The most common colour of the blooming plants was yellow, which was particularly visible in the spring months thanks to such species as *Taraxacum officinale* Web. or *Ranunculus acris* L., and, somewhat later, *Hypericum perforatum* L. or *Lathyrus pratensis* L. In the summer period, however, the colour pink predominated with red, for example, blooming plants such as *Polygonum bistorta* L. or *Trifolium pratense* L. However, species with the blue colour of inflorescences also stood out, represented by such plants as *Campanula glomerata* L. or *Geranium pratense* L. The representatives coloured white, which were fewer in number, were also visible against the background of green grasses and featured such species as *Cerastium holosteides* Fr., *Filipendula ulmaria* (L.) Maxim., and *Stellaria graminea* L.

For spiritual equilibrium and for human health the relationship with the rich flora and fauna of meadows is exceptionally profitable. Among appointed meadow plants there are a predominance of the species defined as herbs which have health aspects. If there is a greater biodiversity in meadows, then the influence on the surrounding environment is more profitable (Trąba and Wyłupek, 1999). The studied meadow contained in its botanical composition plants sending out fithoncyds with germicidal properties, among which belong *Taraxacum officinale* Web., *Betonica officinalis* L., and *Hypericum perforatum* L.

The health values of grasslands are extremely important at present because, according to medical opinion, there is a potential threat of the formation and frequent incidence of allergic illnesses. At the present time at least 30% of the accessible medicines in pharmacies contain components of vegetable origin and they are used as a supplement to chemical medicines. More and more doctors are interested in the medicinal properties of herbs and they often choose medicines of vegetable origin because of the lower risk of bad results and undesirable reactions from the organism (Grzegorczyk and Alberski, 2004).

This endeavour, natural for humans, of looking for beautiful neighbourhoods in which to renew their strength, having all birth-marks of the mass phenomenon of sociological, requires access to attractive and beautiful landscapes in regions often located in close proximity to areas of major human habitation. So, humans should not avoid contact with the world of nature. We should use the potential provided by the environment of grasslands and use them both economically and rationally, in a way that is appropriate for natural conditions, not destroying the existing value of landscapes and not violating the balances of ecological relationships.

Conclusions

Blooming meadows are places characterised by an unusual wealth of colours that change according to the blooming of certain species.

Table 1. Colour and the time of blooming of chosen species from the permanent meadow in the Siedlce region in the valley of the Muchawka River

Latin name	Colour of the blooming	No. of valuation by Oświt	Light indicator**	Thermic indicator**	Humidity indicator**	Time of blooming (month)
Stellaria graminea L.	white	1	4	4-2	3	V–VIII
Cerastium holosteoides Fr.	white	1	4	4-2	3-4	IV–X
**Parnassia palustris* L.	white, pink	8	4	4-2	4-5	VII–IX
**Filipendula ulmaria* (L.) Maxim.	white, light yellow	3	3	4-2	4-5	VI–VIII
**Trifolium repens* L.	white	2	4	4-2	3	V–VIII
**Carum carvi* L.	white, pink	2	4	4-2	3	V–VII
**Ranunculus acris* L.	yellow	3	4	4-3	3-4	V–VIII
**Hypericum perforatum* L.	yellow	1	4	5-3	2-3	VI–VIII
**Trifolium aureum* Pollich	yellow	2	4	4-3	2	VI–VII
**Taraxacum officinale* Web.	yellow	3	4	3	3	IV–V
**Lotus corniculatus* L.	yellow	1	4	4-2	3-4	V–VIII
**Lathyrus pratensis* L.	yellow	6	4	4-3	3-4	VI–VIII
**Agrimonia eupatoria* L.	yellow	2	5	4-5	2-3	VI–VIII
**Dactylorhiza incarnata* L. Soo	red	8	4	4	4-5	V–VI
**Dactylorhiza majalis* (Rchb.)	red, pink	8	4	4-3	4	V–VI
**Polygonum bistorta* L.	pink	3	4	4-2	4	VI–VIII
**Dianthus deltoides* L.	red, pink	1	4/3	4	2	VI–X
**Ononis arvensis* L.	pink	1	5	5-3	3	VII–IX
**Trifolium pratense* L.	purple red	2	4	4-2	3	V–IX
**Lythrum salicaria* L.	purple red, violet	3	4	4-3	4-5	VII–IX
**Pedicularis palustris* L.	pink-purple red	8	4	4-3	4-5	V–VII
**Betonica officinalis* L.	purple red	3	4/3	4-5	2-4	VI–IX
**Geranium pratense* L.	blue, violet	2	4	4	3	VI–IX
**Polygala vulgaris* L.	blue	1	4	4-3	3	V–VI
Myosotis palustris L.	pink, next blue	3	4	4-3	3	V–X
Campanula patula L.	blue, violet	2	5	4-2	3	V–VII
**Prunella vulgaris* L.	light violet	1	4	4-3	3-4	V–X
**Campanula glomerata* L.	light violet	1	4	4-2	3	VI–IX
**Sanguisorba officinalis* L.	high red, brown	1	4	4	4	VI–IX
	mean	2,86				
Total, Grasses landscape *Festuca rubra* (%)		48.6				
Leguminous species (%)		5.7				
Herbs and weeds (%)		45.7				

* The species features active substances (herbs) in its composition
** Ecological indicator values of vascular plants

The colourfulness and the green colour of growing plants create a mood that works psychologically on humans' nervous patterns, and also lets them work out their emotions far away from the noise of the city and the waste it creates.
The grasslands of the studied region are also a special kind of "green drugstore", because there we can find many useful plants which can be used in phytotherapy and the pharmaceutical industry.
With regard to the chosen predominant blooming species, the average obtained value carried out 2.86 points, what the analysed terrain of investigations initially qualified to the average moderated of natural values.

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Effect of permanent meadows on the chemistry of surface waters

Kozłowski S., Zielewicz W. and Swędrzyński A.

University of Life Scices in Poznań, Department of Grassland Sciences, Poznań, Poland
E-mail: walziel@au.poznan.pl

Abstract

Our investigations were carried out in the central part of Poland in the region known as Wielkopolska, distinguished, both in the past and now, by its intensive and well-managed agricultural economy. The research objects comprised mainly small watercourses and their catchment areas. The results of our studies revealed a favourable role of permanent meadows regarding the quantitative occurrence in open waters and absorption of the nitrate nitrogen, potassium, sodium, phosphorus, calcium, magnesium, chlorides, and sulphates by meadow complexes.

Keywords: nitrate nitrogen, waters of rivers, watercourses, permanent grasslands

Introduction

Among the less recognised, as well as less appreciated functions, alternative to the fodder role of permanent meadows is their biogeochemical function as evidenced by continuous changes in biogen concentrations in rivers and watercourses which flow across complexes of permanent meadows.

Materials and methods

The experimental object comprised selected rivers, watercourses, and their catchment basins characteristic for the area of investigations situated in the Wielkopolska region, which is distinguished by a relatively small proportion of meadows and pastures in the structure of agricultural land and the application of intensive farming management systems. Special attention was paid to the plant cover of surfaces extending along watercourses, which were referred to as complexes. Agricultural complexes comprise areas of arable land taken up by the cultivation of cereals and root crops. Small quantities of nitrogen, phosphorus, and potassium are applied in their cultivation. On the other hand, forest complexes are defined as areas covered, primarily, by pine and smaller proportions of trees of broad-leaved species. Investigations had already been carried out on some of the rivers and watercourses examined. This paper presents research results obtained in the years 2003 to 2007.
Object A. The object designated in this way was the most extensive research object with regard to its area with watercourses created at the beginning of the 19^{th} century following land improvement works conducted on vast marshes in the neighbourhood of a place called Wielichowo. The above-mentioned watercourses, called the Northern Canal, Central Canal, and Southern Canal, each 5 km long, flow across a very extensive permanent meadow complex and smaller complexes of cereal and root crop cultivations, as well as through small forest complexes.

Object B. This object comprised the water catchment basin of Lake Grzymisławskie, with an area of about 800 ha. The lake collects waters from 5 midfield and 4 mid-meadow watercourses about 1.0–2.5 km long each, as well as from a river called the Pysząca.
Object C. This object is situated at the border of the Wielkopolska and Małopolska regions within the catchment area of the Widawka River, which is 95 km long. Ten permanent sampling points were determined on its first part (10 km long), along the length of the river which flows across different agricultural complexes. Analytical investigations included the systematic collection of water samples during the vegetation season with the aim of determining the content of biogens important for the assessment of water quality with regard to its suitability for animal watering or the irrigation of agricultural and horticultural crop plants. The components examined were determined employing methods commonly used in Poland which were described in an earlier paper by Falkowski *et al.* (1998).

Results and discussion

The results of the analytical investigations of the water of the watercourses (canals) flowing through Object A, which is very extensive and dominated by permanent meadows which have existed in this place for over 200 years (Table 1), indicate very small contents of all the determined biogens.
The above remark refers, primarily, to nitrate nitrogen, phosphorus, and potassium. In the light of Polish classification standards, water from the above watercourses should be considered as clean. It is worth noticing that biogen levels were found to be lower in the water collected from the Central Canal, which flows between the remaining two canals. Such a location exposes the waters of this canal to the negative impact of complexes of agricultural cultivations to a much lesser extent than the waters of the Southern and Northern Canals, which flow close to areas of agricultural cultivation more frequently. As mentioned earlier, there is a small watercourse in this object flowing across different vegetation complexes. It appears that the greatest impact of the plant cover occurs in spring (Table 2).

Table 1. Biogen content in the water of the Obra Łęg water courses (mg l^{-1})

Component	Northern Canal	Central Canal	Southern Canal	$NIR\text{-}LSD_{0,05}$
Nitrate nitrogen	2.26	0.67	2.08	1.843
Phosphorus	0.31	0.06	0.42	0.873
Calcium	142.31	169.61	135.52	n.s
Magnesium	17.06	24.18	21.15	0.364
Potassium	14.15	8.42	14.78	n.s
Sodium	45.10	37.61	47.28	0.627
Chloride	85.56	121.18	121.08	n.s
Sulphate	156.37	125.95	118.26	1.154

As mentioned earlier, there is a small watercourse in this object flowing across different vegetation complexes. It appears that the strongest impact of the plant cover occurs in spring (Table 2). The favourable influence of permanent plant covers, i.e. meadow and forest complexes, is very distinct and convincing.

Table 2. Content of selected biogens in the water of the watercourse flowing through various complexes in spring (mean from years 1982–2008) (mg l^{-1})

Complex	Nitrate nitrogen	Potassium	Phosphorus	Sulphate	Chloride
Agricultural	38.72	10.93	0.019	100.60	103.19
Meadow	3.10	2.70	0.016	91.62	72.42
Forestry	1.25	2.66	0.013	89.00	67.74
NIR-$LSD_{0.05}$	0.926	0.773	n.s	3.631	3.977

The observed positive impact of permanent plant covers on the biogen content in the waters of rivers and watercourses shows meadows and forests acting as special filters reducing the amount of biogens reaching water reservoirs. Grzymisławskie Lake is a very rewarding object of investigation in this regard. The data collated in Table 3 illustrate the quantity of biogens carried in the waters of these watercourses and discharged into the waters of this lake. It should be added that the velocity of the water flow in these watercourses was estimated at 2 l min^{-1}. On average, mid-meadow watercourses bring into the lake 61% less potassium and 34–37% less nitrates and chlorides, as well as 16–28% less of the remaining components, i.e. calcium, phosphates, chlorides, sodium, and magnesium.

Table 3. Quantity of biogens brought in the water of watercourses discharging into the Grzymisławskie Lake (g^{-1} day^{-1})

Component	Mid-field watercourses	Mid-meadow watercourses	NIR-$LSD_{0.05}$
Nitrate nitrogen	4.32	2.89	0.794
Potassium	5.32	2.09	1.213
Sodium	12.74	9.91	0.942
Magnesium	10.41	8.77	0.876
Calcium	57.04	41.54	2.346
Phosphorus	13.53	10.94	0.627
Sulphate	39.93	31.37	1.273
Chloride	57.24	36.08	2.139

The presence of permanent plant covers, i.e. meadows and forests, combined with the application of lower doses of mineral fertilisers in the cultivation of agricultural crop plants than those used in the past, cause the waters of our rivers and watercourses not to contain high quantities of biogens (Table 4). Water collected systematically from 10 points along this river throughout the vegetation season was characterised by a considerable stability of the quantities of all the biogens analysed.

The results of our investigations are in agreement with the research results of such researchers as Borowiec and Zablocki (1996), Falkowski *et al.* (1988, 1998), or Sileika

Table 4. Occurrence of biogens in waters of the Widawka River

Component	Content (mg l^{-1})	*VC*%
Nitrate nitrogen	1.264	18
Phosphorus	0.026	12
Calcium	67.327	6
Magnessium	10.786	11
Potassium	2.681	13
Sodium	20.225	7
Manganese	0.011	28
Chloride	35.243	10
Sulphate	34.161	16

(1996) and emphasise the advantageous influence of permanent meadows on the quantities of biogens found in watercourses flowing through them. Moreover, they also correspond with papers presented at various conferences, among others, at a conference entitled: “Nitrates in agricultural ecosystems”, which was held in Poland in 1996.

Conclusions

Permanent meadows provide a unique filter reducing biogen migration into surface waters and, therefore, modify water quality in rivers and water reservoirs positively. Because of the multifaceted functions played by permanent meadows in the natural environment, as well as in the landscape, they should not be ploughed and turned into arable land.

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Geomorphological variability of river valleys and natural values of meadow communities

Kryszak A., Kryszak J. and Klarzyńska A.

Poznan University of Life Sciences, Department of Grassland Science, Poznan, Poland
E-mail: akryszak@up.poznan.pl

Abstract

The geomorphological variability of river valley beds and, hence, variations in site conditions, affects the spatial configuration of meadow communities in the landscape, as well as their wealth and floristic diversity. Phytocoenoses developed on a floodplain show the greatest number of species, as well as the highest index of floristic diversity. On the other hand, communities occurring in old river-beds and along river banks, as well as on floodplains in sites with changing moisture conditions, are characterised by the presence of many floristic peculiarities which affect their natural values.

Keywords: meadow communities, site conditions, plant diversity, natural valorisation index

Introduction

The bottom surface configuration of river valleys, as well as the distribution of geomorphological forms, depends on natural fluvial processes**.** The above, in turn, results in variations in site conditions, diversification of the developed phytocenosis, and landscape variability (Kryszak *et al*., 2006). The aim of the investigations performed was to determine the impact of the configuration of river valleys on site variability, as well as on the occurrence and natural values of meadow communities.

Methods

The investigations described were carried out during the period 2000–2007 in several river valleys in Western Poland, varying with regard to their surfaces and geomorphology. The evaluation of the natural value of the meadow communities examined was conducted on the basis of the number of plant species found in a phytosociological relevé (about 1,000) and the Shannon-Wiener floristic diversity index (H'), as well as a natural valorisation index using the Oświt method (2000). Site conditions – a moisture indicator (F) and the nitrogen content in the soil (N) – were determined with the assistance of Ellenberg's method (1992).

Results and discussion

Extensive river valleys, seemingly monotonous with regard to their landscape, reveal diversification of their geomorphological forms, among which we can distinguish, among others, the banks of river beds, floodplains, old river valleys, and local elevations. This is the cause of a considerable mosaicity and variability of site conditions in a given valley and, consequently, of the distribution of plant communities, as well as considerable floristic diversity. Extensive areas of floodplains are overgrown mainly with rush-meadow communities. Initially, they include communities from the *Phragmitetea* class, but as the distance from the river bed increases, communities from the *Molinio-Arrhenatheretea* class begin to dominate. Occasionally, the monotonous landscape of the floodplain is interrupted by hillocks which are covered by the vegetation of xerothermic swards which are represented by communities from the *Koelerio glauca-Corynephoretea canescentis* class.

The highest natural value can be observed in communities which occur in old river beds and along river banks or on the floodplain in sites which are characterised by changing moisture conditions and whose floristic composition is characterised by the presence of many floristic peculiarities (Table 1).

Table 1. Variability of natural values of selected plant communities in relation to the geomorphological configuration of a river valley (wide – A, narrow – B)

Plant communities	Mean plant species in releve		Floristic diversity index* H'		Natural valorisation index**	
	A	B	A	B	A	B
Bank of the river bed						
Glycerietum maximae	7.4	–	1.95	–	4.03	–
Caricetum ripariae	6.8	24.2	1.63	1.90	4.10	2.56
Caricetum gracilis	8.5	29.6	1.20	1.95	4.82	3,41
Phragmmitetum australis	13.5	25.4	1.40	1.76	3.98	2.70
Phalaridetum arundinaceae	12.3	15.0	1.61	1.50	4.28	2.78
Floodplain						
Glycerietum maximae	13.0	–	1.64	–	–	–
Caricetum gracilis	14.5	11.0	2.10	1.15	2.59	3.40
Phalaridetum arundinaceae	18.7	21.5	2.35		2.27	
Alopecuretum pratensis	40.0	18.3	3.72	1.65	2.69	2.14
Com. *Agrostis stolonifera – Potentilla anserine*	18.0	–	2.47	–	2.41	–
Potentillo–Festucetum arundinaceae	25.0	25.4	1.50	1.79	2.52	2.29
Com. *Deschampsia caespitose*	15.3	18.3	2.01	1.65	2.69	2.14
Arrhenatheretum elatioris	38.0	19.4	3.42	1.76	1.96	2.26
Com. *Poa pratensis – Festuca rubra*	12.6	29.6	1.54	1.84	2.05	2.33
Lolio–Cynosuretum	27.0	14.1	1.90	1.52	2.33	2.44
Local elevation						
Com. *Poa pratensis – Festuca rubra*	18.1	–	1.59	–	1.90	–
Diantho–Armerietum elongatae	20.0	–	1.45	–	2.19	–
Old river bed						
Glycerietum maximae	7.5	–	1,30	–	4.47	–
Caricetum gracilis	9.7	–	1.10	–	4.90	–
Phalaridetum arundinaceae	13.2	–	1.60	–	5.24	–

*according to Shannon-Wiener; **according to Oświt (2000)

These interrelationships are (frequently) quite different in the narrow valleys of small rivers, which exhibit poor diversification of geomorphological forms, as evidenced by lower site mosaicity and, consequently, by a lower number of recorded communities. Areas of narrow floodplains are dominated by communities from the *Molinio-Arrhenatheretea* class, albeit with considerable proportions of segetal and ruderal species infiltrating from the neighbouring arable land. Communities from the *Phragmitetea* class are recorded only as narrow strips along the banks of small river beds. Communities transformed in this way as a result of strong human pressure exhibit lower natural values in comparison with the communities developed in extensive river valleys.

The differences between the natural values of extensive and narrow river valleys can be attributed, primarily, to variations in site conditions but also to the direction and intensity of utilisation (Table 2). In particular, a lower moisture level in the floodplain contributes

Table 2. Relationship between site conditions of selected communities and variability of geomorphological forms of river valleys (wide – A, narrow – B)

Plant communities	Moisture indicators F		Nitrogen content in soil N	
	A	B	A	B
Bank of the river bed				
Glycerietum maximae	9.85	–	8,64	–
Caricetum ripariae	8.57	7.13	5,01	4.43
Caricetum gracilis	8.60	7.62	5,90	3.76
Phragmmitetum australis	9.30	8.20	6,74	5.52
Phalaridetum arundinaceae	8.54	7.59	6,57	6.39
Floodplain				
Glycerietum maximae	7.50	–	5,80	–
Caricetum gracilis	8.03	9.00	4,66	389
Phalaridetum arundinaceae	7.80	7.10	5,70	6.30
Alopecuretum pratensis	6.32	5.01	6,47	5.91
Com. *Agrostis stolonifera–Potentilla anserine*	5.62	–	5,83	–
Potentillo–Festucetum arundinaceae	6.82	4.91	6,62	3.60
Com. *Deschampsia caespitose*	7.01	6.43	3,66	3.27
Arrhenatheretum elatioris	6.13	4.85	5,03	5.97
Com. *Poa pratensis–Festuca rubra*	5.59	5.58	5,51	3.04
Lolio–Cynosuretum	5.71	4.82	5.40	5.57
Local elevation				
Com. *Poa pratensis–Festuca rubra*	3.60	–	2.30	–
Diantho–Armerietum elongatae	3.30	–	2.71	–
Old river bed				
Glycerietum maximae	9.50	–	790	–
Caricetum gracilis	8.86	–	4.65	–
Phalaridetum arundinaceae	7.90	–	5.50	–

F and N – values according to Ellenberg (1992) most to the increased species abundance of rush communities which, in this zone, are of a transitory character.

The existing mosaic of geomorphological forms and developed phytocenoses affects the diversity of the landscape, which can fulfil not only natural but also recreational and tourism functions. In addition, vegetation growing in river valleys, especially in the zone situated close to the river bed, and frequently characterised by a considerable degree of naturalness and significant natural values, provides a valuable ecological corridor (Jankowski and Świerkosz, 1995; Kryszak *et al*., 2006). This explains why many such places are protected within the framework of the Nature 2000 programme. It is worth emphasising that the maintenance or restoration of the naturalness of part of communities growing in river valleys is favoured by extensive meadow-pasture management, as well as by the application of oversowing using endangered species or their introduction with the aim of increasing their population in the sward (Benstead *et al*., 1999).

Conclusions

The geomorphological configuration of river valleys preconditioning the variability of site conditions contributes to the distribution of plant communities and the diversification of their natural and landscape values. Plant communities developed on the floodplain taking up the largest areas exhibit the greatest floristic wealth and diversity in comparison with those which occur in other parts of the valley.

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Soil nitrogen content in relation to meadow and pasture utilisation

Kryszak J., Grzyl S. and Musiał M.

Poznan University of Life Sciences, Department of Grassland Science, Poznan, Poland
E-mail: kryszak@au.poznan.pl

Abstract

Investigations were carried out on permanent grasslands utilised for cutting and grazing. The research results obtained indicate considerable differences in the floristic diversification of the communities examined, levels of the yields obtained, and sward nutritive value, depending on the direction and level of meadow and pasture utilisation. Similarly, the level of meadow and pasture utilisation was found to influence the site, i.e. the content of available forms of nitrogen. A meadow in an agricultural-environment programme (A), utilised extensively (2 cuts), not fertilised, and with cattle grazing management (D) led to excessive accumulations of ammonia and nitrate nitrogen in the soil layer.

Keywords: grasslands, sward composition, utilisation, nitrogen in soils

Introduction

Changes in the site, which depend largely on the level of utilisation, precondition the botanical composition of the sward as well as the productivity of meadows and pastures. Nitrogen fertilisation, in particular, is an important factor which increases grassland productivity. However, in the case of organo-genetic soils, it requires continuous monitoring because of the possibilities of nitrogen outflow from meadow soils to ground and surface waters. This is an uninterrupted process which depends, among other factors, on the atmospheric precipitation, season of the year, soil texture composition, and sodding and botanical composition of the sward, as well as on the fertilisation level and intensity of utilisation (Büchter *et al*., 2002; Frame, 1992; Roberts, 2006; Seidel *et al*., 2004; Warda and Ufniarz, 2004).

The aim of this study was to determine the concentration of the available forms of nitrogen (nitrate and ammonia) depending on the utilisation intensity of grasslands situated in the valley of the Notec River.

Material and methods

Investigations were conducted in the valley of the Notec River in an area dominated by permanent grasslands included in the Natura 2000 network project. The experiments performed comprised grasslands characterised by similar site conditions situated in farms specialising in the breeding of both dairy and meat cattle. Grasslands in this region occur on soils of organic origin, currently strongly mineralised.

The investigations were carried out in the following meadow types:

A – a meadow in an agricultural-environment programme (typical peat soil), utilised extensively – 2 cuts, not fertilised

B – a meadow utilised intensively (2–3 cuts), fertilised with farmyard manure and slurry (200 kg N ha^{-1})

C – a meadow cut 3–4 times and fertilised with mineral nitrogen (200 kg N ha^{-1})

D – a pasture with mixed grazing – cattle and horses (mineral-organic fertilisation at the level of 120 kg N ha^{-1}).

This study presents the botanical composition of the sward (determined with the assistance of the botanical-gravimetric method), the yields of the experimental meadows and pasture, and the sward usability value – FVS (according to Filipek, 1973). The content of N-N0_3 and N-NH_4 in the soil profile (i.e. in the layers 0–10, 11–30, 31–60, and 61–90 cm) was determined using a FIAstar^{TM}5000 apparatus, FOOS Company, Sweden.

Results

The utilisation and fertilisation of meadows and pastures affects the degree of soil sodding through floristic composition (Table 1).

Table 1. Sward botanical composition of grasslands

Treatment	Meadow						Pasture	
	A		B		C		D	
	(%)	No. species	(%)	No. species	(%)	No. species	(%)	No. species
Grasses	57	11	78	8	69	9	86	8
Legumes	2	3	1	1	10	2	4	1
Other plant species	41	38	21	22	21	24	10	9

For example, in the case of the meadow which was not fertilised and utilised extensively (A), where only one cut was made, a low-yielding community was found to develop, dominated by *Holcus lanatus*. A total of 52 plant species was determined in the sward of this meadow, including 38 plants from the group of 'herbs and weeds' which became apparent in its low usefulness value – FVS = 3.9. On the other hand, the pasture (D) dominated by *Poa pratensis* and *Lolium perenne* utilised in a continuous system revealed the highest usefulness value (FVS = 8.5) with only 18 species of plants, of which 8 comprised grasses and white clover and the remaining 9 plants other dicotyledons. In the case of the meadows (C and D) whose swards were dominated by *Lolium perenne, Alopecurus pratensis, Poa pratensis,* and *Holcus lanatus*, which were fertilised with 150–200 kg N ha^{-1} and cut three times during the vegetation season, approximately 30 species of plants were identified, of which two thirds were species from the class of dicotyledons. Dry matter yields ranged from 3 to 10.5 t ha^{-1}, depending on the fertilisation and utilisation (Table 2).

Table 2. Cover index, yields and fodder value score (FVS) of grasslands

Treatment	Meadow			Pasture
	A	B	C	D
Cover index (%)	85	90	95	95
DM yield (t ha^{-1})	3.0	9.0	10.5	6.5
FVS*	3.9	6.3	7.5	8.0

*1 – low fodder value, 10 very good fodder value

On the basis of the chemical analyses performed, considerable variability was determined in the content of the available forms of nitrogen in the soils examined, depending on the intensity of their utilisation (Table 3). The lowest concentrations of the available forms of nitrogen, both in the autumn and spring, were determined in the case of the meadow which was fertilised with farmyard manure and slurry and utilised 4 times during the vegetation period (object B). It can be concluded that in this treatment nitrogen was utilised well by the plants and removed with the harvest which was estimated on the level of 10.5 t of dry matter per hectare. On the other hand, in the case of the meadow participating in the agricultural-environment programme and utilised extensively (object A) in organic soil conditions, a significant concentration of nitrogen in soil profiles was observed (on average 376 kg of nitrogen in nitrate and ammonia forms). It should be emphasised that the highest increase in the nitrogen concentration in soil profiles was found on the pasture in spring, which can be attributed to the process of mineralisation of

Table 3. Content of nitrogen available forms in the profiles of grasslands (kg ha^{-1})

Season	Nitrogen form	Soil layer (cm)	Meadow			Pasture
			A	B	C	D
Autumn	$N\text{-}NO_3$	0–10	14.3	12.5	7.4	8.9
		11–30	26.8	20.4	17.2	29.3
		31–60	44.7	14.7	8.8	19.7
		61–90	29.7	12.6	15.0	13.9
	$N\text{-}NH_4$	0–10	19.0	23.7	22.0	28.5
		11–30	86.7	55.8	75.5	54.9
		31–60	87.4	76.9	73.6	75.5
		61–90	97.8	53.3	42.4	71.3
	Total N_{min}	0–10	33.3	36.2	29.4	37.4
		11–30	113.5	76.2	92.7	84.2
		31–60	132.1	91.6	82.4	95.2
		61–90	127.5	65.9	57.4	85.2
Spring	$N\text{-}NO_3$	0–10	10.5	4.6	6.9	16.1
		11–30	31.1	14.3	15.5	31.7
		31–60	26.4	19.7	14.3	29.8
		61–90	22.8	12.0	20.6	65.7
	$N\text{-}NH_4$	0–10	25.4	32.4	18.7	32.5
		11–30	79.2	53.8	49.0	58.4
		31–60	96.3	108.0	50.7	74.5
		61–90	64.3	69.8	42.9	87.3
	Total N_{min}	0–10	35.8	36.9	25.6	48.6
		11–30	110.3	68.1	64.5	90.1
		31–60	122.8	127.7	65.0	104.3
		61–90	87.1	81.8	63.5	153.0

the organic nitrogen and the infiltration of the nitrogen of the excreta left by the grazing animals. The concentration of nitrogen in its nitrate and ammonia forms, irrespective of the time of sample collection, utilisation, and the type of fertilisers applied, was found to be lowest in the upper soil profile (to 10 cm). In all the soil profiles examined, considerably higher quantities of N-NH_4 than N-$N0_3$ were determined, which is explained by the much easier uptake by plants of nitrate forms, as well as their faster leaching.

Conclusions

Investigations of the content of nitrogen concentrations in soil, especially before the beginning of the vegetation of meadow plants, make it possible to manage the nitrogen fertiliser rationally and economically, depending on the level of the intensity of utilisation of meadows and pastures. This, in turn, contributes to the limiting of nitrogen losses and its infiltration to ground and surface waters.

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Effect of grazing intensity on the structure of sward patches

Ludvíková V.[1], Pavlů V.[2, 1], Hejcman M.[1] and Gaisler J.[2]

[1]*Czech University of Life Sciences Prague, Department of Ecology, Prague, Czech Republic*
[2]*Crop Research Institute, Prague, Grassland Research Station Liberec, Czech Republic*
E-mail: ludvikovavendula@fzp.czu.cz

Abstract

The aim of our study was to reveal how the intensity of cattle grazing affects the spatial heterogeneity and the plant species richness in an upland grassland. The study is a part of a long-term grazing experiment concerning intensive (IG) and extensive (EG) treatments established in 1998 in the Jizerské hory Mts. (Czech Republic). According to the sward height patches in IG and EG treatments were *a priori* categorised: (*i*) frequently grazed (INT); (*ii*) moderately grazed (MOD), and (*iii*) extensively grazed (EXT). The cover of plant species (%) and sward height (cm) were recorded at fixed points along permanent transects during the years 2006–2007. The mean frequency of the INT patches was more than 50% in the IG treatment, whereas in the EXT patches it only occurred up to 10%. On the contrary, the mean rate of INT patches in EG treatment was 7%, but the abundance of the MOD and EXT patches was similar and reached 45% and 49%, respectively. The effect of grazing intensity on the plant species richness of the sward was not statistically significant ($P = 0.067$). Redundancy analysis revealed that the interaction of the treatment and the patch category were found to be a significant predictor of sward structure. The structure of the EXT and MOD patches did not differ inside specific grazing intensity, whereas in the case of the INT patches it was similar, regardless of whether the grazing was intensive or extensive.

Keywords: heifer grazing, sward patches, sward height, spatial heterogeneity

Introduction

The selectivity of grazing causes changes in the spatial heterogeneity of sward structure and its diversity. The result is a heterogeneous sward structure with a mosaic of patches of different heights (Bakker *et al.,* 1983). Sward height is one of the most important predictors of species to intensive defoliation of regularly grazed species (Pavlů *et al.,* 2003). Plant structure, involving factors such as sward height or dead material, affects the diet preferences of herbivores (Dumont *et al.,* 2007). Short patches are preferred by cattle as they have a higher quality of biomass compared to non-grazed old patches (Dumont *et al.,* 2007). The established mosaic structure of a sward can remain stable for months (Cid and Brizuela, 1998). The objective of the paper is to evaluate the effect of cattle grazing of different intensities on the structure of patches on the basis of sward height.

Material and methods

The study site was performed on experimental grassland in the Jizerské hory Mountains, 10 km north of the city of Liberec, Czech Republic. The average total annual precipitation in the region is 803 mm and the mean annual temperature is 7.2°C. The altitude of the study site is 420 m above sea level. The following treatments were studied: extensive (EG) and intensive (IG) continuous heifer grazing. The plots were arranged as two completely randomised blocks (0.35 ha) in 1998. See Pavlů *et al.* (2007) for a detailed description of the experimental design.

The cover of vascular plants and sward height were collected in permanent transects (2 transects of 40 m per each plot) in both study treatments. Measurements were performed at forty fixed points along a line transect (regularly at a 1-m distance). The percentage cover of plant species was estimated in 100-cm^2 circles (diameter 11.2 cm). To measure a sward height at each point of the transect the compressed sward height method was used (Correl *et al.*, 2003). The study sward in the transects was *a priori* categorised according to the sward height: (*i*) intensively grazed patches (INT), height less than 5.0 cm; (*ii*) moderately grazed patches (MOD), height from 5.5 to 10.0 cm; (*iii*) extensively grazed patches (EXT), height more than 10.5. The data in both study treatments were collected at the beginning and at the end of the grazing seasons in the years 2006 and 2007. The species nomenclature is according to Kubát *et al.* (2002). The plant species distribution in different sward height categories was analysed by redundancy analysis (RDA) in the CANOCO package followed by a Monte Carlo permutation test. ANOVA was used to evaluate the species richness in patches and distribution patches, followed by a post hoc comparison Tukey HSD test.

Results and discussion

In the IG treatment INT patches predominated (47.2% and 51.9%), whilst EXT patches were relatively infrequent (15.0% and 6.2%) in the years 2006 and 2007, respectively (Figure 1a). On the other hand, the rate of INT patches in the EG treatment was only 5.3% and 7.8%, whereas the rates of the MOD (37.8% and 51.9%) and EXT (55.9% and 40.3%) patches were similar, with insignificant differences. The abundance of the patches created reflected the defoliation management applied and was in accordance with the study of Correl *et al.* (2003).

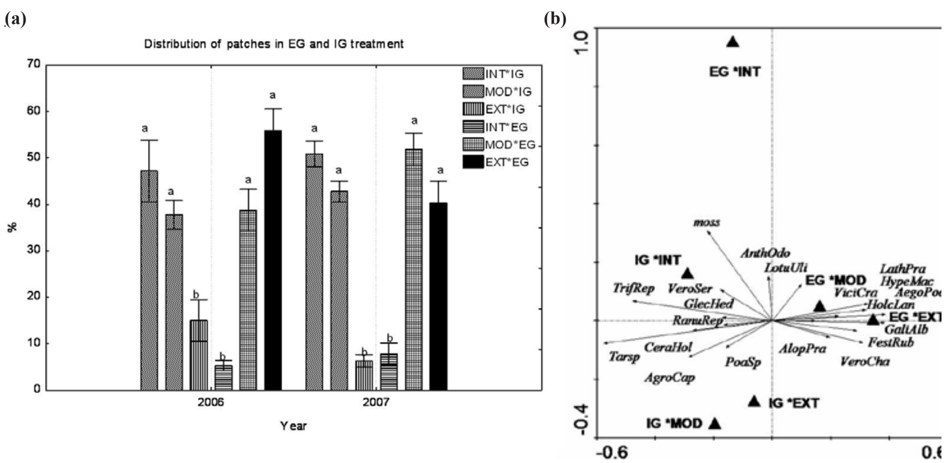

Figure 1. (a) Percentage distribution of patches. Error bars represent the standard error of the mean (SE). The treatments with the same letter were not significantly different ($P < 0.005$), Tukey HSD test; (b) Ordination diagram showing the result of RDA analysis. Species abbreviations indicate genus (4 letters) and species (3 letters) names

The abbreviations of the treatments and patch category interactions are given in Material and methods

During the course of the vegetation season the sward height declined and the rate of MOD and INT increased in both treatments.

The number of plant species was slightly higher under extensive grazing, but the effect of grazing intensity on species richness was not statistically significant (P = 0.067). According to the redundancy analysis the interaction of the treatment and patches category was found to be a significant predictor of sward structure and plant species distribution (Figure 1b). The first and all axes explained 9.4% (P = 0.001) and 12.0% (P = 0.001), respectively, of the total variation in species data. Tall forbs (*Aegopodium podagraria, Galium album, Hypericum maculatum*) and tall grasses (*Holcus lanatus, Alopecurus pratensis*) had a higher abundance in EG*EXT, similarly also in EG*MOD. The species associated with the patches IG*MOD and IG*EXT were short grasses (*Agrostis capilaris, Poa* sp.). Several prostrate species (*Taraxacum* sp., *Trifolium repens,* or *Ranunculus repens*) increased in cover more under intensive grazing by both the intensively defoliated patches IG*INT and IG*MOD. Mosses were promoted especially by EG*INT patches. The similarity of the plant species composition between EG*EXT and EG*MOD and also between the IG*MOD and IG*EXT treatments was revealed. It means that the MOD and EXT types of patches did not differ in particular grazing intensity. Only the INT patches were similar, in spite of the grazing intensity.

Conclusion

Applied different grazing intensities affected plant species composition (Pavlů *et al.,* 2007) and also patch abundance (Correl *et al.*, 2003). Preliminary results show that the structure of the EXT and MOD patches did not differ within specific grazing intensities, whereas the INT patches were similar, regardless of whether the grazing was intensive or extensive.

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Non-productive properties of selected grass varieties under mulching

Macháč R. and Cagaš B.

OSEVA PRO Ltd., Grassland Research Station, Rožnov-Zubří, Czech Republic
E-mail: machac@oseva.cz

Abstract

A large area of grassland in the Czech Republic is not used for grazing or fodder conservation. This grassland is often treated only by mulching, but relatively scant information about the behaviour of grass species and their varieties under this regime of treatment is known. The non-productive properties of selected grass varieties were verified in small-plot field trials (established 2004) at the Grassland Research Station at Zubří. In this trial 25 varieties of perennial ryegrass, 10 varieties of meadow fescue, 21 varieties of red fescue, 5 varieties of timothy, and 5 varieties of Kentucky bluegrass was tested. The sward stand, persistence, and diseases resistance of these grass varieties were evaluated under mulching conditions. The evaluation three years after the establishment did not show any significant differences among the varieties within one grass species. The occurrence of moulds and saprophytic fungi on the sward was minimal with respect to the weather pattern. There was no significant difference between the varieties, or rather grass species.

Keywords: mulching, sward stand, density, grass varieties

Introduction

In the Czech Republic, grassland occupies more than 970,000 ha of agricultural land. However, regarding the high degree of arable land it is desirable to raise the grassland area to 1.5 million ha. The reduction of the cattle population in the last twenty years means that only 745,000 ha is needed for forage production (Kvapilík, 2003). For other grasslands it is necessary to find an alternative use. Many studies have been conducted into the use of grass for energy. Unfortunately, it is impossible to assume that all the redundant grass biomass will be used for biogas production or combustion (because of a lack of manufacturing capacity and high transport costs from far-off sites). Therefore, part of the grasslands will be mulched to prevent the spread of weeds or alien species. The aim of our study was to compare the sward stand, density, level of weed infestation, and occurrence of diseases on mulched sward of selected grass varieties.

Material and methods

The experiment was carried out in Zubří, located in the north-eastern part of the Czech Republic. The altitude of the trial site is 356 m a.s.l. and the average temperature is 7.5°C, the precipitation is 886 mm, and the soil type is Cambisol. The plot trial, with 25 varieties of perennial ryegrass (*Lolium perenne* L.), 10 varieties of meadow fescue (*Festuca pratensis* Huds.), 21 varieties of red fescue (*Festuca rubra* L.), 5 varieties of timothy (*Phleum pratense* L.), and 5 varieties of Kentucky bluegrass (*Poa pratensis* L.) was established in May 2004. The plot size was 7.5 m^2 and each grass species was arranged in 3 randomised blocks. No fertilisers or pesticides were applied. The trial plots were mulched three times: June, in mid-August, and at the end of October. The following characteristics were recorded: sward stand (9 best–1 worst), density (% projective dominancy), weed infestation (%), and occurrence of diseases. The health of the grass varieties was tested predominantly by long-term snow cover in the 1st year and subsequent natural infection with *Typhula incarnata*. The statistical analysis was carried out with Statistica 8.0.

Table 1. Properties of perennial ryegrass and fescue varieties

Variety (2*n*)	Sward stand (9–1)	Density (%)	Weed infestation (%)	Variety (4*n*)	Sward stand (9–1)	Density (%)	Weed infestation (%)
Ryegrass varieties							
Aberdart	8.4	94	9.8	Alligator	8.4	91	13.8
Aberelan	8.7	92	9.3	Baristra	7.6	91	9.7
Ahoj	9.0	90	9.3	Jantar	8.9	94	11.5
Algol	8.6	93	11.2	Jaspis	8.3	92	10.3
Bača	8.4	93	9.5	Kentaur	8.7	92	10.7
Bravo	8.8	91	12.0	Kertak	8.0	92	10.3
Mara	7.7	93	9.8	Lonar	8.7	93	11.5
Olaf	8.7	93	11.0	Mustang	8.1	92	10.0
Option	8.3	93	12.2	Sirius	8.8	92	11.5
Premium	8.3	94	10.7	Tarpan	8.9	93	10.8
Recolta	8.2	91	10.5	SD (P = 0.05)	*1.7*	*5.7*	*7.5*
Respect	8.6	93	10.2				
Sponsor	8.7	93	11.0	2*n*	8.4	93.6	8.7
Sport	8.2	95	12.0	4*n*	8.3	94.0	8.8
Talon	7.9	93	12.8	*P*	0.57	0.39	0.84
Fescue varieties							
Barborka	8.0	88	9.7	Barustic	8.0	90	8.3
Baroyal	7.7	88	8.0	Camilla	7.3	88	6.7
Barpusta	7.7	88	8.3	Corail	8.7	88	6.0
Citera	8.3	88	5.7	Echo	7.7	92	8.3
Ferota	8.3	92	9.7	Florentine	9.0	90	7.7
Lifine	7.7	90	10.7	Licoletta	7.7	88	8.7
Makyta	8.3	88	8.3	Tagera	7.3	90	8.0
Rosana	8.3	85	5.7	*SD* (P = 0.05)	*1.8*	*8.6*	*4.7*
Suzett	8.7	87	8.0				
Táborská	8.0	88	11.7	6*n*	8.0	89.3	8.6
Tradice	8.0	92	7.7	8*n*	7.9	88.6	7.2
Valaška	7.3	90	9.3	*P*	*0.91*	*0.41*	*0.03*
Veverka	7.3	90	7.0				
Viktorka	8.0	88	7.7				

Results and discussion

The results presented are from the evaluation in October 2007 (three years after the establishment, mulched 8 times). The best results were achieved with the perennial ryegrass varieties Ahoj, Tarpan, and Aberdart, and conversely the worst results were shown by Talon, Baristra, and Option. No significant differences were observed between the diploid and tetraploid varieties (Table 1). The varieties most attacked by *Typhula incarnata* were Bravo, Premium, and Respect (data not shown).

Within the red fescue varieties, the best sward stand values were shown by varieties Florentine, the best density by varieties Ferota, Tradice, and Echo. The best competitive ability against weed infestation was observed in varieties Citera, Rosana, and Corail. Significant differences were recorded between the hexaploid and octoploid red fescue varieties only as regarded weed infestation. Compared with the other grass species, the mulched biomass of red fescue was the slowest to decompose.

The best results among the meadow fescue varieties were shown by varieties Otava, Pronela, and Lipanther. The worst sward stand and competitive ability against weeds was recorded for variety Stella (see Table 2). However, no differences were significant ($P = 0.05$).

Table 2. Properties of meadow fescue

Variety	Sward stand (9–1)	Density (%)	Weed infestation (%)	Variety	Sward stand (9–1)	Density (%)	Weed infestation (%)
Rožnovská	7.1	92	12.7	Limosa	6.7	88	12.0
Otava	7.6	92	11.0	Lipanther	8.1	90	11.7
Pronela	7.6	88	8.3	Preval	7.4	92	9.2
Bartran	7.8	88	11.8	Stella	6.3	88	14.0
Pradel	6.7	88	11.8	Premil	6.9	90	11.5
				SD ($P = 0.05$)	3.0	10.3	5.9

Similar values were observed for the timothy varieties; the weakest records were for the oldest variety among the assortment tested, Vetrovsky. Among the Kentucky bluegrass varieties Lato showed the best results; the other varieties were slightly worse. Generally,

Table 3. Properties of timothy and Kentucky bluegrass varieties

Variety	Sward stand (9–1)	Density (%)	Weed infestation (%)	Variety	Sward stand (9–1)	Density (%)	Weed infestation (%)
Phleum pratense				*Poa pratensis*			
Sobol	7.3	91	12.2	Slezanka	6.3	76	13.7
Větrovský	7.0	93	12.2	Balin	6.6	78	15.5
Bobr	7.7	93	14.2	Moravanka	6.3	74	14.8
Lirocco	7.3	94	11.0	Delft	6.6	75	14.7
Licora	7.2	93	12.8	Lato	6.9	76	15.8
SD ($P = 0.05$)	2.6	8.5	7.5	SD ($P = 0.05$)	2.0	21.5	8.9

Kentucky bluegrass has the worst response to mulching ($P < 0.01$), evidently in consequence of its very slow initial development and poor competitive ability.
Additionally, no significant differences among the grass varieties and species were observed regarding the attack of saprophytic fungi or moulds on mulched biomass (data not shown).

Conclusion

The study showed that it is possible to use each grass variety tested for the establishment of sward for non-productive use (set-aside), treated by mulching. The evaluation of the sward stand, density, level of weed infestation, and occurrence of diseases do not show any significant difference among the grass varieties tested. Perennial ryegrass showed significantly better results than the other grasses.

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Research regarding establishment of the sown grassland for the anti-erosion protection of a thermal power station ash dump

Marusca T.[1], Mocanu V.[1], Hermenean I.[1], Blaj V.A.[1], Filip M.[1] and Marusca S.[2]

[1]*Grassland Research Institute, Brasov, Romania*
[2]*Renaturopa Association, Brasov, Romania*
E-mail: maruscat@yohoo.com

Abstract

Taking into account the conditions near the city of Brasov, some different types of seed mixtures of perennial grasses + cereals + *Amaranthus* sp. + fertilisers for the establishment of grassland on a coal ash and cinder dump covered with eutrophic peat were studied. The use of a mixture with cereal grains and, especially, *Amaranthus* sp. 1–2 kg ha^{-1} consolidates the pulverised sub-layer of the deposit much faster and also protects the young grass plants against heavy sunburn and hydro stress. By the establishment of some reseeded grasslands, which have a protection role, in the seed mixture to which a percentage of 10% *Phalaris arundinacea* was added, the result proved that this species reaches a participation percentage up to 85–98%, or better in a north facing slope area, after a 6-year period. The paper also contains numerous data regarding the establishment and the role of sown grasslands as an alternative for protecting an ash and cinder dump.

Keywords: sown grassland, ash dump, eutrophic peat, grass mixture, chemical fertilisation

Introduction

The establishment of sward is one of the principal methods used for the erosion protection of deposits, without regard to their provenance. Ash dumps have different physical-chemical properties, being in a pulverulent form, easily transported by wind and water action. They have an alkaline reaction, and are poor in nutritive elements, excepting potassium. Therefore a layer of 10–20 cm, preferably consisting of fertile soil or other materials (peaty soil, loess, compost, etc.) is used before sward establishment. The sown grasses must firstly have an eco-protective value and only secondarily an economic function. In addition to perennial grasses and herbage legumes, the composition of the seed mixture involves the utilisation of some annual species, such as cereals and *Amaranthus* sp., which can rapidly consolidate the soil and ensure the good protection of young grass plants against sunburn and during the drought period. The extra quantities of nutritive elements are involved by the utilisation in the composition of a mixture of species that biologically fix nitrogen, such as the herbage legume (*Fabaceae*) family and others. For the establishment of sown grasslands there is no research for determining the composition of the grass composition, the necessary seed rate, and the fertilisation level, suitable for ash deposits covered with eutrophic peat. These aspects are presented in this paper.

Materials and methods

The preliminary research was carried out on the establishment of sward on an ash deposit located on eutrophic peat from the village of Sanpetru, near the Brasov, thermal-

electrical station (Marusca *et al*., 2000, 2002). The stationary area conditions consist of an in intermountainous valley, at an altitude 600 m a.s.l., with holm-oak (*Quercus petraea*) forest, an annual average temperature of 7.8°C, and an annual average rainfall of 750 mm. The hydraulically transported ash was put in a deposit and covered with a 15–20 cm eutrophic peat layer, with acceptable agrochemical properties. The ash pH was alkaline (pH 8.3), with a low content of phosphorus and organic matter, and was very rich in potassium (over 400 ppm). The eutrophic peat was low alkaline (pH 7.5), very rich in organic matter (> 50%) and poor in available nutritive elements (P and K).
The treatments in three replications, located in two fields, with north and south locations and a 30° slope, were the following:

A. NPK fertilisation level	B. Seeding rate
1. Control (no fertilising)	1. Control (no seeding)
2. N 75 P 75 K 75 kg ha^{-1} (P = P_2O_5; K = K_2O)	2. 125 kg ha^{-1} (75 kg grasses + 50 kg cereals)
3. N 150 P 150 K 150 kg ha^{-1}	3. 250 kg ha^{-1} (150 kg grasses + 100 kg cereals)

A complex grass mixture was used, comprising 7 perennial grasses (70 %) and 6 herbage legumes (30%), presented in Table 2, to which *Amaranthus* sp.1 kg ha^{-1} was added for the B_2 variant, 2 kg ha^{-1} for B_3 and 50 or 100 kg ha^{-1} cereals (40% oat, 30% two-row-barley, and 30% rye).
The sowing and fertilisation were performed in April, 2002. The botanical observations were carried out in the first, second, and sixth vegetation years. The soil samples and biomass (stems and roots) were harvested in the autumn of 2008, after 6 vegetation years.

Results and discussion

The establishment of sown grassland was more difficult in the south location, in the first year. The influence of the fertilisation level and seeding rate are presented in Table 1.

Table 1. The influence of fertilisation and sowing on vegetation establishment, southern location, first year 2002 (in %)

Factor		Covering level	Grasses	Legumes	Other fam.	*Amaranthus* sp.	Cereals
Fertilisation rate (kg N ha^{-1})	0	73	15	37	36	8	4
	75	93	7	8	34	51	+
	150	96	9	4	34	53	+
Sowing rate (kg ha^{-1})	0	65	8	1	91	-	-
	75	97	12	24	8	55	1
	150	100	11	24	6	57	2
Mean (%)		87	10	16	35	37	2

The covering level of the south embankments was 65% for alternative B_1 (no sowing) and 73% for alternative A_1 (no fertilisation) and almost completely covered with vegetation only for sown variants (B_2 and B_3). With the sown variant, 125 kg ha^{-1} achieved a 99% covering level, consisting of 48% *Amaranthus* sp., 22% forage legumes, 19% grasses, 1% cereals and other species from spontaneous flora, this being the cheapest solution.

Table 2. Botanical composition of vegetation in the southerly location, in the second year 2003 (in %)

Species	Sown 2002	N 0		N 75		N 150	
		11*	13**	21*	23**	31*	33**
Covering level	–	65	100	97	100	95	100
Grasses	(70)	(52)	(23)	(42)	(43)	(70)	(64)
Agropyron intermedium	10	–	+	–	+	–	+
Agrostis stolonifera	10	–	+	–	1	–	+
Bromus inermis	10	–	3	–	5	–	8
Dactylis glomerata	10	–	1	–	4	–	7
Festuca pratensis	10	–	1	–	5	–	5
Phalaris arundinacea	10	–	18	–	25	–	42
Phleum pratense	10	–	+	–	2	–	2
Agropyron repens	•	27	+	9	+	35	+
Agrostis capillaris	•	13	+	20	1	22	+
Festuca rubra	•	12	+	13	+	13	+
Legumes	(30)	(1)	(73)	(+)	(55)	(+)	(35)
Lotus corniculatus	5	–	10	–	12	–	2
Medicago sativa	5	–	17	–	9	–	5
Melilotus albus	5	–	40	–	25	–	23
Onobrychis viciifolia	5	–	8	–	9	–	4
Trifolium pratense	5	–	+	–	+	–	1
Trifolium repens	5	+	+	+	+	–	–
Trifolium hybridum	•	1	+	+	+	+	–
Other families	•	(47)	(4)	(58)	(2)	(30)	(1)
Carduus acanthoides	•	23	–	13	–	18	+
Daucus carota	•	+	–	+	–	+	–
Mentha longifolia	•	7	2	15	1	6	+
Potentilla anserina	•	17	1	28	1	6	1
Other species	•	+	1	2	+	+	+

*11, 21, 31 – no sowing; **13, 23, 33 sowing with 150 kg ha^{-1}

In the northern location, the success rate of establishment of sown species establishment is superior by 12%, thanks to better humidity conditions.

In the second year, regarding the botanical composition of fertilised (A_1 and A_2) and reseeded variants (B_3) the sward is full of herbage legumes, followed by perennial grasses (Table 2).

After 6 years of vegetation the *Phalaris arundinacea* species has become dominant, reaching 85% in the southerly location and 98% in the northerly location.

The biomass of the reseeded grassland was 30.8 t ha^{-1} DM, of which 9.6 t was above ground and 21.2 t ha^{-1} was underground. At a depth of 0–30 cm the agrochemical parameters are modified, especially the reduction of pH at 7.9, the mineralisation of organic matter, and increase in the $CaCO_3$ content (33.4%) on the surface, and smaller quantities of P and K quantities, necessitating proceeding with fertilisation.

Conclusion

For establishing the sward on ash deposits covered with eutrophic peat, 75 kg ha^{-1} N fertilisation and the same quantity of P_2O_5 and K_2O was sufficient, in addition to a suitable perennial grass and herbage legume mixture from which *Phalaris arundinacea* (10%) and *Amaranthus* sp. cultivars 1 kg ha^{-1} should not be missing, which proved the assured establishment of one anti-erosion sward, rapidly and for a long period.

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Xerothermic grasslands as a source of biodiversity in the agricultural landscape

Misztal A. and Zarzycki J.

Agricultural University of Cracow, Ecological Bases of Environmental Engineering, Cracow, Poland
E-mail: rmmiszta@cyf-kr.edu.pl

Abstract

Xerothermic grasslands are stenothermal grass communities of a steppe character, the occurrence of which is conditioned by climatic, soil, and orographic conditions. In the xerothermic grasslands of the Małopolska Upland one can distinguish four plant associations: *Sisymbrio-Stipetum capillatae, Thalictrio-Salvietum pratensis, Inuletum ensifoliae* and *Adonido-Brachypodietum pinnati*. The economic significance of xerothermic grasslands is small, but their impact on the environment is profitable and heterogeneous. They enrich biodiversity, and support protected, rare, endangered and medicinal plants in the sward. They are a unique refuge for many plant and animal species, and increase the landscape's aesthetics.

Keywords: xerothermic grasslands, habitat conditions, biodiversity

Introduction

Xerothermic grasslands are created, primarily, by steppe plants which first appeared on the territory of our country in the post-glacial periods. The migrations of steppe plants took place through two principal routes: via the Podolski route, plants mainly from Podole and Bessarabia, and via the Moravian route, xerothermic plants from the Hungarian plain migrated to us through the Moravian gate and Moravia. Via the third, Brandenburg-Pomeranian, route (through the basin of the middle Elbe River), xerothermic plants reached the lower valley of the River Oder and Lower Silesia mainly from Thuringia (Kostuch, 2006). These plants, on the whole, occupy small areas, mainly on hillsides exposed to the sun's rays and slopes with a southern exposure. The focus of this paper is the geobotanical characteristics of xerothermic plant communities distributed in the Małopolska Upland, with particular consideration given to biodiversity and rule assessment in the environment.

Materials and methods

Research on xerothermic grasslands was conducted in the Małopolska Upland, which occupies an area stretching between the Pilica and Vistula valleys. This is a strongly undulating terrain with a relatively dense hydrographical network. The average elevation a.s.l. amounts to 350 m, with a height deference reaching 170 m. Xerothermic plants have developed on sites where bedrock appears on the surface and is covered by a thin layer of loess soil. In the period 2004–2006, after xerothermic plant communities had been located, all the vascular plants within the communities were registered by applying the Braun-Blanquet method. The communities were also classified in their respective plant associations.

Results and discussion

In the phytosociological respect, the xerothermic grasslands of Poland belong to the *Festuco-Brometea* class, comprising two orders: *Brometalia erecti* and *Festucetalia valesiacae*. In the xerothermic grasslands that were studied, on the terrain of the Małopolska Upland, four plant communities were identified. On gypsum rock covered by a thin layer of loess soil, one can encounter the *Sisymbrio-Stipetum capillatae* association with the following characteristic species: *Stipa capillata* and *Stipa joannis, Festuca valesiaca*, *Poa bulbosa* var. *vivipara*, *Sisymbrium polymorphum*, *Veronica praecox*, *Carex supina*, *Oxytropis pillosa*, *Achillea setacea*, *Hieracium echioides*, *Arabis recta*, and *Alyssum montanum*. The second one is the *Thalictro-Salvietum pratensis*, an association which develops on a gypsum substratum covered by a slightly thicker loess layer. The characteristic species of this association are: *Elymus hispidus*, *Eryngium campestre*, *Campanula bononiensis*, *Carex praecox*, *Ranunculus illiricus*, *Salvia pratensis*, *Thalictrum minus*, *Adonis vernalis*, *Scabiosa ochroleuca*, and *Falcaria vulgaris*. In the Małopolska Upland, the *Inuletum ensifoliae* association is frequently encountered. It occurs on southern cliffs, created from Senonian marls on cretaceous rendzina, usually with a thin soil cover which contains a lot of rock skeleton. The characteristic species of the association are: *Inula ensifolia*, *Cirsium pannonicum*, *Linum flaum*, *Linum hirsutum*, *Aster amellus*, *Festuca rupicola*, and *Carex humilis*. Species which also occur frequently in the association under discussion are: *Anemone sylvestris*, *Peucedanum cervaria*, *Geranium sanguineum*, and *Carlina onopordifilia*. The fourth association appearing commonly in the Małopolska Upland is *Adonido-Brachypodieto pinnati*. They are luxuriant grass-flowery grasslands which occur on deeper loamy clay, relatively humus, brown soils similar to black earth. The characteristic species of this association are primarily: *Adonis vernalis* and *Brachypodium pinnatum*, as well as *Campanula sibirica*, *Mylampyrum arvense*, *Scorzonera purpurea*, *Gentiana cruciata*, *Seseli annuum, Orchis* sp., and *Filipendula vulgaris*.

The sward of xerothermic plants does not yield great economic profits, because of the considerably scattered small areas which they occupy, and the fact that they are generally situated in difficult terrain. Despite this, the xerothermic grasslands which appear in Poland are highly valued. Thanks to the presence in them of plant species originating in the steppe areas of Europe, they increase the biodiversity of the agro-ecological systems in which they usually occur. Many of them are listed in the Annex I Council Directive 92/43/EWG as natural and semi-natural variants of dry grasslands and shrubs on calcareous subsoil. Their sward usually consists of dozens of vascular plant species. It has been shown that in the xerothermic plant communities of the Małopolska Upland there are over 200 species of vascular plants from many botanical families. In relation to the usually small area occupied by xerothermic plants, one can affirm that the biodiversity of the habitats being discussed is very high. This is also confirmed by the research of Trąba (2007), who states that the xerothermic flora of the Lublin region, including xerothermic shrubs, number about 500 species of vascular plants. A similar species abundance in xerothermic habitats was also found by Urban (2006) in the Ciemięgi Valley near Lublin. Xerothermic grasslands include in their composition many species which are legally protected or rare or of which the existence is threatened. A very significant feature of xerothermic grasslands is their landscape value.

Table 1. Occurrence of legally protected, rare and threatened species in xerothermic grasslands associations in the Małopolska Upland

Species	Species status	Association			
		Sisymbrio-Stipetum capillatae	*Thalictrio-Salvietum pratensis*	*Inuletum ensifoliae*	*Adonido-Brachy-podietum pinnati*
Adonis vernalis L.	*	+	+	+	+
Anemone sylvestris L.	*	+	+	+	+
Aster amellus L.	*			+	
Aquilegia vulgaris L.	*	+		+	+
Campanula bononiensis L.	*	+	+	+	+
Campanula sibirica L.	*			+	+
Carex supina Wahlenb.	*, VU	+	+		+
Carlina acaulis L.	*	+	+	+	+
Carlina onopordifolia Besser	*, VU		+	+	+
Cephalanthera damasonium (Mill.) Druce	*			+	+
Chamaecytisus ratisbonensis Schaeff.	*			+	+
Cirsiun pannonicum (L. f.) Link	*		+	+	+
Cypripedium calceolus L.	*			+	+
Dactylorhiza maculata (L.) Soó	*		+	+	+
Epipactis atrorubens (Hoffm.) Besser	*			+	+
Epipactis helleborine (L.) Crantz	*			+	+
Linum hirsutum L.	*, VU		+	+	+
Linum flavum L.	*		+	+	+
Ophrys insectifera L.	*	+		+	+
Orchis mascula ssp. *signifera* (Vest) Soó	*			+	+
Orchis militaris L.	*			+	+
Orchis pallens L.	*, VU		+	+	+
Orchis ustulata L.	*, EN			+	+
Oxytropis pilosa (L.) DC.	*	+	+	+	+
Platanthera bifolia (L.) Rich.	*			+	
Prunus fruticosa Pall.	*, VE		+	+	+
Pulsatilla pratensis (L.) Mill.	*		+	+	+
Scorzonera purpura L.	*		+	+	+
Sisymbrium polymorphum (Murray) Roth	EN	+		+	+
Stipa capillata L.	*	+		+	+
Stipa joannis Čelak. s. s.	*, VE	+		+	+
Veronica praecox All.	CR	+	+	+	
Total number of species		61	89	128	123

*legally protected, CR – critically endangered, EN – endangered, VU – vulnerable

Conclusions

1. In the xerothermic grasslands of the Małopolska Upland one can distinguish four plant associations: *Sisymbrio-Stipetum capillatae*, *Thalictrio-Salvietum pratensis*, *Inuletum ensifoliae* and *Adonido-Brachypodietum pinnati*, the occurrence of which is, to a large degree, decided by the soil substratum and its thickness.
2. The environmental significance of xerothermic grasslands derives from their enrichment of biodiversity, their survival in the sward, and the presence of protected, rare, threatened, and medicinal plants. They are unique refuges for many plant and animal species, and also add an element of landscape aesthetics.

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The effect of shade on a silvopastoral system with *Populus* × *euroamericana* in Galicia, NW Spain

Morán-Zuloaga D., Mosquera-Losada M.R. and Rigueiro-Rodríguez A.

Universidad de Santiago de Compostela, Escuela Politécnica Superior, Lugo, Spain
E-mail: anriro@lugo.usc.es

Abstract

The evolution of pasture production and tree growth will determine the adequate evolution of the stocking rate in a recently established silvopastoral system. This study aims to evaluate the effect of lime and sewage sludge doses on soil pH, tree growth (diameter at breast height DBH and height) and pasture production in different positions (beneath and beyond the tree and N, W, E, and S) after six years of the experiment. Soil pH, tree height, and DBH were improved when no lime and a high dose of sewage sludge were applied, which limited pasture production. The same effect on soil and tree variables was found in the lime and intermediate sewage sludge dose treatments, but in this case this improvement increased pasture production and may have been due to the greater effect of the sun on ecological variables (temperature and humidity), which allowed the incorporation of the remains of the leaves of the tree and pasture into the soil. The position of the pasture affected the effect of the treatments on pasture production, being more important in northern and western positions, where the effect of the sun on temperature and humidity is more important.

Keywords: poplar, pasture production, tree position, liming, sewage sludge

Introduction

Silvopastoral systems are a sustainable way of land management, thanks to the multiple outputs that proportionate (wood and pasture) in the Atlantic Spanish biogeographic region. The study of the evolution of tree development and the effect on pasture production response to fertilisers (a cheaper way to increase pasture production in a predictable way) is of high importance in proportionate guidelines to the farmer about the appropriate evolution of the stocking rate in this system. *Populus* × *euroamericana* ((Dode) Guinier) is a fast-growing species which modifies the understorey environment faster than other tree species. On the other hand, fertilisation with sewage sludge is promoted by the European Union in order to reduce the impact of the high level of sewage sludge production as a result of the implementation of the European Regulation to reduce continental water contamination. This research aims to understand the effects caused by liming and sewage sludge and tree development on the pasture production of a silvopastoral system in Galicia six years after its establishment.

Material and methods

The experiment design was a split plot, with the main plot treatments being liming (application of a dose of 2.5 Mg ha^{-1} before the sowing of the pasture) and a lack of liming and three sewage sludge doses to sub-plots, which means the application of 0, 200, and

400 kg of total N ha^{-1} at the start of 2002 and 2003. No fertilisation was applied from 2004 to 2007 in order to evaluate the residual effect of the treatments. Soil samples were taken at a depth of 25 cm in January 2007, conducted to the laboratory, air-dried, sieved (2 mm), and ground in order to analyse the soil water pH (2.5:1). The tree height and DBH (diameter at breast height) were measured in the winter of 2007. Every year four pasture samples (0.09 m^2) per experimental unit were taken in the spring (May or June) and autumn before sheep grazing at a very high stocking rate (80 sheep ha^{-1}) for a period of two or three days. From 2005 to 2007 and as a result of the development of the tree canopy, eight samples were taken beneath (four) and beyond (four) the tree following the four orientations (N, S, W, and E) before the sheep grazing. In this paper, the tree and pasture results of the year 2007 are shown. ANOVA was performed to analyse the different variables and the Duncan test to distinguish means.

Results and discussion

Water pH, tree height and DBH were significantly affected by the interaction of the lime*doses (Table 1). The water pH interactions show that the effect of the sewage sludge treatment depended on the previous lime treatment (Figure 1). When lime had been applied a high dose of sewage sludge significantly reduced the pH, but no differences were found between the sewage sludge plots when no lime was applied, the pH of the high-dose no-lime treatment being significantly higher than that of the high-dose lime treatment.

Table 1. ANOVA results for water pH, tree height and DBH in 2007

	Model	Lime	Dose	Lime*dose
Water pH	*	ns	ns	*
Height	**	ns	*	**
DBH	***	ns	**	**

ns – not significant; *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$

Poplar growth in the experiment was low compared with the studies described by Harvey (1985) and González-Antoñanzas (1986), which found that seven-year-old poplars have a height of 14.3 m and a DBH of 0.2 m in poor soil conditions but with a higher soil pH

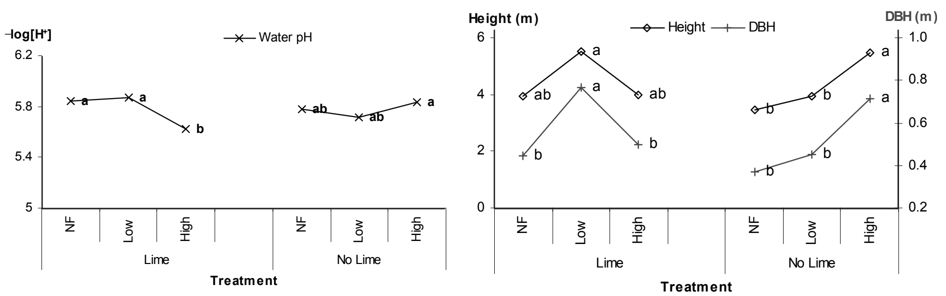

Figure 1. Soil water pH and tree height and DBH of *P. × euroamericana* in each treatment in 2007. Lime (2.5 Mg $CaCO_3$ ha^{-1}); no lime (0 Mg $CaCO_3$ ha^{-1}); NF (0 kg total N ha^{-1}); low (200 kg total N ha^{-1}) and high (400 kg total N ha^{-1}). Means with the same letter do not differ significantly ($P < 0.05$)

than in our experiment, which probably limited the tree growth (Rigueiro-Rodríguez *et al*., 2008). There was a clear positive effect of fertilisation on the heights of the poplars (3.4–5.5 m) and their DBH (0.4–0.7 m), with positive increments when low and high doses of sewage sludge and no lime were applied. However, no differences were found when lime was applied if different sewage sludge treatments were used as fertiliser.
The lime*dose interaction significantly affected pasture production in all the different positions (beneath and beyond the tree and in N, W, E, and S positions) at a $P < 0.5$ level in 2007. Pasture production varied from 4.3 to 9.7 Mg ha^{-1} and from 4.2 to 7.0 Mg ha^{-1} (Figure 2) beneath and beyond the tree position, respectively.

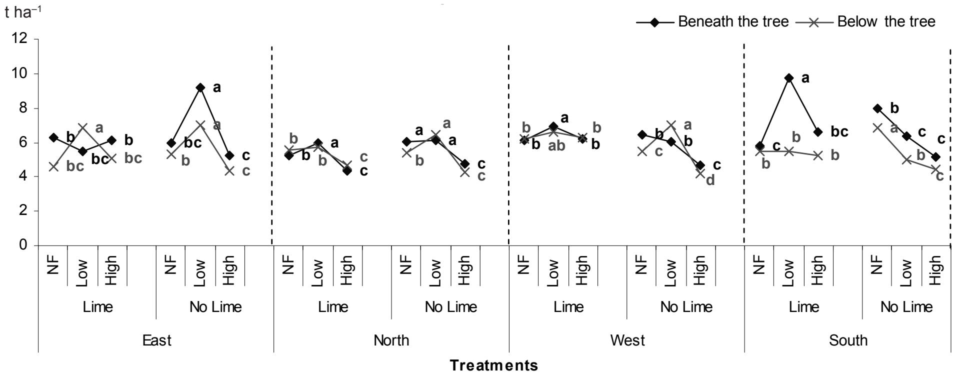

Figure 2. Pasture production in the different orientations (East, North, West, South) for beneath (-♦-) and (-×-) for below the tree in 2007. Lime: 2.5 Mg $CaCO_3$ ha^{-1}; no lime: 0 Mg $CaCO_3$ ha^{-1}; NF: 0 kg total N ha^{-1}; low: 200 kg total N ha^{-1} and high: 400 kg total N ha^{-1}. Means with the same letter do not differ significantly between beneath and below the tree ($P < 0.05$)

Pasture production was negatively affected when no lime and a high dose of sewage sludge were applied, probably because of this combination producing the best tree development, which limited pasture production. However, when lime was applied slightly higher production is usually found in the intermediate sludge doses, when tree growth reached better values and being specially important beneath the tree in the southern position and beyond the tree in the eastern position, which are the positions with higher temperatures through the day, which could speed up the decomposition of poplar leaves and senescent material, helped by the higher pH and therefore the residual response of pasture production.
Pasture production did not differ beneath or beyond the trees in the northern and western positions; however, this variable differs as a result of fertilisation treatments in the southern and eastern positions. In the northern and western positions, where the effect of the sun on water evaporation or temperature is lower, it can be found that pasture production was generally significantly lower when a higher sewage sludge dose was applied and particularly when no lime was used at the start of the experiment.

Conclusions

Soil pH, tree height, and DBH were improved when no lime and a high dose of sewage sludge were applied, which limited pasture production. The same effect on soil and tree variables was found in the lime and intermediate sewage sludge dose treatments, but in this case this improvement increased pasture production, possibly because of the greater effect of the sun on ecological variables (temperature and humidity), which allowed the incorporation of the remains of the leaves of the tree and pasture into the soil. The position of the pasture affected the pasture production response to the treatments, being more important in the southern and western positions, where the effect of the sun on temperature and humidity is more important.

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Fertiliser type effect on copper cycling in a *Fraxinus excelsior* L. silvopastoral system

Mosquera-Losada M.R., Ferreiro-Domínguez N., Rigueiro-Rodríguez A. and Fernández-Núñez E.

University of Santiago de Compostela, High Polytechnic School, Crop Production Department, Lugo, Spain
E-mail: romos@lugo.usc.es

Abstract

The use of sewage sludge on grasslands is an adequate and suitable way to improve pasture production and to recycle the nutrients of this residue. The municipal sewage sludge of big cities usually produces anaerobically digested sludge, because this process is faster in time compared with aerobic plants. However, anaerobic sewage sludge has a high water content (around 25%), which makes the use of this residue as fertiliser expensive if the distance between the plant and the pastureland is high. In order to avoid this, other processes, such as drying and composting, are usually carried out, and these can modify the characteristics of fertiliser sludge. The aim of this study was to evaluate the fertiliser effect of different types of sewage sludge: anaerobically digested, composting, and thermically dried, as well as inorganic fertilisation, on copper cycling in a silvopastoral system established under *Fraxinus excelsior* L. and a sown sward with *Dactylis glomerata* L. var. Artabro (12.5 kg ha^{-1}), *Lolium perenne* L. var. Brigantia (12.5 kg ha^{-1}) and *Trifolium repens* L. var. Huia (4 kg ha^{-1}) in Galicia (Spain). The results showed that fertilisation with composted sludge increased the amount of copper in soil and grass in comparison with the other sludge types.

Keywords: inorganic fertiliser, anaerobic digestion, composting and pelletisation

Introduction

Fertilisation is a way to increase pasture production in silvopastoral systems. Fertiliser can be applied in organic or inorganic form. The use of sewage sludge as fertiliser is promoted by European Union regulations (Commission of European Community, 1986) in order to improve soil chemical and physical fertility, while it also allows waste recycling (Navarro-Pedreño *et al.*, 1995). When sewage sludge is used as fertiliser the nitrogen concentration and the rate of mineralisation of the sludge should be taken into account, and these depend on the treatment of the sludge (EPA, 1994). The use of compost and anaerobically digested sludge are the form of sewage sludge stabilisation most promoted by the EU in order to use this waste as fertiliser. Pelletisation consists of the thermic drying of sewage sludge, which reduces storage, transport and spreading costs compared with anaerobic or composted sludge, thanks to their lower water concentration (around 2%), which makes it more profitable than the others as fertiliser.
The objective of this study was to evaluate the effect of inorganic fertiliser and municipal sewage sludge stabilised by anaerobic digestion, composting, and pelletisation on copper cycling in a silvopastoral system established under *Fraxinus excelsior* L.

Materials and methods

The experiment was conducted in an area of abandoned agricultural land in A Pastoriza (Lugo, Galicia, NW Spain) at an altitude of 550 m above sea level. The pasture was sown with a mixture of *Dactylis glomerata* L. var. Artabro (12.5 kg ha^{-1}), *Lolium perenne* L. var. Brigantia (12.5 kg ha^{-1}) and *Trifolium repens* L. var. Huia (4 kg ha^{-1}) in autumn 2004, being naked root plants of *Fraxinus excelsior* L. planted at a density of 952 trees ha^{-1}.
The experimental design was a randomised block with three replicas and five treatments in experimental units of 168 m^2 with 25 trees distributed in a frame of 5 × 5. Treatments consisted of (a) no fertilisation (NF); (b) mineral fertilisation (MIN) with 500 kg ha^{-1} of 8:24:16 at the beginning of the growing season; (c) fertilisation with anaerobically digested sludge with an input of 320 kg total N ha^{-1} before pasture sowing; (d) fertilisation with composted sewage sludge with an input of 320 kg total N ha^{-1} before pasture sowing, and (e) the application of pelletised sewage sludge, which involves a contribution of 320 kg total N ha^{-1} split into 134 kg total N ha^{-1} just after pasture sowing in 2004 and 93 kg N ha^{-1} at the end of 2004 and 2005. The calculation of the required amounts of sludge was conducted according to the percentage of total nitrogen (EPA, 1994) and taking into account the Spanish regulation 1310/1990 regarding the heavy metal concentration for the application of sewage sludge.
Soil samples were collected at a depth of 25 cm, as described in the RD 1310/1990, in February 2006 and pasture copper was estimated by taking four samples per plot at random (0.3 × 0.3 m^2) in August 2005, December 2005, June 2006, and December 2006.
Soil total (CEM, 1994) and available copper (Mehlich, 1985), as well as the pasture copper concentration (CEM, 1994), were estimated in the laboratory. The data were analysed using ANOVA and the differences between the averages were shown by the Duncan test using the SAS statistical package (SAS, 2001).

Results and discussion

Figure 1 shows the total (a) and Mehlich copper (b) in the soil in 2006, one year after sewage sludge was applied. In spite of the smaller copper concentration of the compost compared with the other types of sludge, the soil total and available copper concentration was higher if compost was applied. This could be explained by the slower rate of mineralisation compared with anaerobic or pelletised sludge (EPA, 1994), which makes

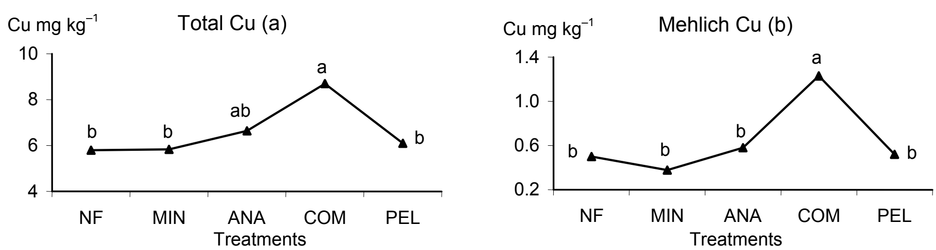

Figure 1. Total copper concentration in soil (a) and amount of copper extracted by Mehlich, (b) in each treatment in the year 2006

NF – no fertilisation, MIN – mineral; ANA – anaerobic sludge; COM – composted sludge, PEL – pelletised sludge; Different letters indicate significant differences between treatments

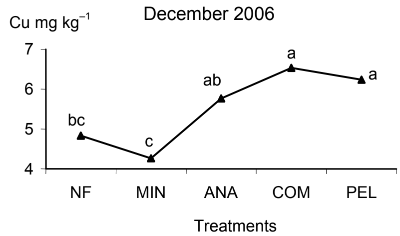

Figure 2. Copper concentration in pasture expressed in mg kg^{-1} in the different treatments

NF – no fertilisation, MIN – mineral; ANA – anaerobic sludge; COM – composted sludge, PEL – pelletised sludge; Different letters indicate significant differences between treatments

the total dose of compost higher than those treated with anaerobic digested and pelletided sewage sludge, which increases the inputs of copper applied through the compost treatment. The measured concentration of nitrogen and copper in the anaerobically digested sludge was around 2.62% and 238.5 mg kg^{-1}, being around 1.19% and 246.8 mg kg^{-1} in the composted sewage sludge and 4.56% and 121.20 mg kg^{-1} in the pelletised sewage sludge. This means that around 3.59 kg ha^{-1} copper, 8.49 kg ha^{-1} copper, and 0.95 kg ha^{-1} copper was applied with anaerobic, composted, and pelletised sewage sludge, respectively.

In all treatments the total soil copper values were below the maximum set by Spanish regulations for the use of sewage sludge in agriculture in acid soils (50 mg kg^{-1}) (R.D. 1310/1990, BOE of November 1, 1990).

The copper concentration in the pasture did not differ between treatments in the harvests that took place in August 2005, December 2005, and June 2006, when the values were always below 4 mg kg^{-1}, which is lower than the copper range defined as normal by Loué (1988) and Alloway (1995) (5–20 mg kg^{-1}) in temperate grasslands. However, in December 2006, the copper concentration in the pasture was also significantly higher when compost was applied (COM) compared with mineral fertilisation (MIN), as happened in the total and available soil analyses. This fact was also noticed by Mosquera-Losada et al. (2001), and can be explained by the fact that copper is the second most abundant heavy metal in waste of those taken into consideration by Spanish regulations on the application of sewage sludge in agriculture, after zinc.

The copper levels in the pasture were always below the minimum maintenance needs for cattle (7 mg kg^{-1}; NRC, 1978) and sheep (5 mg kg^{-1}; NRC, 1985), being those needs covered in the autumn harvest for sludge-fertilised plots, which makes it necessary to supply this element to animals.

Conclusions

Composted sludge is a type of residue that increases the total and Mehlich copper in soil and copper as a result of the higher inputs of copper made with it, as its rate of mineralisation and its nitrogen concentration are lower compared with the other sludge types tested, which increases the amount of total waste to be applied, and therefore the copper total inputs.

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Effects of sewage sludge type on *Pseudotsuga menziesii* and pasture production

Mosquera-Losada M.R., Santiago-Freijanes J.J., García-Fernández M., Fernández-Núñez E. and Rigueiro-Rodríguez A.

University of Santiago de Compostela, High Polytechnic School, Crop Production Department, Lugo, Spain
E-mail: antonio.rigueiro@usc.es

Abstract

Municipal sewage sludge production has been increased in recent years in Europe as a result of an EU directive which aims to reduce continental water pollution. This has exacerbated the problems related to sewage sludge disposal. The EU promotes the use of sewage sludge in agriculture in order to promote nutrient recycling. Sewage sludge should be stabilised before being used as fertiliser, but, depending on the stabilisation, its fertiliser capacity can be modified. This study aims to evaluate the effects of different types of sewage sludge (compost, pelletised) and mineral fertiliser on tree growth and pasture production under different silvopastoral systems established with *Pseudotsuga menziesii*. An increase in the diameter of *Pseudotsuga menziesii* is benefited by mineral treatment compared with composted or pelletised sewage sludge treatments, which increase pasture production.

Keywords: fertiliser, organic, agroforestry

Introduction

Improving and increasing pasture production could be a way of increasing the economic benefit of afforested lands with *Pseudotsuga menziesii*. Improving pasture production is usually attained through fertilisation, but, in the case of silvopastoral systems, the effect of fertilisation on the pasture must take into account the effect on tree growth. Fertilisation could be carried out with inorganic or organic fertilisers such as sewage sludge which can be stabilised by composting or pelletisation (thermic treatment) after anaerobic digestion, which allows the use of the nutrients of sewage sludge. Trees enhance the deep uptake of heavy metals and nutrients not used by fertilisers, so allowing more sustainable agricultural systems (Rigueiro-Rodríguez *et al*., 2008a). The use of composted sewage sludge as fertiliser is promoted by the European Union. Pelletised sewage sludge is a sewage sludge thermic treatment which reduces the water content by 98%, which cuts down application and storage costs. Fast-growing species and pasture production are usually improved with anaerobic digested sewage sludge (Mosquera-Losada *et al*., 2006; López-Díaz *et al*., 2009). However, it is necessary to know if a similar effect is found with other tree species. This paper aims to evaluate the effect of different types of organic fertilisers (composted and pelletised sewage sludge) and inorganic fertiliser on tree growth and pasture production.

Material and methods

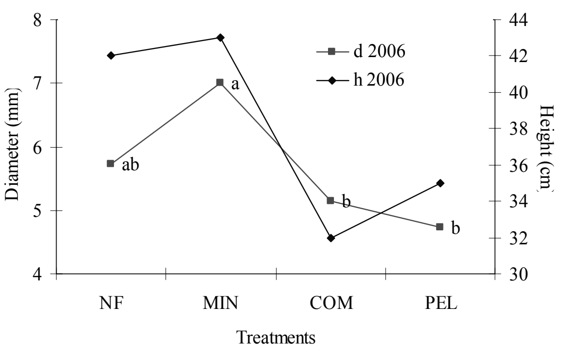
The experiment was carried out in Pastoriza county (NW Spain). The pasture was sown with a mixture of *Dactylis glomerata* L. var. Artabro (12.5kg ha^{-1}), *Lolium perenne* L.

var. Brigantia (12.5 kg ha^{-1}), and *Trifolium repens* L. var. Huia (4 kg ha^{-1}) in the autumn of 2004, these being plants in containers of *Pseudotsuga menziesii* L. planted at a density of 952 trees ha^{-1} in February 2005. The experimental design was randomised blocks with three replicas. Each experimental unit had 25 trees arranged in a rectangle. The treatments consisted of the application of four different types of fertilisers: (a) Min: Mineral inorganic fertilisation with 500 kg ha^{-1} of 8:24:16 ($N:P_2O_5:K_2O$) meaning 40, 120, and 80 kg per ha of nitrogen, phosphorus, and potassium at the beginning of the growing season during 2004 and 2005; (b) fertilisation with composted sewage sludge with an input of 320 kg total N ha^{-1} before the sowing of the pasture; (c) the application of pelletised sewage sludge, which involves a contribution of 320 kg total N ha^{-1} split into 134 kg total N ha^{-1} after the sowing of the pasture in 2004 and 93 kg N ha^{-1} at the end of 2004 and 2005, and (d) a no-fertilisation treatment applied as a control.

Tree diameter and height was measured every winter in the nine inner trees; the data from early 2006 are shown in this paper. The pasture was harvested in July and December 2005. Four pasture samples (0.09 m^2) were taken before sampling between the nine inner trees of the plot in order to avoid the border effect. ANOVA was used to analyse the data obtained and an LSD test to distinguish means (SAS, 2001).

Results and discussion

The tree diameter and height growth at the end of the first year of study can be seen in Figure 1. The height was not significantly affected in the first year of the experiment. However, the tree diameter was significantly reduced by all the organic fertilisers tested in the experiment (MIN, COM, and PEL).



NF – no fertilisation; MIN – mineral fertilisation; COM – compost; PEL – pelletised sewage sludge. Different letters distinguish significantly different diameter means

Figure 1. Tree diameter (d2 006) and height (h 2006) in February 2006

Pasture production was positively increased by the mineral, compost, and pelletised treatments in the first harvest, being also significantly higher for the compost and pelletised treatments compared with the no-fertiliser treatment in the second harvest. This could be explained by the fact that organic fertilisers usually have a residual effect compared with inorganic fertilisers.

This answer differed from those found with other tree species which are faster-growing, such as *Pinus radiata* D. Don (Mosquera-Losada *et al*., 2006) or *Populus × euroamericana* (Rigueiro-Rodríguez *et al*., 2008b), which usually responded better to organic fertiliser (anaerobic digested sewage sludge) compared with a mineral or no-fertiliser treatment, probably because of the better competitive capacity of fast-growing species, which are able to use the residual effect of organic fertilisers better than inorganic fertilisers. Moreover, the growth of *Pinus radiata* is usually negatively affected by min-

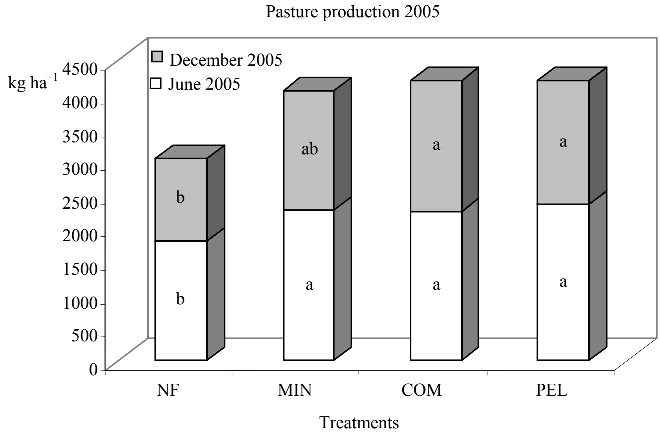


Figure 2. Pasture production in 2005

NF – no fertilisation; MIN – mineral fertilisation; COM – compost; PEL – pelletised sewage sludge. Different letters distinguish significantly different diameter means

eral fertilisation when this treatment increases pasture growth (Mosquera-Losada *et al*., 2006), which did not happen with *Pseudotsuga menziesii* in this experiment.

Conclusion

The growth in the diameter of *Pseudotsuga menziesii* is benefited by mineral treatment compared with composted or pelletised sewage sludge treatments, which increase pasture production.

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The effects of wild boar grazing on the floristic diversity of a silvopastoral oak system

Mpampouli S.[1], Abraham E.M.[1], Kyriazopoulos A.[2], Fotiadis G.[3], Parissi Z.M.[1] and Tsiouvaras C.N.[1]

[1]*Laboratory of Range Science (236), Faculty of Forestry and the Natural Environment, Thessaloniki, Greece*
[2]*Department of Forestry and Management of the Environment and Natural Resources, Orestiada, Greece*
[3]*Technological Education Institute of Lamia, Department of Forestry and Management of the Natural Environment, Karpenisi, Greece*
E-mail: eabraham@for.auth.gr

Abstract

The effect of combined grazing by small ruminants and wild boar (*Sus scrofa*) on the understorey vegetation of an open oak forest was studied. The research was conducted on Mount Cholomontas, in Chalkidiki prefecture, northern Greece, in an open *Quercus frainetto* forest. Two experimental areas were selected: (1) a stand grazed by sheep, goats, and wild boar, and (2) a stand grazed by sheep and goats. An area of 150 m^2 in each stand was fenced in the autumn of 2006, in order to be protected from grazing. A similarly-sized area was assigned next to the fenced plot. Four permanent transects were established in every grazed and protected plot. The plant cover was measured in June 2007 and ecological diversity indices were determined. Plant cover and floristic diversity decreased significantly in the areas where small ruminants and wild boar grazed in combination, compared to the areas grazed only by small ruminants. However, there were no significant differences in plant cover and floristic diversity between the grazed and protected plots in both cases.

Keywords: combined grazing, wild game, plant cover

Introduction

Traditionally, the main commercial uses of oak forests in Europe have been timber, livestock grazing, cork stripping, charcoal, and firewood. Multiple agroforestry land uses of oak forests contributed to the improvement of animal husbandry, wildlife, and the environment, and are of great ecological and economic interest. Oak forests occupy 1,471,839 ha in Greece (Ministry of Agriculture, 1992). Most of these forests are grazed by livestock, as silvopastoralism is well adapted to the Mediterranean environment (Papanastasis *et al.,* 2008).
Wild boars (*Sus scrofa*) are present in a wide variety of environments across their distribution area, although a preference for oak forest habitats exists (Abaigar *et al.,* 1994). They are omnivorous feeders that root up the ground while searching for roots, rhizomes, worms, and beetles. Through this process many seedlings and young plants are destroyed. Wild boar grubbing is suspected to accelerate soil erosion and affect soil pH and decomposition processes and hence the nutrient contents in the soil (Singer *et al.,*

1984). Consequently, wild boar may strongly influence plant cover, plant species abundance, and the diversity of the understorey vegetation.

Species composition and diversity can be used as indicators of past management practices in forested areas (Kneeshaw *et al.,* 2000). Therefore, understanding the interactive influence of livestock and wild boar grazing on understorey plant diversity in oak ecosystems is important for their long-term sustainable management.

This paper evaluated the effect of combined grazing by small ruminants and wild boar on the understorey vegetation of an open oak forest.

Materials and methods

The study was conducted in the area of Cholomontas, Chalkidiki prefecture, northern Greece (40°23'N, 23°28'E) at 800 m a.s.l. The climate of the area is classified as subhumid Mediterranean, with a mean air temperature of 11.1°C and an annual rainfall of 767 mm. The area is situated in the *Quercion confertae* subzone of the *Quercetalia pubescentis* (sub-Mediteranean) zone (Athanasiadis, 1986). The whole forested area was grazed by goats and sheep. A population of 300 wild boars also existed in a part of the area.

In a *Quercus frainetto* forest two study areas were selected: (1) a stand with long-term grazing by sheep, goats, and wild boar, and (2) a stand with long-term grazing by sheep and goats. The two study areas were established in even-aged stands with similar canopy cover and site quality. An area of 150 m^2 in each stand was fenced in the autumn of 2006, in order to be protected from grazing. A similarly-sized area was assigned next to the fenced plot. Four permanent transects were established in every grazed and protected plot.

The plant cover was measured by using the line-point method (Cook and Stubbendieck, 1986) in June 2007. Species richness was estimated by using two 0.5 × 0.5 m^2 quadrats in every transect line. Floristic diversity was determined at the species level by the number of species or “species richness” (N), and by the relative abundance. From these measurements the ecological index of Shannon-Wiener (H) was calculated as (Henderson, 2003):

$$H' = -\sum_{i=1}^{S} p_i \ln p_i$$

where: S – maximum recorded number of taxa

p_i – proportional abundance of the *i-th* taxa

Contacts were obtained every 20 cm (50 contacts per transect) and taxa were recorded according to their name given by Flora Hellenica, Volumes 1 & 2 (Strid and Tan, 1997–2002) and Flora Europaea (Tutin *et al.,* 1968–1980; 1993). The total plant cover and the diversity indices were subjected to analysis of variance (ANOVA) using the SPSS program while the LSD test was used for means comparison (Steel and Torrie, 1980).

Results and discussion

The plant cover decreased significantly in the areas where small ruminants and wild boar grazed in combination, compared to the areas grazed only by small ruminants (Table 1). It seems that wild boars’ feeding behaviour of rooting can result in a significant reduction of plant cover (Howe and Bratton, 1976). However, there were no significant differences between the grazed and protected plots in both cases, probably because of the short protection period.

Species richness, as described by the number of species and Shannon's diversity index, were significantly higher when grazing was performed only by small ruminants. This result is in agreement with a wild boar exclosure study which showed that after only two years, species richness increased inside exclosures compared to control plots to which wild boars had access (Ickes *et al.,* 2001). No significant differences were found for these floristic diversity indices between the grazed and protected plots in both cases, possibly because the period of protection was short. However, these results are preliminary and more research is needed.

Table 1. Plant cover (%) and species diversity indices of the different grazing treatments

	Small ruminants & wild boar		Small ruminants	
	grazed	protected	grazed	protected
Plant cover	39.50[a]*	35.50[a]	62.50[b]	79.00[b]
Diversity indexes				
Species richness (N)	8.00[a]	8.75[a]	10.50[b]	12.50[b]
Shannon's index (H)	1.84[a]	1.74[a]	2.03[b]	2.33[b]

*Means in the same row followed by the same letter are not significantly different ($P \leq 0.05$)

The effects of wild boar rooting on bulbous forb species and on the accelerated erosion of unstable slopes is of primary concern for the sustainable management of oak silvopastoral areas in the Mediterranean region. The management and control of wild boar populations is important in order to minimise their negative impacts on the ecosystem. Furthermore, a major highlight of these forests is the growing financial importance of big game such as deer and wild boar (Campos *et al.,* 2008).

Conclusions

This study provides evidence that wild boar grazing has negative impacts on the plant cover and floristic diversity of silvopastoral oak systems. The control of their population is a key factor for the sustainable management of these ecosystems.

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Species richness and diversity of foxtail-type stand during long-term fertilisation

Mrkvička J. and Veselá M.

Czech University of Life Sciences Prague, Department of Forage Crops and Grassland Management, Prague, Czech Republic
E-mail: mrkvicka@af.czu.cz

Abstract

The influence of fertilisation (combination $N_0P_0K_0$, $N_0P_{40}K_{100}$, $N_{100}P_{40}K_{100,}$ $N_{200}P_{40}K_{100}$) on species richness, species diversity, and the stand composition of a foxtail stand type was studied over a period of 40 years. From the long-term point of view the best combination is $N_0P_{40}K_{100}$, when, in terms of species diversity expressed by the Simpson's index after 21 to 22 years, the values of non-fertilised stands are exceeded. A dose of 100 kg N per ha with PK fertilisation according to soil fertility is the lowest for the sustainable dominance of *Alopecurus pratensis* L. in the community. For the analysis of the observed values of species richness and diversity, basic statistical characteristics were used and we made a study of a chronological series of experimental dates using analytical functions by applying mathematical analyses and to obtain evidence on their course.

Keywords: foxtail stand type, species richness, species diversity, Simpson's index

Introduction

The floristic composition of permanent meadow stands is the result of the interaction between all the ecological factors in the whole ecosystem and the controlled conditions. Each change in stand conditions results in changes in the species composition and representation of agrobotanical groups (Klimeš, 2000; Mrkvička and Veselá, 2002). Directed management influences species diversity for the benefit of valuable forage species, which are usually dominant in stands. According to Moravec and Jeník (1994), the number of species present in a locality provides basic information about the species richness of the community, which is influenced by site factors when the species richness of phytocenosis is higher in favourable conditions. The most significant influence on species diversity is presented by the intensity of fertilisation and the mineral fertilisers used. N fertilisation, particularly in higher doses, influences the stand composition quickly and considerably (Fiala, 2002, etc.).

Material and methods

Stand composition, species richness, and species diversity were observed in a permanent meadow in the locality of Černíkovice (Benešov district) in the years 1967–2005. The original growth type was *Alopecuretum.* The altitude above sea level is 363 m, the average annual precipitation sum 617 mm, and the average annual temperature 7.8°C. The soil type is gley, the soil species (0–0.2 m) loam, pH 5.0; % C_{ox} 2.90; % N_t = 0.41; C_t / N_t = 7.07. The experiment was established in a randomised block design with four replications. The plot size was 30 m^2 (5 m × 6 m). The variants studied are presented in Table 1.

The botanical analysis of the stands was performed by the method of reduced projective dominance (D in % before the first cut harvest). For reducing the inaccuracy of the estimation the relevés were evaluated on each replication and the basic agro-botanical groups were separated according to the individual species (Regal and Veselá, 1975). Simpson's index was used for the estimation of species diversity (Begon *et al.*, 1997), and the total dominance of the vegetation was considered. For the analysis of the observed values of species richness and diversity basic statistical characteristics were used and we made the study of a chronological series of experimental dates. For chosen years for which relations and values of species richness (Q) and species diversity (*D*) are presented, theoretical reconstruction of data with the use of created dynamic models was carried out.

Table 1. Variants of fertilisation

Variant	Nutrient combination	Fertilisers/application/doses of nutrients (kg ha^{-1})		
		ammonia saltpetre with limestone spring	superphosphate autumn	potash salt after 1st cut
1	$N_0P_0K_0$	–	–	–
2	$N_0P_{40}K_{100}$	–	40	100
3	$N_{100}P_{40}K_{100}$	100	40	100
4	$N_{200}P_{40}K_{100}$	200	40	100

Results and discussion

Many authors have studied the influence of different levels of fertilisation on changes in the grass stand species composition and species richness (Velich, 1996; Klimeš, 2000; Holúbek, 2002; Mrkvička and Veselá, 2002), shown in Tables 2 and 3.
The highest average species number (Q) was found in a non-fertilised stand (var. 1) in the period under consideration and also the lowest variation of Q value (V_Q = 4.364%).

Table 2. The development of botanical groups – reduced projective dominance (*D*%)

Variants	Agrobotanical groups	Years					
		1967	1975	1984	1993	2002	2007
1	grasses	65	54	59	60	73	75
	leguminoses	11	12	9	2	2	5
	other herbs	19	30	31	32	13	14
2	grasses	65	58	70	53	50	48
	leguminoses	15	13	10	15	25	27
	other herbs	15	18	18	16	10	12
3	grasses	89	90	93	92	86	88
	leguminoses	5	+	+	+	+	+
	other herbs	5	8	6	4	6	5
4	grasses	98	93	93	97	94	92
	leguminoses	–	+	+	–	–	–
	other herbs	2	6	3	1	–	2

Table 3. Species richness of foxtail-type stand

Variants	Years					
	1967	1975	1984	1993	2002	2007
1	31	32	33	32	29	29
2	27	28	25	31	25	27
3	21	19	18	17	18	16
4	22	21	20	12	14	14

Table 4. Average values and basic statistical characteristics of species richness expressed in total number of vascular plant species (Q), variants 1–4

Variants	$\bar{Q}$	S_Q	V_Q (%)	$Q_{0.25}$	$Q_{0.75}$
1	31.231	1.363	4.364	30.000	32.000
2	27.462	2.025	7.374	25.500	29.000
3	18.000	3.674	20.411	16.000	20.500
4	16.615	4.942	29.744	13.000	20.500

Table 5. Dynamic model of stand species richness development, variants 1–4 (i = 1 to 4), expressed in total number of vascular plant species (Q)

$Q'_i = f(t)$	I_{Qt}
$Q'_1 = 30.814 + 0.269t - 0.008\,789t^2$	0.847**
$Q'_2 = 27.473 - 0.517t + 0.047\,662t^2 - 0.000\,972t^3$	0.686**
$Q'_3 = 21.019 - 0.290t + 0.005\,662t^2$	0.861**
$Q'_4 = 21.599 + 0.542t - 0.064\,752t^2 + 0.001212t^3$	0.812**

Table 6. Values of Simpson's index of species diversity (D) in observed stands, variants 1–4

Variants	Years					
	1967	1975	1984	1993	2002	2007
1	11.295	3.980	5.810	4.876	4.370	4.521
2	8.653	4.081	3.911	5.205	10.980	5.587
3	4.109	1.351	1.950	1.355	1.343	1.462
4	1.363	1.204	1.573	1.211	1.065	1.103

Dynamic model analysis of the species richness development (Table 5) shows that after 15 years the number of species increases, which results in a reduction in species richness. It confirms the need for long-term experiments in grassland (Regal and Veselá, 1975). The gradual decrease of species richness in consequence of more intense fertilisation (Tables 2–4) is consistent with the information provided by many authors (Velich, 1996; Holúbek, 2002, etc.). The different directions of the development tendencies of species richness values (Q) and their small changes during monitoring (Tables 2–4) contrast with the trends in species diversity values (expressed in Simpson's index), where clear differentiation caused by fertilisation was found (Table 6).

Conclusions

The development of the species composition is influenced by pratotechnic management, fertilisation, exploitation, and conservative ecological factors and the most important is the water regime of the site. In our experiment, which lasted for 40 years, the predominant species was *Alopecurus pratensis* in the majority of cases but its dominance fluctuated in variants $N_0 P_0 K_0$ and $N_0 P_{40} K_{100}$ (17–50%, 20–50% respectively), particularly in the first ten years.

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The long-term influence of fertilisation on the botanical composition of a fen grassland

Müller J.[1], Jurasinski G.[1] and Dittmann L.[2]

[1]*University of Rostock, Institute for Management of Rural Areas, Working Group Landscape Ecology and Site Evaluation, Rostock, Germany*
[2]*University of Rostock, Institute for Management of Rural Areas, Working Group Geodesy and Geoinformatics, Rostock, Germany*
E-mail: juergen.mueller3@uni-rostock.de

Abstract

Information about the influence of fertilisation on the botanical composition of grassland swards is often based on short-term investigations of swards with a strictly limited amount of species. We intended to overcome these limits by a long-term investigation on a low peat site with a very high biodiversity 10 years ago. The effects of different fertilisation treatments (null, K, PK, NPK) on botanical composition and soil characteristics were observed over a period of 9 years. Using multivariate statistics helps to identify the reaction of single grassland species to the different trophic situations. We find that the different treatments had a strong effect on phytodiversity and botanical composition.

Keywords: biodiversity, low peat soil, nutrient status, fertilisation, phyto-indication

Introduction

Most fens in Northern Germany are drained and cultivated as grasslands. They still serve a number of landscape ecological functions (Kratz and Pfadenhauer, 2001). From a conservation point of view, the maximum possible plant diversity in combination with typical wet site conditions is aspired to (Kapfer, 1988; Schwartze, 1992). A number of grassland ecosystem studies highlight the positive effects of high plant diversity on nutrient retention (Tilman *et al*. 1996; Hooper and Vitousek, 1998). Thus, a general conflict between nature conservation (maximised biodiversity) and agriculture (profitable yield) does not seem to exist. However, if the agricultural value is lost because of fallowing, a valuable habitat for conservation might disappear because of a lack of economic alternatives (Bakker *et al*., 1980). The nutrition status turns out to be the key factor in maintaining the balance between plant diversity and profitable yields in managed wet grasslands (Müller, 2001). Increased soil nutrient contents, especially regarding phosphorus, might have negative effects on plant species richness (Janssens *et al*., 1998; Tracy and Sanderson, 2000), whilst nutrient depletion might challenge the agricultural usability quantitatively, as well as qualitatively. Considering these constellations, we investigated the effects of different trophic levels on species composition and diversity.

Material and methods

The investigation site is situated in North-eastern Germany, in the floodplain of the River Warnow, on a drained fen. The average water level of the meadow is about 50 cm below ground. The experiment was set up in 1999. At that time the grassland had already been in extensive conservation sound use with no fertilisation for 8 years. Four different trophic levels were established through different fertilisation regimes that were applied to 4 replicate plots, each in a double randomised block design (Figure 1). The experimental plots are squares with an area of 10 m^2 and were mown thrice a year. Before the experiment was set up, representative species composition was recorded for the whole experimental area. Since 2001 the floristic composition of each plot has been determined prior to every harvest. Cover values were estimated as percentages. Soil samples were taken in 2002 and 2007 and analysed for soil nutrient contents (DL extraction).

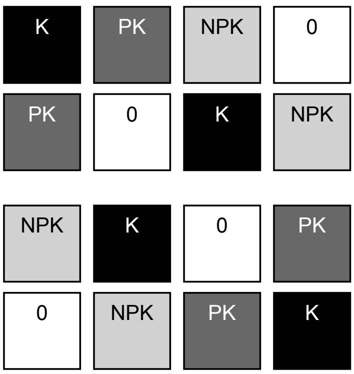

Figure 1. Experimental design. Fertilisation treatments: NPK (160 kg N, 160 kg K, 48 kg P), PK (160 kg K, 48 kg P), K (160 kg K) and a control (no fertilisation). All fertiliser component quantities are given per ha and year

For the analysis presented here the vegetation data were pooled for each treatment and year of record. Cover percentages were standardised per species to a scale between 0 and 1 before further analysis. The resulting species matrix was used to calculate diversity measures per treatment and year of record. The development of species composition was evaluated by multivariate ordination procedures. Principal components analysis (PCA) and its canonical equivalent redundancy analysis (RDA) were used after checking for gradient lengths with a DCA (Leps and Smilauer, 2003; Leyer and Wesche, 2007). All calculations were carried out with the statistics package R version 2.8.1 (R Development Core Team 2008). Analyses were obtained using the vegan package (Oksanen *et al*., 2008).

Results and discussion

The total number of species in the experimental site increased slightly from 49 to 53 during the 9 years of the study. Figure 2 depicts the development of phytodiversity per treatment. The total species richness has been added to the richness plot (Figure 2a). It is apparent that from 2002 total richness deviates from the treatment and control species numbers: the species compositions in the different treatments drift apart. Furthermore, there is considerable variability between years and no directional change to generally lower or higher species richness. The non-fertilised control shows neither higher species richness nor higher diversity (Shannon-Wiener) than most of the treatments. Only the NPK treatment exhibits considerably lower species richness and diversity in the later years of the study.
That the species compositions of the treatments drift apart is also apparent in the ordination plots (Figure 3). The first axis apparently reflects a developmental gradient that follows a negative soil nutrient gradient (all the vectors for measured soil nutrients point in the negative axis direction, Mg and P showing a large absolute value). The second axis

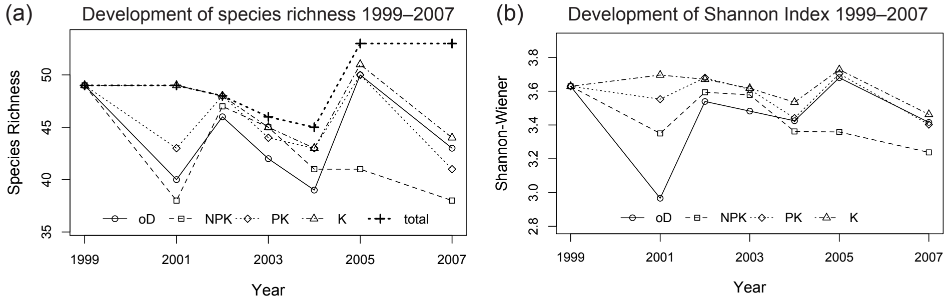

Figure 2. Development of phytodiversity over 9 years described by species richness (a) and Shannon Index (b). In (a) the development of total species richness is added (bold dotted line)

clearly separates the control (no fertilisation) and the K from the two other treatments (NPK, PK). Note that the start point (species composition in 1999, black dot in Figure 3) is in the lower part of the ordination between the points, reflecting a better nutrient supply (NPK/PK plots). Some species follow the nutrient supply situation; others, such as *Holcus lanatus* (HOLLA) or *Festuca rubra* (FESRB), do not clearly show any affinity to the kind of treatment (Figure 3a). Sedges and rushes have an obvious focus in the control plots, whereas the index species *Cirsium oleraceum* (cabbage thistle, CIROL) reaches its highest cover values in fully fertilised plots (NPK).

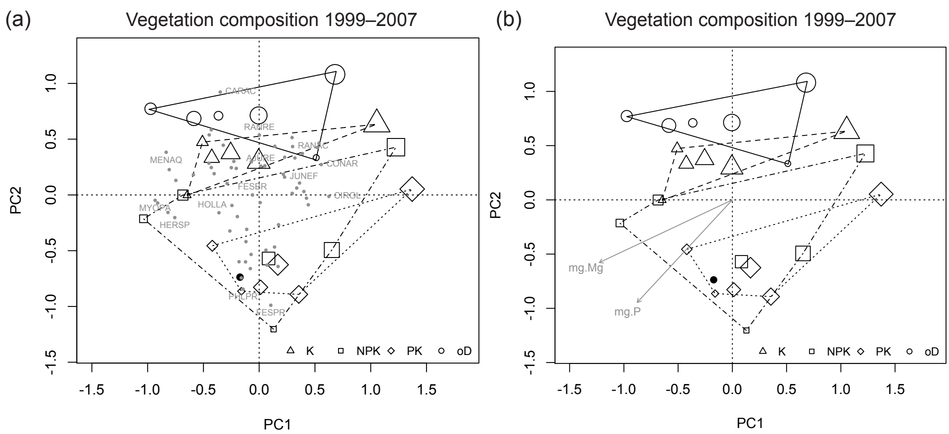

Figure 3. Development in species composition as represented by PCA ordination. The records of each treatment (same symbol, see legend) are enclosed with a polygon. The symbol size increases with the years of study. Note that the positions in the ordination space reflect the development in species composition through time. The black dot denotes the species composition in 1999 at the start of the experiment. (a) PCA plot including the species cloud (grey dots). Selected species are given by name; (b) Same PCA plot. Grey arrows reflect the correlation of the measured environmental variables with the ordination result. Only significantly correlated variables are shown

Conclusions

Our results suggest that long-term nutrition depletion alters the species composition considerably. Slight fertilisation (PK) allows an economically justifiable yield to be maintained whilst supporting a certain plant species diversity and richness (Figure 2).

In Figure 3 it is obvious that meadow species with a good biomass yield have a focus in these plots. This also holds true for legumes. When a larger cover of more typical representatives of wet grasslands is intended, K or no fertilisation can be applied. Apparently, the combination of nutrition depletion and three cuts a year favours rosette and reptant species that keep their shoot apical meristem out of the reach of the mower and thus relatively benefit from that kind of management. However, one has to be aware that in the long run this comes at the cost of the yield and therefore cannot be implemented as a permanent strategy.

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The effect of use way of the catchment on the content of mineral nutrients in waters of small river

Niczyporuk A.[1] and Jankowska-Huflejt H.[2]

[1]Białystok Technical University, Department of Technology in Environmental Engineering and Protection, Poland
[2]Institute for Land Reclamation and Grassland Farming, Falenty, Poland
E-mail: h.jankowska@imuz.edu.pl

Abstract

Studies were carried out in the buffer zone of Białowieża Forest – in agricultural (reclaimed meadow) and forest catchments of the Perebel River. Yielding, sward cover and botanical composition were analysed in 2007. At the river edges the plant and water samples were taken in May and August for analyses of: NO_3^-, NH_4^+, PO_4^{3-}. Yield from 2 cuts was 4–8 Mg ha^{-1}; the third regrowth was grazed. In the autumn, sward cover ranged from 52% to 76%; the larger followed lower fertilisation rates, smaller yields and grazing, particularly that less intensive. Concentration of mineral nutrients in water samples was higher in May than in August. It was significantly higher in plants and water from meadow than from forest catchment. Vegetation from the river edges contained many times more mineral nutrients than the outflowing water. Despite significant differences most water samples did not exceeds standards for the I and II water quality classes. The Perebel River carries water of high quality.

Keywords: plants, mineral components, water, sward cover, forest and meadow catchment

Introduction

Unused mineral nutrients (from soil and fertilisers) may pollute ground and surface waters (Kopeć, 1987). Appropriate land management may counteract this phenomenon. This paper was undertaken to assess the productivity of a meadow catchment and to compare it with a forest catchment in view of water quality protection.

Study methods

Agricultural and forest catchments were compared as buffer zones protecting water quality of the Perebel River. Agricultural catchment was represented by a meadow object Perebel (8 km × 1.5 km, 166 m a.s.l.) in north-western part of the buffer zone of Białowieża Forest. In its central part there is a watershed separating the Perebel River that flows south-east from the Orla River flowing north-west. The meadow object neighbours arable lands on its eastern side (169 m a.s.l.) and diverse tree stands on its western side (167 m a.s.l.). In the years 1960–1962 the object (peat bog covered by agriculturally invaluable vegetation) was reclaimed (ground water table at 50 cm below ground) and was managed by sowing grass mixture of *Alopecurus pratensis* (35%), *Festuca pratensis* (20%), *Phleum pratense* (10%), *Poa pratensis* (20%), *Festuca rubra* (15%). Other plants appeared afterwards so now there are over 40 plant species there.

Forest catchment is dominated by lessive, brown and gley soils and the area close to the river channel is filled with peat and organic-mineral alluvia. The vegetation is dominated by: *Calamagrostis: canescens neglecta, Agrostis: stolonifera, canina, Carex: canescens, stellulata, vesicaria, Hudsonii, acutiformis,* and grasses are represented by *Eriophorum anqustifolium, Scirpus silvaticus*. Grassy forest undergrowth is supplemented by shrubs, (*Corylus* and *Ribes alpinum)* and by tree seedlings (*Fraxinus, Alnus*, and *Picea).*

Mineral nutrients were determined in river waters since 2004 in the area of both catchments (Niczyporuk and Wiater, 2006). Yielding, sward cover and botanical composition in the meadow object were determined in 2007. Plant samples were collected on both river sides in the middle belts between the river and the object's borders. Besides on 15th May and 15th August plant and water samples were collected for chemical analyses in selected fixed sites at the river edges. The same dominating plant species permanently present along the whole river length (28 km) were taken as a basis for this study. The following ions were determined in plant and water samples: NO_3^- and NH_4^+ – with the microdistillation method; PO_4^{3-} – colorimetrically with ammonium metavanadate. Fisher-Snedecor and Tukey tests were used for statistical assessment. Water quality was evaluated based on the Minister of Environment Directive of 11th February (Rozporządzenie ..., 2004).

Results and discussion

Present agricultural activity in the buffer zone of Białowieża Forest is monitored due to special protection of the forest. Meadow object covers a lowered part of the buffer zone. Intensive agricultural production after reclamation was followed by regress since 1990 and now meadow management may be dealt with as semi-intensive with mineral fertilisation of 50–100 kg N, 20–30 kg P and 30–50 kg K ha^{-1}. Hay yields in 2007 was 4–8 Mg ha^{-1} (two cuts and grazed autumn regrowth). Sward cover of 52–76% was larger on used (mown-grazed) meadow (71–76%) and smaller on mown meadow (52–57%). Valuable grasses sown in 1962 maintained in 40% of plant cover; the share of other, not sown crop plants, increased. Higher yields were obtained at more intensive fertilisation and their amount was determined mainly by tall grasses. Larger sward cover was accompanied by smaller yield and a greater share of low grasses. Moisture was higher at both river edges than in other parts of the object. Therefore, the same riparian plant species were recorded and sampled in both catchments. Agriculturally invaluable species dominated there (Table 1). Moreover, due to flooding and water movements riparian vegetation was mechanically soiled.

Mineral nutrient content in both plants (Table 1) and water (Table 2) was significantly higher in agricultural than in forest catchment. Koc and Sidoruk (2006) obtained similar results for mineral N whose concentration in water flowing to a lake from forest catchment was smaller than from agricultural catchment. Amounts of mineral nutrients accumulated by plants of particular groups differed significantly. Dicotyledons appeared most useful for the role of a barrier protecting water quality, then grasses that accumulated 20% less and finally sedges accumulating 30% of mineral components less than dicotyledons. In May there were more nutrients in water and less in plants; the reverse relationship was noted in August. Similar seasonal variability of nitrates in running waters in agricultural catchment was described by Skorbiłowicz (2006). It is a result of enhanced plant uptake of mineral nutrients in summer and low in early spring – the effect also observed in earlier studies (Niczyporuk and Wiater, 2006). Noteworthy, the content

Table 1. The botanical composition (BC) and content of mineral components (in mg kg^{-1} dry mass) in dominating plant species at the edges of the Perebel River in 2007 (mean of plants)

Plant species	Meadow catchment							Forest catchment						
	BC*	NO_3^-		NH_4^+		PO_4^{3-}		BC*	NO_3^-		NH_4^+		PO_4^{3-}	
		V	VIII	V	VIII	V	VIII		V	VIII	V	VIII	V	VIII
Agrostis gigantea	4.1	226	332	64	71	18	20	3.8	192	231	42	54	14	16
Alopecurus pratensis	6.7	241	356	68	78	21	33	5.6	181	243	44	62	15	18
Glyceria aguatica	7.3	230	360	70	81	22	30	4.4	196	254	47	68	16	17
Pha. arundinacea	9.4	212	342	66	76	20	29	6.1	200	260	43	60	15	17
Poa palustris	6.8	216	311	53	70	17	19	3.7	180	210	40	51	13	15
Grasses: sum/mean	40.4	225	340	64	75	20	26	29.4	190	240	43	59	15	17
Carex acutiformis	2.0	122	262	42	53	15	17	3.5	155	170	25	38	11	15
Carex limosa	2.4	138	250	40	61	15	17	3.7	142	166	28	40	11	14
Carex riparia	5.5	132	272	44	50	16	18	9.0	160	183	30	49	14	16
Carex rostrata	3.8	110	240	47	60	16	19	4.9	152	175	28	46	13	17
Scirpus silvaticus	6.0	145	283	51	66	17	18	6.8	181	194	33	51	14	17
Sedges: sum/mean	22.3	129	252	45	58	16	18	31.0	158	178	29	45	13	16
Filipendula ulmaria	11.0	310	412	80	101	23	25	13.1	266	314	58	76	21	23
Lotus uliginosus	6.9	332	445	83	112	24	27	5.4	273	342	62	87	18	20
Pedicularis palustris	4.0	312	416	71	94	22	24	3.6	260	310	55	73	18	21
Polygonum bistorta	8.2	322	411	77	115	24	26	9.3	270	321	54	80	19	25
Ranunc. sceleratus	4.7	314	400	70	97	22	25	4.0	258	300	57	71	17	23
Dicots: sum/mean	37.3	318	419	76	104	23	25	39.6	265	317	57	77	19	22
LSD for A		37	41	4	10	3	6		30	36	8	14	3	8
LSD for B		7	14	2	6	1	4		7	12	5	9	3	5
LSD for AB		17	26	3	8	2	5		13	21	5	12	3	7

*% cover (mean from sampling sites and terms of sampling); A – months of sampling; B – plant species; AB – terms × species

of components in plants from river edges was many times higher than in the outflowing water. Despite their variability, the concentrations of mineral nutrients in water flowing out of both catchments usually did not exceed the standards for the I and II water quality class (Rozporządzenie ..., 2004). It means that waters of the Perebel River are relative clean and that the unfavourable effect of meadow catchment should be considered in further economic activity.

Conclusions

Diverse vegetation at the river edges accumulated the excess of mineral nutrients playing thus a positive role in environmental protection. Most mineral nutrients were taken up by dicotyledons, less (by 20%) by grasses and still less – by sedges (by 30% less than dicots).

The concentrations of the nutrients in river waters were higher in May than in August.

Table 2. Concentration of mineral nutrients in waters of the Perebel River in 2007 (mean of sampling sites and months)

Catchment	Months	Concentration (mg dm^{-3})					
		NO_3^-	NH_4^+	PO_4^{3-}	Cl^-	K^+	Na^+
Agricultural (meadow)	V	2.47	0.34	0.12	11.16	5.15	9.12
	VIII	2.00	0.26	0.10	8.10	4.10	6.14
	mean	2.23	0.30	0.11	9.63	4.63	7.63
Forest	V	1.12	0.30	0.08	5.11	3.17	7.18
	VIII	0.90	0.21	0.05	3.00	2.30	4.20
	mean	1.01	0.25	0.07	4.05	2.74	5.69
$LSD_{0.05}$ for	catchments	0.40	0.10	0.02	1.12	1.08	1.24
	months	0.20	0.05	0.02	1.08	1.03	1.12

The content of mineral nutrients was significantly larger in water and plant samples from meadow than from forest catchment. The content of mineral nutrients was many times larger in plants from river edges than in the outflowing water.

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Comparison of the understorey vegetation in grazed kermes oak stands differing in canopy cover

Panogeorgos A.[1], Kyriazopoulos A.[2], Fotiadis G.[1], Abraham E.M.[3] and Fraggakis I.[1]

[1]*Technological Education Institute of Lamia, Department of Forestry and Management of Natural Environment, Karpenisi, Greece*
[2]*University Democritus of Thrace, Department of Forestry and Management of the Environment and Natural Resources, Orestiada, Greece*
[3]*Aristotle University of Thessaloniki, Faculty of Forestry and Natural Environment, Laboratory of Range Science (236), Thessaloniki, Greece*
E-mail: apkyr@for.auth.gr

Abstract

Quercus coccifera L. is one of the most common species of the Greek and Mediterranean flora. Although it can assume the form of a tree, it is usually found as a shrub forming extensive shrublands. The objective of this study was to investigate the effects of canopy cover on the understorey vegetation of grazed *Quercus coccifera* L. stands at Kredi, Evryitania prefecture, Central Greece. The experimental area had been long-time grazed by sheep and goats. The study was conducted in a dense kermes oak forest, in a silvopastoral kermes oak system with moderate canopy and in open grassland. Species composition and species richness were measured. Species composition altered from the grassland to the dense forest. The contribution of legumes and forbs was decreased while the contribution of grass species was higher in the dense forest compared to the silvopastoral system and grassland. Species richness was significantly lower in the kermes oak forest compared to the silvopastoral system and the open grassland.

Keywords: silvopastoral, species richness, dense forest, floristic diversity

Introduction

Kermes oak (*Quercus coccifera* L.) is one of the most common species of the Greek and Mediterranean flora (Tutin *et al.,* 1993). Although it can be in the form of a tree, it is usually found as a shrub (Athanasiadis, 1986; Bergmeier, 1990), mainly because of human intervention or of the local climatic and soil conditions (Moulopoulos, 1965). The economic and ecological importance of kermes oak is huge, considering that it provides food of high nutritional value for domestic and wild animals, prevents soil erosion and improves the aesthetic value of the landscape (Tsiouvaras, 1987; Papachristou, 1997).
Human activities, such as forest management and livestock grazing, affect the understorey species diversity and composition as well as the forest structure and function. In particular, moderate grazing contributed to the increase of floristic diversity of the Mediterranean ecosystems (Noy-Meir, 1998), while an intensified or ceased pastoral activity may lead to low diversification of herbaceous and shrubby species (Papanastasis, 2004). Similarly low diversification can be observed in forests with a dense closed can-

opy (Kyriazopoulos *et al.,* 2006) where heavy shading affects plants of the understorey by influencing their photosynthetic capability resulting to the predominance of a few shade-tolerant species (Bergez *et al.*, 1997).

The objective of the present study was to investigate the effects of canopy cover on the diversity of the understorey vegetation of grazed *Quercus coccifera* L. stands.

Materials and methods

The study was conducted at Kredi, Evritania prefecture, Central Greece (38°59'53''N, 21°39'E at 700 m a.s.l.). The climate of the area is classified as subhumid Mediterranean, with a mean air temperature of 12.5°C and an annual precipitation of 1,529 mm. The study area is situated in the Ostryo-Carpinion and Quercion confertae subzones of Quercetalia pubescentis (sub-Meditteranean) zone (Athanasiadis, 1986) and consists of *Quercus coccifera* L. forest stands with different canopy cover and open grasslands. In the area, 2,476 sheep and 1,280 goats grazed continuously from March to November. The following three habitats were selected: (1) a dense *Quercus coccifera* L. stand with canopy cover of approximately 85% (Forest), (2) an open *Quercus coccifera* L. stand with canopy cover of approximately 45% (Silvopastoral system) and (3) an open grassland (Grassland). Species composition was measured by using the line and point method (Cook and Stubbendieck, 1986) in June 2008. Four transect lines of 25 m long were used in each habitat. Species richness was estimated by using four 0.5 × 0.5 m quadrats in every transect line of each habitat.

General linear models procedure (SPSS 14 for Windows) was used for ANOVA. The LSD at the 0.05 probability level was used to detect the differences among means (Steel and Torrie, 1980).

Results and discussion

The understorey vegetation composition differed in the three habitats. The highest percentage of legumes and forbs was in the grassland (Figure 1) and their contribution to vegetation composition decreased from the silvopastoral system to the forest. On the contrary, the highest percentage of grasses was in the dense forest.

Species richness was significantly higher in the grassland compared to the silvopastoral system and to the forest, for all the plant groups. The only exception was the woody spe-

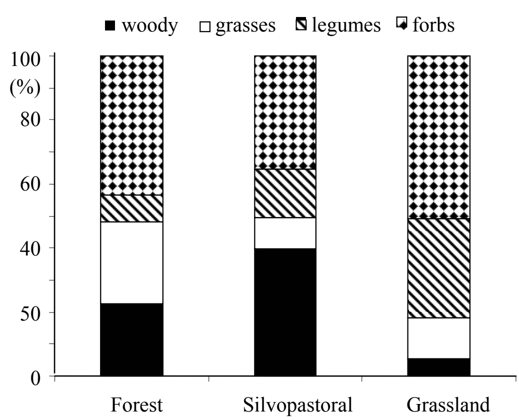

Figure 1. Composition (%) of species in the three habitats

cies, where no significant differences were recorded among the habitats (Table 1). Forbs had the highest number of species in all habitats.

Table 1. Species richness (N) in plant groups for the three habitats

	Forest	Silvopastoral system	Grassland
Woody	1.0[a*]	2.3[a]	1.0[a]
Grasses	1.7[a]	3.0[ab]	3.5[b]
Legumes	1.3[a]	1.3[a]	4.0[b]
Forbs	5.0[a]	10.7[b]	13.0[c]

*Means in the same row followed by the same letter are not significantly different ($P \leq 0.05$)

Species richness and diversity are favoured in open grasslands, where legumes and forbs dominated. Conversely, dense forest had the lowest species richness and was dominated by grasses. This is probably due to differential responses of species to shade. It has been reported by Pieper (1990) that many grasses benefit from light to moderate shading, while almost all legumes are suppressed. The main reason for the present high canopy density of this oak forest is the abandonment of traditional human activities like coppicing to make charcoal and for firewood. Additionally, the high canopy density of the kermes oak forests discourages livestock from grazing there.

Conclusions

Species richness and diversity decreased in the dense kermes oak forest. Thus, the aim of forest management has to be the maintenance of a moderate canopy cover in order to conserve species diversity and forest function.

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Determination of suitable management for a mountain hay meadow in a nature reserve in the Jizerské hory Mts.

Pavlů L., Pavlů V. and Gaisler J.

Crop Research Institute, Prague, Grassland Research Station, Liberec, Czech Republic
E-mail: lpavlu@vurv.cz

Abstract

The aim of this study was to identify changes in a mountain hay meadow (alliance *Polygono-Trisetion*) when management ceases. Five permanent paired plots were established in 1999 in the Bukovec nature reserve in a protected landscape area in the Jizerské hory Mts. The changes in the plant species composition and percentage of cover in mown plots (in mid-July) and abandoned control plots were studied for ten years. The number of vascular plant species with cover higher than 1% remained almost the same during the study period. The proportion of grasses (both tall and short) was significantly higher on the mowing treatments. Abandonment considerably increased the abundance of total and tall herbs and, on the contrary, the cover of short herbs was promoted by mowing. Grass species such as *Festuca rubra*, *Agrostis capillaris*, *Anthoxanthum odoratum*, *Briza media*, and *Trifolium repens* (short herbs) were positively affected by mowing. On the other hand, mowing suppressed the cover of *Cirsium heterophyllum*, *Geranium sylvaticum*, *Trisetum flavescens*, and *Luzula luzuloides. Hypericum maculatum* thrived under the unmanaged plots. The proportions of some species, e.g. *Bistorta major*, *Veronica chamaedrys*, *Potentilla erecta*, and *Alchemilla millefolium* remained unchanged with the different management. Our results show that management practices, such as long-term mowing, may be needed to reduce the dominance of tall herbs and to maintain a suitable proportion between the dominant species.

Keywords: mowing, abandonment, grassland, plant species composition, diversity

Introduction

The decline of grassland diversity throughout Europe within recent decades is threatening biological diversity and is a major conservation problem. When management in the form of cattle grazing and mowing ceases, the abundance of competitively superior plant species tends to increase in abandoned semi-natural meadows. But the results of the responses of individual species and/or functional groups to different approaches to grassland management are not straightforward and differ in various types of grasslands.
The aim of this study was to find a suitable cutting frequency for a species-rich mountain hay meadow (alliance *Polygono-Trisetion*) without significant changes in the composition of the vegetation and any decrease in the diversity of the plant species.

Material and methods

The experiment was carried out in a mountain hay meadow in the Bukovec nature reserve in the north-west of the Jizerské hory Mountains, the Czech Republic. The altitude of this study site is 910 m, the average annual precipitation is 1,500 mm, and the

mean annual temperature is 4.5°C. The bedrock in the Jizerské hory Mountains is mainly formed of granite, but on this hay meadow patches of basalt can occur. According to the phytosociological nomenclature (Moravec *et al.*, 1995), the vegetation of the experimental sites was classified as *Polygono-Trisetion*; the dominant species at the beginning of the experiment were *Festuca rubra*, *Agrostis capillaris*, *Trisetum flavescens*, *Cirsium heterophyllum*, and *Geranium sylvaticum*.
The experiment was established in 1999. The treatments applied were cutting once a year with the removal of the biomass in mid-July (C) and unmanaged control (U). The vegetation was monitored in 5 pairs of permanent 5 m × 5 m plots annually before cutting at the same phenological stage in mid-July. The cover of all plants on each plot was recorded using a percentage scale. The nomenclature followed Kubát *et al*. (2002). On the basis of a description of vascular plants in the regional flora (Kubát, 2002), all vascular plant species within the study area were *a priori* categorised according to their main traits: short grasses, tall grasses, short forbs, and tall forbs (Table 1).

Table 1. Functional groups of the study sward (only the most common species present are included)

Tall grasses	Short grasses	Tall herbs	Short herbs
Trisetum flavescens	*Agrostis capillaris*	*Achillea millefolium*	*Alchemilla* sp.
Festuca rubra agg.	*Anthoxanthum odoratum*	*Bistorta major*	*Galium saxatile*
Poa pratensis	*Briza media*	*Cirsium heterophyllum*	*Leontodon hispidus*
Luzula luzuloides	*Luzula multiflora*	*Geranium sylvaticum*	*Meum athamanticum*
		Hypericum maculatum	*Trifolium repens*
		Ranunculus acris	
		Rumex acetosa	
		Vicia cracca	

To reveal the differences between abandoned and mown grassland they were counted and analysed by repeated measures ANOVA.

Results and discussion

The cover of grasses (both tall and short) was significantly higher ($P < 0.001$) on the mown plots during our experiment (Figure 1a). On the other hand, abandonment significantly ($P < 0.001$) supported the total herb cover (Figure 1b), which was mainly formed of tall herbs. According to our results, the number of vascular plants with cover higher than 1% remained almost the same during the course of the study, but the number of all vascular plants, regardless of cover, increased ($P < 0.001$) during the study in the mown plots. Although similar results were also reported by Hellström *et al.* (2006), Huhta and Rautio (1998) described completely opposite ones. Surprisingly, in their study the plot diversity was higher in the abandoned meadows than in the managed meadows.
In our study on the mown plots a significant increase in cover was observed especially in the case of these dominant grasses: *Festuca rubra*, *Agrostis capillaris*, *Briza media*, and *Anthoxanthum odoratum*. On the other hand, *Luzula luzuloides*, *Trisetum flavesces*, and *Alopecurus pratensis* decreased significantly.

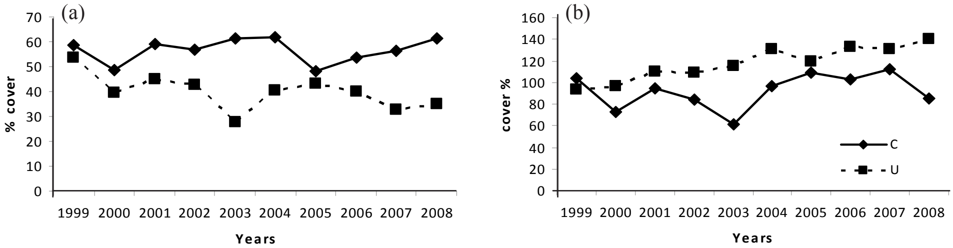

Figure 1. Changes in coverage (%) of grasses (a) and herbs (b) during the study years

The proportion of grasses such as *Festuca rubra* and *Agrostis capillaris* also increased in the managed plots in mountain meadows (Krahulec *et al.*, 2001).
The tall herbs *Cirsium heterophyllum* and *Hypericum maculatum* increased their cover on the abandoned plots, and *Geranium sylvaticum* was suppressed by mowing. On the contrary the short herbs *Meum athamanticum* and *Trifolium repens* significantly increased their cover on the mown plots in the course of the experiment.
These results are in accordance with other studies concerning the behaviour of plant species under different management regimes in temperate grasslands, e.g. *Hypericum maculatum* (Krahulec *et al.*, 2001), *Trifolium repens* (Correll *et al.*, 2003), and *Geranium sylvaticum* (Krahulec *et al.*, 2001; Huhta and Rautio, 1998).

Conclusions

The cover of grasses (both tall and short) was significantly higher on the mown plots during our experiment. On the other hand, abandonment significantly supported the total herb cover, which was mainly formed of tall herbs. Long-term mowing may be needed to reduce the dominance of tall herbs and to maintain a suitable proportion between the dominant species.

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Effects of wood expansion on the specific biodiversity of mountain pastures

Pornaro C., Susan F. and Ziliotto U.

University of Padova, Department of Environmental Agronomy and Crop Productions, Legnaro (Padova), Italy
E-mail: Cri_sti_na@libero.it

Abstract

One of the most negative consequences of the abandonment of mountain pastures is represented by the expansion of trees and shrubs in grazing areas. In order to study the effect of wood expansion on specific biodiversity, ninety sampling areas characterised by increasing tree cover values were studied at 9 different sites. The pastures were clustered according to the main expending wood species: *Fagus sylvatica* L., *Picea abies* L., *Larix decidua* L., and *Pinus mugo* L. In each sampling area a botanical survey was performed, during the year 2006. Specific biodiversity, the Sorensen Similarity Index and forage value were measured. The results suggested that both biodiversity and forage value initially increased when passing from null to low wood cover values, pointing out a dramatic decrease in the case of higher cover values. These effects were evident in *Fagus sylvatica* and *Picea abies* areas, with no significant decreases in *Larix decidua* and *Pinus mugo* pastures.

Keywords: pasture abandonment, wood expansion, specific biodiversity, forage value

Introduction

Until 30 years ago mountain grasslands, usually located below the forest vegetation limit, maintained an artificial equilibrium with the environment, as a result of long-established traditional agro-pastoral activity. When this activity stopped, considerable changes to the pastoral vegetation occurred (Sabatini *et al*., 2000), such as forest expansion and loss of biodiversity.

Nowadays the maintenance of specific biodiversity represents one of the most important purposes of international environmental politics. Consequently, the aim of this study was to deepen knowledge on the effects of abandonment on specific biodiversity (i.e. the number of species) and forage value in some grazing areas overrun with four arboreal species at different wood recovering stages.

Materials and methods

The study area was located in the Sette Comuni upland (Vicenza, NE Italy, 1,000 m a.s.l.). In this site the grazing land is often overrun by the following arboreal species: *Fagus sylvatica*, *Picea abies*, *Larix decidua* and *Pinus mugo*. In the study area 9 pastures were selected so that only one wood species was mainly expanding at each site (Table 1). All the pastures were clustered into 4 groups, according to the dominant arboreal species: Group F (*Fagus sylvatica)*, P (*Picea abies),* L (*Larix decidua*) and M (*Pinus mugo*). For each group 10 sample areas 100 m^2 wide (Pirola, 1960) were chosen in relation to arboreal per cent cover, passing from null to 100% tree cover. At each site, during the year 2006, the botanical composition and per cent cover of all species were estimated, in accordance with the Braun-Blanquet method (Westhoff and Van der Maarel, 1978). Subsequently, the total number of species was compared with the proportion of herbaceous species in order to evaluate the pastures' specific biodiversity. In addition, in each group the Sorensen Similarity Index (*SSI*) was calculated in order to estimate similarity among samples differing in wood cover values in terms of botanical composition. Finally, differences in forage value (*FV*) were analysed, in accordance with Klapp (1971) and Stahlin (1970): with this aim in mind a numerical index was assigned to each species, passing from –1 (i.e. poisonous species) to 8 (i.e. species with a very high forage value).

Results and discussion

Considering the total number of species recorded in the sample areas of each group (Table 1), *Fagus sylvatica* pastures displayed the highest number of species (186), followed by *Picea abies* (162), *Larix decidua* (123) and *Pinus mugo* (90). Herbaceous spe-

Table 1. Specific biodiversity and forage value measurements in the pastures analysed at different wood cover values

	Groups			
	F	P	L	M
Total number of species	186	162	123	90
Total number of herbaceous species	172	151	114	82
0% wood cover				
Total number of species	38	43	45	43
Total number of herbaceous species	36	43	43	42
% of herbaceous species with high *FV* (> 5)	15.51	13.95	12.79	16.66
Total cover of herbaceous species with high *FV*	54.51	30.34	38.92	37.01
Peak wood cover (%)				
P_t	45–50	30–45	–	25–45
P_h	40–45	25–40	–	25–35
Total number of species	57	48	–	47
Total number of herbaceous species	53	51	–	49
% of herbaceous species with high *FV* (> 5)	18.62	11,76	–	12.24
Total cover of herbaceous species with high *FV*	38.13	16.61	–	14.72
SSI	0.61	0.7	–	0.69
100% wood cover				
Total number of species	29	29	45	23
Total number of herbaceous species	24	26	41	21
% of herbaceous species with high *FV*	0.00	0.33	15.85	4.76
Total cover of herbaceous species with high *FV*	2.01	2.32	29.58	1.64
SSI	0.14	0.24	0.24	0.46

cies accounted for 91–93% of the total specific biodiversity in all groups. In Groups F, P, and M specific biodiversity displayed a unimodal pattern passing from null to 100% wood cover, with the highest number of species measured at low or intermediate wood cover values. The per cent arboreal cover in which the peak of total biodiversity (P_t) was measured differed among the groups, and passed from 25–45% in Group M to 40–50% for Group F. In addition, a different peak of the trend (P_h) was measured within each group when only herbaceous species were considered. In contrast, in Group L no correlation was found between the number of species and the arboreal cover. In Group F the number of herbaceous species increased from 36 to 53 (+47%), passing from null to 40–45% wood cover; an analogous trend was also recorded in Group P (+18%) and Group M (+16%). In contrast, passing from 0% to 100% wood cover, the number of herbaceous species dramatically decreased in Groups F (–33.3%), P (–39.53%), and M (–50%), while no significant variations were observed in Group L (–4.6%). The decrease in biodiversity in relation to higher tree cover values was also associated with a shift in botanical composition; the *SSI* values, in fact, were quite high at the peak wood cover (0.66 on average), but clearly decreased when there was 100% tree cover (0.27 on average).

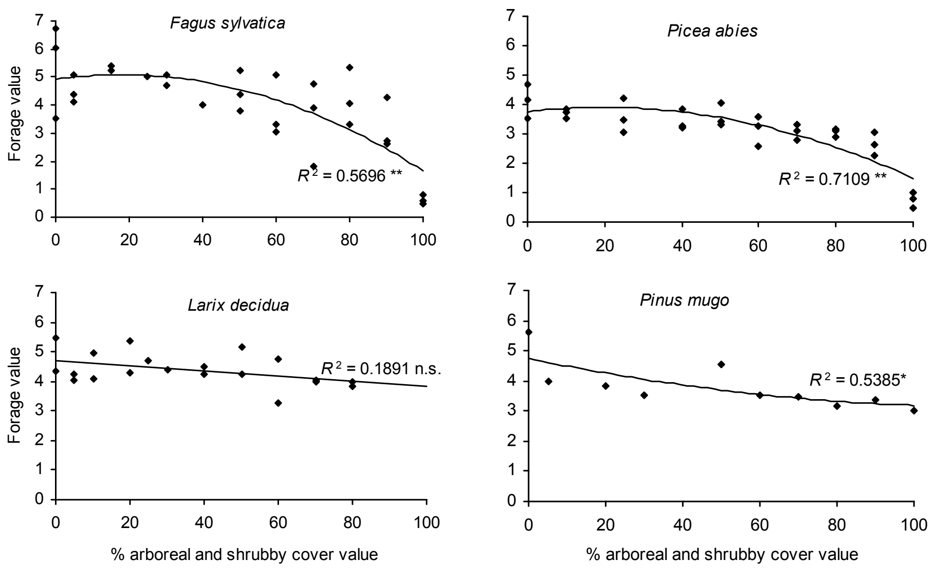

Figure 1. Relation between per cent cover of wood species and forage value of pastures dominated by *Fagus sylvatica*, *Picea abies*, *Larix decidua* and *Pinus mugo*

When the forage value was considered, a similar trend was observed. On the average, the forage value increased slightly when passing from null to low arboreal cover values, and then displayed a dramatic decrease in the case of wood cover values higher than 25% (Figure 1). This trend was observed in the case of *Fagus sylvatica*, *Picea abies* and *Pinus mugo* while the results were not significant in the case of *Larix decidua*. Considering the proportion of high-quality fodder plants (*FV* > 5) in the herbaceous component of the pasture, it was possible to notice that 45–50% cover values of *Fagus sylvatica* led to an increase in the frequency of fodder plants (from 15.61% to 18.62%). In Groups P and M, on the other hand, arboreal cover values and the frequency of good fodder plants were negatively correlated. In Groups F, P, and M fodder plants almost disappeared from the grazing area in the case of maximum tree cover; in contrast, in pastures dominated by *Larix decidua* the proportion of fodder species increased compared to the absence of tree cover, passing from 12.79% to 15.85%. In all groups the total cover of good fodder species decreased when passing from null to 100% tree cover.

Conclusions

In pastures dominated by *Fagus sylvatica*, *Picea abies* and *Pinus mugo*, pasture biodiversity showed a unimodal trend passing from null to 100% of arboreal cover; the highest biodiversity values resulted in the case of low or intermediate cover values. The observed trend was more evident in the case of *Fagus sylvatica*, although no qualitative (i.e. *SSI*) variations were noted among the three groups. The same trend was observed when the forage value of the pastures was considered. On the opposite, in pastures where *Larix decidua* was spread no relationships between the specific biodiversity or forage value with increasing tree cover values were measured.

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Effect of calcified seaweed on nitrogen fixation and yield of legumes in an acid soil

Radic S.[1,3] and McAdam J.H.[1,2]

[1]*Queen's University, Belfast, United Kingdom*
[2]*Agri-Food and Biosciences Institute, Belfast, United Kingdom*
[3]*Magallanes University, Punta Arenas, Chile*
E-mail: sergio.radic@qub.ac.uk

Abstract

Calcified seaweed can improve legume growth on acid and organic soils in the Falkland Islands (FI), by increasing the pH and adding some minerals. The effect of application rate of calcified seaweed (CS) on nitrogen fixation and yield of two forage legumes on an organic acid soil was investigated. In a field experiment in the FI five different rates of CS (0; 0.63; 1.26; 2.5 and 5.0 Mg CS ha^{-1}) were applied to two legumes species (*Lotus uliginosus* var. Maku and *Lotus corniculatus* var. Leo). The ^{15}nitrogen isotope dilution technique was used to measure nitrogen fixation. The experimental design was a randomized block experiment with three blocks. Yield, nitrogen fixed, soil pH, exchangeable calcium (Ca) all increased, and soil exchangeable aluminium (Al) and plant Al concentration decreased with increasing of application of CS. It can be concluded that application rates of CS significantly affected the pH, exchangeable Ca and Al in the soils, and yield, Al content and N fixed for two legumes species. *Lotus uliginosus* responded better than *Lotus corniculatus* over all application rate of CS. This information on levels of nitrogen fixation by legumes in the FI will aid the process of selecting a suitable forage legume.

Keywords: calcium, aluminium, pH, Falkland Islands, legumes

Introduction

Limitations to agricultural production in the FI are poor individual sheep performance in terms of growth rate and fertility. These problems can be related to the poor quality and quantity of the natural grasslands and the adverse climate – mean temperature is 5.6°C and mean annual wind-speed 30 km h^{-1} varying over the year (McAdam, 1985). Forage legumes can help improve this situation as they can fix atmospheric nitrogen (N), and can increase the quality of FI pasture (Parsons, 1997). FI soils have a low pH, low calcium (Ca) and phosphorus (P) (Cruickshank, 2001), and are poor soil conditions for legume growth. Calcified seaweed (CS), an indigenous organic material, can help forage legumes grow, as they could raise soil pH and mineral content. The overall aim of this work was to investigate the effect of application rate of calcified seaweed on nitrogen fixation and yield of two forage legumes on an organic acid soil.

Materials and methods

In a field experiment in the FI (51°00' and 52°30' South, and 57°45' and 61°30' West), five different rates of CS (0; 0.63; 1.26; 2.5 and 5.0 Mg CS ha^{-1}) were applied. CS had

280 g Ca kg^{-1} (mainly as $CaCO_3$). Two legume species (*Lotus uliginosus* var. Maku – LU and *Lotus corniculatus* var. Leo – LC) were sown at 4 kg ha^{-1} per species. A maintenance application of triple super phosphate was applied at 30 kg P ha^{-1}. Each plot (20 m^2) was split in two, one half of the plot with legumes and *Dactylis glomerata* (Cocksfoot) sown separately and another half as a bare soil control. The soil organic matter was 170 g kg^{-1} soil. Plant mineral content analysis was carried out for legumes (aluminium – Al and manganese – Mn). The ^{15}nitrogen (^{15}N) isotope dilution technique was used to measure nitrogen fixation (NF) by Legumes. *Dactylis glomerata* was used as a reference plant, i.e. it is completely dependent on soil N for growth. The method used is highly accurate, utilises differences in ^{15}N enrichment of atmospheric N and soil N enriched with ammonium sulphate (Ledgard and Peoples, 1988). When the experiment finished, the soils were sampled for the first 15 cm for chemical soil analysis. The exchangeable Al extraction was with KCl (1M), Ca extraction was with ammonium acetate (adjusted to pH 7.0), and pH in 0.01M $CaCl_2$ (pHca) was determined with the ratio 1:2.5 (20 mls soil:50 mls 0.01M $CaCl_2$). The experimental design was a randomized block experiment with three blocks and the data were analysed using analysis of variance ($P < 0.05$) with Genstat. The model included rates of CS, species and the interactions of rate x species as sources of variation.

Results and discussion

For Figures 1–3 the values with different lower cases indicate statistically significant differences between rates. At the highest rate of application, LU yielded 3.28 Mg DM ha^{-1} and was fixing 88 kg N ha^{-1} compared to 1.26 Mg DM ha^{-1} and 28 kg N ha^{-1} for LC, respectively. They are the first measures of NF in the region and can help determine which is the most suitable legume for improving the natural grasslands in the FI.

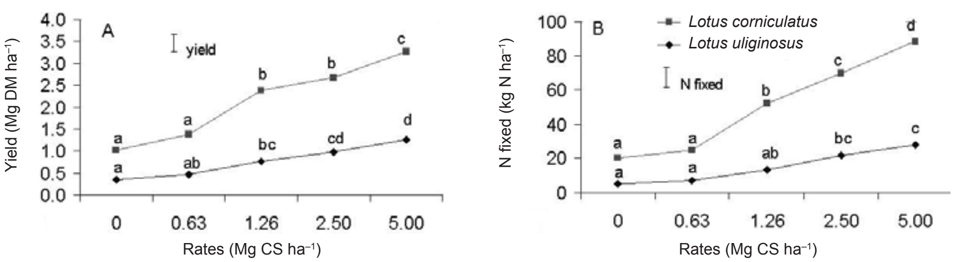

Figure 1. Calcified seaweed effect on dry matter yield (A) and quantity of nitrogen fixed (B) for *Lotus uliginosus* and *Lotus corniculatus*. Bars on graphs are LSD: (A) 0.41; (B) 10.2

Yield and nitrogen fixation of LU was unaffected by the lower two rates of application of CS, but was increased by the higher rates (Figure 1). Yield of LC significantly increased for application rates above 0.63 Mg CS ha^{-1}; and NF increased above 1.26 Mg CS ha^{-1} (Figure 1). LU gave higher yield than LC. Haynes and Ludecke (1981), in a pot experiment, found increments in yield of *Lotus uliginosus* and *Trifolium repens* with increase in lime application.

Plant Mn content was unaffected by CS applications for both species (Figures 2B). Aluminium content of legumes decreased with increment in CS, *Lotus corniculatus* had the highest aluminium concentration (568 mg Al kg^{-1} DM as average for the treatment without CS). Haynes and Ludecke (1981) found decreases in Al with increases in lime application.

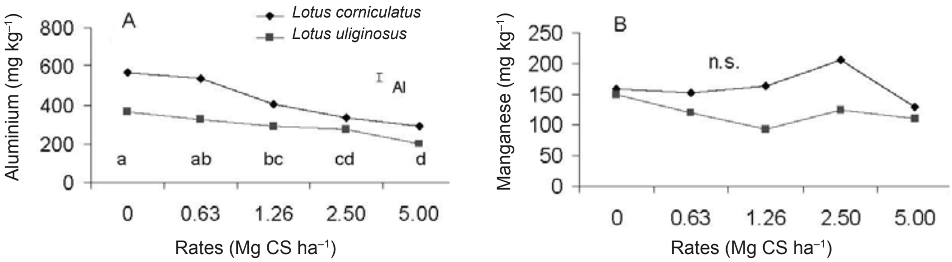

Figure 2. Effect of calcified seaweed rates on aluminium (A) and manganese (B) content for *Lotus uliginosus* and *Lotus corniculatus*. Bars on graphs are LSD: (A) 29.8; (B) n.s.

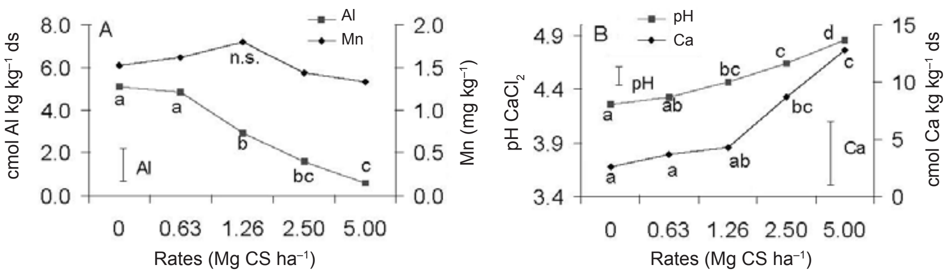

Figure 3. Effect of calcified seaweed rates on soil aluminium and manganese concentration (A) and soil pHCa and exchangeable calcium (B). Bars on graphs are LSD: Al 29.8; pH 0.17; Ca 5.6

At rates of calcified seaweed above 1.26 Mg CS ha^{-1}, pH $CaCl_2$ and Ca concentration were increased (Figure 3B). Exchangeable Al was reduced by CS and Mn was unaffected (Figure 3A). Tye *et al*. (2001) also found increases in calcium and pH following applications of CS and Tye *et al*. (2000) found that CS decreased manganese content.

Conclusions

It can be concluded that application rates of calcified seaweed significantly affected the pH, exchangeable Ca and Al in the soils, and yield, Al content in herbage and N fixed for two legumes species. *Lotus uliginosus* responded better than *Lotus corniculatus* over all application rate of CS. These results of nitrogen fixation by legumes in the Falkland Islands will help local farmers select a suitable forage legume.

Acknowledgements: We acknowledge support from the UK Falkland Islands Trust, Department of Agriculture Falkland Islands Government, Agri-food and Biosciences Institute (AFBI), Queen's University Belfast and Universidad de Magallanes.

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Liming and sewage sludge effects on soil fertility and understorey development in reforested *Pinus radiata* D. Don plantations

Rigueiro-Rodríguez A., Cuiña-Cotarelo R., Fernández-Núñez E. and Mosquera-Losada M.R.

University of Santiago de Compostela, High Polytechnic School, Crop Production Department, Lugo, Spain
E-mail: mrosa.mosquera.losada@usc.es

Abstract

One of the main factor limiting pasture production in Galicia is the important tendency to acidity of its soils, which limits fertility and has made necessary the use of liming. On the other hand, fertilisation is an extended practice to improve forage biomass productivity to compensate for crop extractions, which can be done in an organic or inorganic way. The use of sewage sludge in forest lands is a good way to increase their potential productivity at low cost and limit its contaminant effect. The contaminant effect should be carefully evaluated in very acid soils due to the higher availability of heavy metals in very acid soils. The objective of the study was to evaluate the effect on Zn evolution (soil and pasture) and pasture production of the use, on different dates, of liming and three sewage sludge doses and a no-fertilisation control in silvopastoral systems established in a very acid soil with *Pinus radiata* D. Don and after a pasture had been sown. The different results show that the application of lime and high doses of sewage sludge increased the Zn concentration in the soil, especially when the date of fertilisation was late.

Keywords: silvopasture, organic fertilisation, zinc

Introduction

Agroforestry is an ancient practice in the world, consisting of the combination of a woody component (trees or shrubs) with crops and/or animals in the same land management unit (Rigueiro-Rodríguez *et al*., 2008). Galician soils are characterised by very high acidity, which significantly limits forest growth and potential understorey production, so it is advisable to carry out fertilisation and liming to increase the global agroforestry productivity. Pasture fertilisation with sewage sludge use is promoted by European Union policies because of the recycling of the residue and the improvement in soil fertility that it causes. Because of the higher heavy metal concentration in sludge than soil, the use of sewage sludge in agriculture is limited in Spain by Royal Decree 1310/90. The objective of this experiment was to evaluate the residual effect of liming and the application of three doses of sewage sludge on different dates, on soil and pasture Zn concentration in grass in a silvopastoral system established in a forest area reforested with *Pinus radiata* D. Don.

Materials and methods

The experiment is located in the San Breixo Forest Community (Guitiriz, NW Spain). A plantation of *Pinus radiata* D. Don was established at a density of 1,667 trees ha^{-1} after the harvesting of a pinus radiate stand 30 years old. Scrubland was the main understorey vegetation. When the forestry plants were one year old, in October 1999, an experiment was established in 39 (13 treatments × 3 replicas) experimental units of 12 × 8 m^2, each one consisting of 25 trees arranged in a 5 × 5 frame. The experimental design was a randomised block with three replicates. The treatments consisted of two doses of sewage sludge involving 50 (B: low) and 100 (A: high) kg total N ha^{-1}, applied on three different dates (1. beginning of February; 2. early March, and 3. early April) in limed and unlimed plots. A no-fertilisation (NF) treatment was used as a control. Fertilisation with sewage sludge was conducted during the years 2000, 2001, 2002 and 2003. After the addition of lime a mixture of 25 kg ha^{-1} *Lolium perenne* L. var. Brigantia, 4 kg ha^{-1} *Trifolium repens* L. var. Huia, and 10 kg ha^{-1} *Dactylis glomerata* L. var. Artabro was sown. The sewage sludge was anaerobically stabilised and met the requirements for use in agriculture laid down by Spanish regulation (RD 1310/1990). Three surveys were conducted before each harvest; four samples (each 30 × 30) of pasture were taken in the spring and autumn of 2001, 2002, and 2003. The samples were transported to the laboratory and the Zn concentration of the pasture was estimated (CEM, 1994). Soil samples were taken at the end of 2004 at a depth of 25 cm and conducted to the laboratory, where the Zn (Zn-Me) extracted by the Mehlich method (M3) (Mehlich, 1985) was determined.

Results and discussion

Soil

Zn-Me was significantly higher in those treatments with a high dose of sewage sludge and liming applied on the last date (Figure 1). Lime increases the sewage sludge mineralisation rate, making Zn more available compared with unlimed treatments. On the other hand, higher levels of Zn-Me were found when sewage sludge was applied later in the season, as a result of the lower pasture production of this treatment, which reduced the extraction of this element by pasture from the soil, as found by Mosquera-Losada *et al*. (2001).

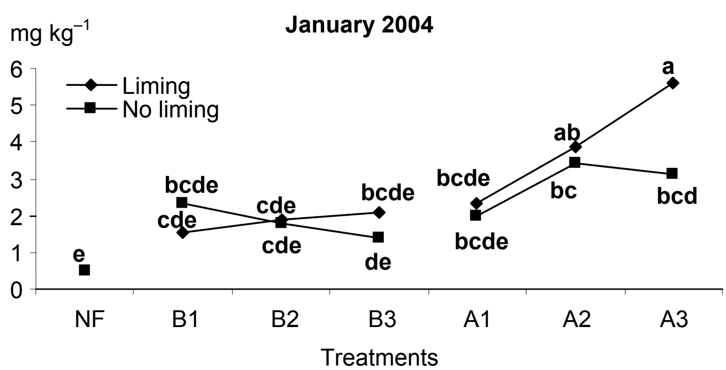
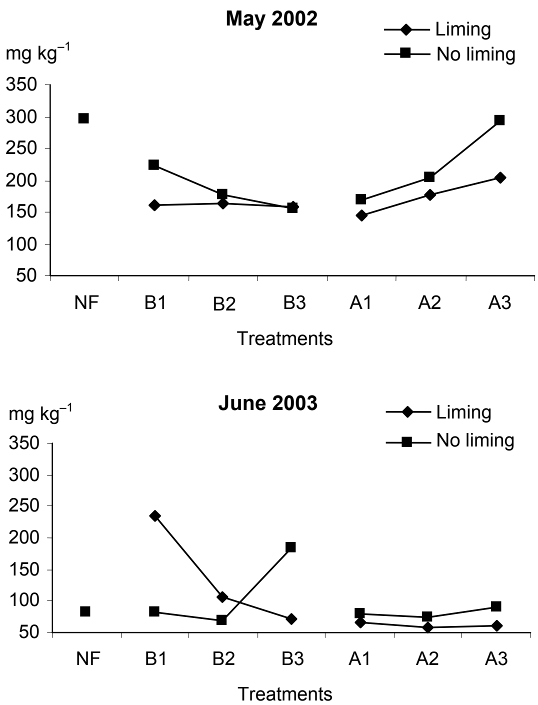


Figure 1. Zinc concentration (mg kg^{-1}) obtained by the Mehlich method for each of the treatments

NF – no fertilisation, B – low dose (50 kg N ha^{-1} total); A – high dose (100 kg N ha^{-1} total): 1, 2, 3 – different dates of application of sewage sludge in February, March, and April. Different letters indicate significant differences between treatments

Pasture

There was no significant effect of treatments on the annual pasture production in 2003, when it varied between 3.8–5.5 t MS ha^{-1}. There was no significant effect on the Zn concentration in grass (Figure 2). However, the zinc concentration in the pasture was very high; this may be the result of the high presence of senescent material and shrubs rich in this element, in this study, but does not exceed the concentration required by the nutritional needs of animals.



NF – no fertilisation, B – low dose (50 kg N ha^{-1} total); A – high dose (100 kg N ha^{-1} total): 1, 2, 3 – different dates of application of sewage sludge in February, March, and April

Figure 2. Zinc concentration in grass (mg kg^{-1}) obtained in each of the samplings conducted during 2002 and 2003 for each of the treatments

Conclusions

Zn-Me was significantly affected by treatments, but this did not affect the Zn concentration in the pasture thanks to the low concentration in bushes and grass. It should be further noted that in none of the five cuts made during the two years covered by our study of Zn concentration in the grass does the concentration exceed that required by the nutritional needs of animals.

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Effect of inorganic and organic fertilisation on sward production and Cu and Fe pasture concentration

Rigueiro-Rodríguez A., García-Fernández M., Santiago-Freijanes J.J. and Mosquera-Losada M.R.

University of Santiago de Compostela, High Polytechnic School, Crop Production Department, Lugo, Spain
E-mail: anriro@lugo.usc.es

Abstract

Sewage sludge production has increased in the last years as a result of the implementation of a European directive, which made it compulsory to have water treatment plants in those cities with more than 2000 inhabitants in all Europe from 2005 on. This directive caused an increment in the production of municipal sewage sludge, which can be used as fertiliser if adequate management is implemented to avoid heavy metal leaching and consumption by animals based on grassland systems. The use of sewage sludge use as fertiliser is regulated in Spain by RD 1310/90, limiting its use because of heavy metal concentration in the soil and in the sludge. The objective of this experiment was to evaluate the effect of eleven treatments (a combination of different doses of sludge with nitrogen and potassium) and two varieties of *Dactylis glomerata* L. (Artabro and Cambria) on forage biomass production. Fertilisation with sewage sludge in high and medium doses increased pasture production compared to low doses, which were favoured by nitrogen and potassium inputs in the first harvest of the year. The application of sewage sludge increased the iron and copper content in the pasture, the response being more important for copper because of the lower soil levels of this element.

Keywords: organic fertiliser, sewage sludge, *Dactylis glomerata* L.

Introduction

The inadequate disposal of sewage sludge can create important environmental problems. Its rational use as fertiliser to increase pasture production could be a good way to dispose of the residue and improve pasture production, as sewage sludge contains appreciable amounts of N and P, which makes it suitable for use as a fertiliser (Smith, 1996). However, it usually has low levels of K, which is necessary to improve legume production. The problem with the use of sewage sludge fertiliser is the fact that it has a higher heavy metal concentration than soil does. The use of sewage sludge as fertiliser depends on the dose, but also on the date and the mineralisation rate once it has been applied. The mineralisation rate depends on the temperature, and if it is low the nutrient availability at the start of the year could be low, delaying the start of the growing season, which will cause an increment in the use of concentrates to feed animals. The aim of this experiment was to evaluate whether or not the combination of K and N at the start of the season with sewage sludge improves pasture production in the conditions found in Galicia and if this modifies the iron and copper concentration in pasture.

Materials and methods

The study was carried out in Lugo (north-west Spain), at an altitude of 452 m a.s.l., latitude of 43º00'N and longitude of 7º32'W and situated in the south-western part of the Atlantic biogeographic region. In the autumn of 1997, two different pasture mixtures were sown: (a) 25 kg ha^{-1} *Dactylis glomerata* L. cv Artabro + 3 kg ha^{-1} *Trifolium repens* L. cv Huia and (b) 25 kg ha^{-1} *Dactylis glomerata* L. cv Cambria + 3 kg ha^{-1} *Trifolium repens* L. cv Huia. The initial soil water pH was 6.5, the total N being 0.12%. Eleven fertilisation treatments of the two previously described varieties of cocksfoot (*Dactylis glomerata* L.) were applied in experimental plots 2 × 4 m^2 in a randomised block design with four replicates. The treatments consisted of three sewage sludge doses (L1: 160 kg total N ha^{-1}; L2: 320 kg total N ha^{-1}; L3: 480 kg total N ha^{-1}), another three treatments with the same sewage sludge doses with the extra addition of 100 kg ha^{-1} K_2O (L1K; L2K; L3K), and another three treatments with the same sewage sludge doses and the application of 100 kg ha^{-1} K_2O and 40 kg ha^{-1} of mineral nitrogen at the start of the growing season (L1NK; L2NK; L3NK).Two control treatments were also established: (a) no fertilisation (NF) and (b) mineral fertilisation (Min), which meant the application of 80 kg N ha^{-1}, 52 kg P ha^{-1}, and 166 kg K ha^{-1} at the start of the growing season and 40 kg N ha^{-1} after the second harvest. These treatments were applied yearly from the spring of 1998. The sewage sludge used derived from the sewage plant of Lugo (Gestagua, S.A.) and met the requirements for use on agricultural land according to the Spanish regulation (RD 1310/1990). Pasture samples were taken in an area of 1.1 × 4 m^2 in April, May. and July of 1999. Subsamples were transported to the laboratory, dried at 60ºC for 48 h, and subsequently weighed. The Fe and Cu concentration in the plants was determined after microwave digestion with nitric acid using a VARIAN 220FS spectrophotometer by atomic absorption (Varian, 1989). ANOVA was used for data analysis and the Duncan test for mean separation.

Results and discussion

The treatments led to significant differences in biomass production for all the harvests, the *Dactylis glomerata* variety treatment only being significant in the third one. The Fe and Cu concentration in the pasture were significantly affected by the treatments in the first harvest.

Table 1. ANOVA of biomass production, Fe and Cu concentrations

Harvest	Production			Fe			Cu		
	treatment	species	Trat*sp	treatment	species	Trat*sp	treatment	species	Trat*sp
1st	***	ns	ns	*	ns	ns	*	ns	ns
2nd	***	ns	ns	ns	ns	ns	ns	ns	ns
3th	***	*	ns	ns	ns	ns	ns	ns	ns

*$P < 0.05$; ***$P < 0.001$; ns – no significance

The lowest biomass production (5.8 Mg ha^{-1}) was found when no fertiliser was applied. The effect of sewage sludge and the different combinations with mineral fertilisers de-

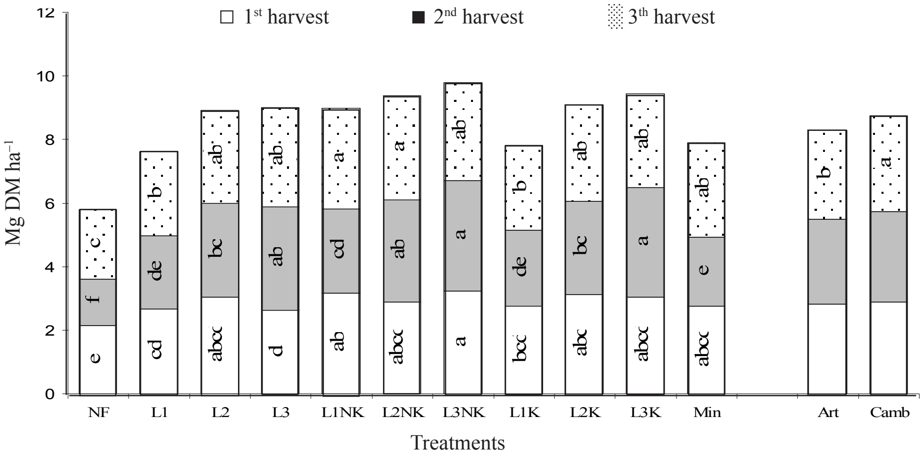

Figure 1. Dry matter production (Mg ha^{-1}) in the spring of 1999 with different fertiliser treatments and cocksfoot varieties

NF – no fertilisation; L1 – low sewage doses (160 kg total N ha^{-1}); L2 – medium sewage doses (320 kg total N ha^{-1}); L3 – high sewage sludge doses (480 kg total N ha^{-1}); K – sewage sludge complemented with 100 kg ha^{-1} K_2O; NK – sewage sludge complemented with 100 kg ha^{-1} K_2O and mineral 40 kg ha^{-1} N; Min – inorganic fertiliser; Art – cv Artabro; Camb: cv Cambria. Different letters indicate significant differences between fertilisation treatments

pended on the harvest. If the April harvest is considered, it can be seen that the combination of sewage sludge and the mineral application as nitrogen + potassium significantly increased pasture production compared with the exclusive application of sludge. This can be explained because the combination of nitrogen and sludge accelerated the mineralisation rate and the degree of incorporation of the nutrients from the sludge. However, no differences were found in the second harvest if we compare the different doses of sewage sludge. Finally, in the autumn, it can be seen that those treatments that previously had higher production are those with high autumn production. This can be explained, because during the summer in the region there is a strong drought which caused the in-

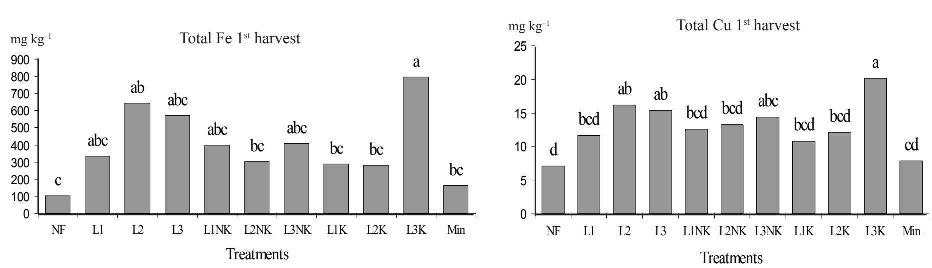

Figure 2. Pasture concentration of Fe and Cu in the first harvest by treatments

NF – no fertilisation; L1 – low sewage doses (160 kg total N ha^{-1}); L2 – medium sewage doses (320 kg total N ha^{-1}); L3 – high sewage sludge doses (480 kg total N ha^{-1}); K – sewage sludge complemented with 100 kg ha^{-1} K_2O; NK – sewage sludge complemented with 100 kg ha^{-1} K_2O and mineral 40 kg ha^{-1} N; Min – inorganic fertiliser. Different letters indicate significant differences between fertilisation treatments corporation of the remains of the unharvested pasture, which can act as a green fertiliser, after the summer harvest.

The iron pasture range was between 36.86–796.1 mg kg^{-1}, being especially high when a combination of a high sewage sludge dose and potassium was applied or when L2 treatment was used. The copper range was between 50 and 300 mg kg^{-1}, described by Whitehead (1995) as being usual in temperate areas. Copper levels were more affected by high doses of sewage sludge treatments, being, together with L2, significantly higher than NF treatment. The different amounts of Fe and Cu in the pasture can be explained because the levels of iron in the soil were higher, so even if more iron was applied with the sewage sludge compared with the dose of copper applied, the higher levels of iron in the soil reduced the differences in the concentration of this element in the pasture, compared with copper. All treatments and all harvests produced forage with enough iron and copper (50 mg kg^{-1} and 7 mg kg^{-1} respectively) for bovine nutrition, and the levels of these were never toxic in terms of animal nutrition (NRC, 2001).

Conclusions

At the beginning of the season mineral nitrogen is needed to speed up the mineralisation process of the sewage sludge. In autumn the response of the pasture production to the sewage sludge depended positively on the pasture production of the previous spring. The response of the copper concentration in the pasture to the application of a dose of sewage sludge was more important than that of the iron, because of the lower levels of copper in the soil compared with iron, and despite the higher dose of iron applied with the sewage sludge.

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Effect of autumn fire on microbial biomass content and dehydrogenase activity in two grassland soils

Russel S.[1], Olejniczak I.[2], Prędecka A.[3], Chojnicki J.[4] and Barszczewski J.[5]

[1]Warsaw University of Life Science and Institute of Soil Reclamation and Grassland Farming, Falenty, Poland
[2]Centre for Ecological Research, Dziekanów Leśny, Poland
[3]The Main School of Fire Service, Warsaw, Poland
[4]Warsaw University of Life Science, Soil Science Department, Warsaw, Poland
[5]Institute of Soil Reclamation and Grassland Farming, Falenty, Poland
E-mail: stefan_russel@sggw.pl

Abstract

The effect of grassland burning on the content of soil microbial biomass and soil dehydrogenase activity was determined in mesocosm scale experiments established on Experimental Fields of the Institute for Soil Reclamation and Grassland Farming at Falenty near Warsaw, Poland. Experimental circular mesocosms, 1m in diameter, were located on two meadows: one on mineral soil (Janki) and the second one on peat soil (Puchały). The grassland mesocosms were burnt at the end of November, 2007. The soil samples were taken directly after the meadows were burnt and on April, July and November, 2008 from two levels 0–5 cm and 5–10 cm of non-burned sites (control), ecotones and burned mesocosms. The soil microbial biomass was determined by the chloroform fumigation – extraction method. The dehydrogenase activity in soil was measured using the TTC method. It was established that experimental grassland burning affected soil microbial biomass and dehydrogenase activity. The decrease of microbial biomass and activity of dehydrogenase after grassland fire was observed mainly in the case of surface soil levels and in the first months of the experiment.

Keywords: fire, grassland, microbial biomass, dehydrogenase activity, soil

Introduction

In Poland some groups of people, both on rural and urban areas, burn grassland especially weedy plants for aesthetic and sanitary reasons, because it seems to be simple to execute and contro1. The burning of weedy grasses and herbs is still common in Poland among many pastorals and rural people although not allowed by law. The ease with which grasslands are ignited, however, led to cases of senseless, promiscuous, and destructive burning. These type of practices are commonly regarded by officials as dangerous because they often lead to buildings and forests fires.

The biological role of controlled and uncontrolled grassland fires is still discussed. It is not doubted that grassland fires modify the physical, chemical and biological characteristics of soil. Prescribed burning is often suggested for use by farmers because it does not reduce the species biodiversity and may even increase it by promoting the growth of additional grasses, legumes and other species.

There have been only a few studies on the direct effect of grassland and forest fires on soil microbial biomass and soil enzyme activity. The action of fire modifies the soil environment, so changes in biological activity of the soil may be expected following burning.

The aim of present paper is to study of the influence of experimental grassland fire on soil biological activity measured by biomass and dehydrogenase activity.

Materials and methods

The effect of experimental grassland fire, ignited at the end of plant vegetation season, on soil microbial biomass and dehydrogenase activity was investigated in mesocosm scale studies established on Experimental Fields of Institute of Soil Reclamation and Grassland Farming at Falenty near Warsaw, Poland. Experimental, circular mesocosms, 1 m in diameter, were located on two meadows, one cultivated on mineral soil (Janki), the second one on peat soil (Puchaly). The burning was done at the end of November 2007. The soil samples were taken directly after burning and on April, July and November, 2008 from two levels, 0–5 cm and 5–10 cm of non-burned sites (control), ecotones and burned mesocosms. The soil samples were collected randomly from several places on each burning site using Egner's stick and placed into polyethylene bags and taken to laboratory for immediate analysis.
The soil microbial biomass content was determined by chloroform fumigation-extraction method. The soil dehydrogenase activity was measured using triphenyltetrazolium chloride (TTC) method.
The results were submitted to variance analysis and the means compared by the test of Tukey with $P < 0.05$.

Results and discussion

Soil biological activity may be measured using different indicators. In the present work the soil microbial biomass content and dehydrogenase activity were used to determine of effects on soil organisms activity, as shown in Table 1.

Table 1. Microbial biomass content in soil samples (in µg C g^{-1} d.m. of soil) taken from depth 0–5 and 5–10 cm of burned sites, ecotones and no-burned sites of two meadows located in Janki and Puchały

Name of meadow	Site and dept of sample collection (cm)	Time of analysis			
		Nov., 2007	April, 2008	July, 2008	Nov., 2008
Janki	Fire 0–5	110.2	137.0	144.8	130.3
	5–10	90.2	100.4	110.4	109.8
	Ecotone 0–5	129.0	135.1	137.5	135.2
	5–10	102.0	112.0	105.8	105.9
	Control 0–5	139.2	142.1	140.2	137.5
	5–10	100.2	114.7	110.9	107.5
Puchały	Fire 0–5	235.2	275.4	300.0	302.4
	5–10	225.2	300.3	322.9	306.0
	Ecotone 0–5	250.2	358.0	361.5	378.1
	5–10	300.1	328.4	336.6	350.0
	Control 0–5	375.2	407.9	411.5	367.2
	5–10	310.2	350.4	360.9	333.5

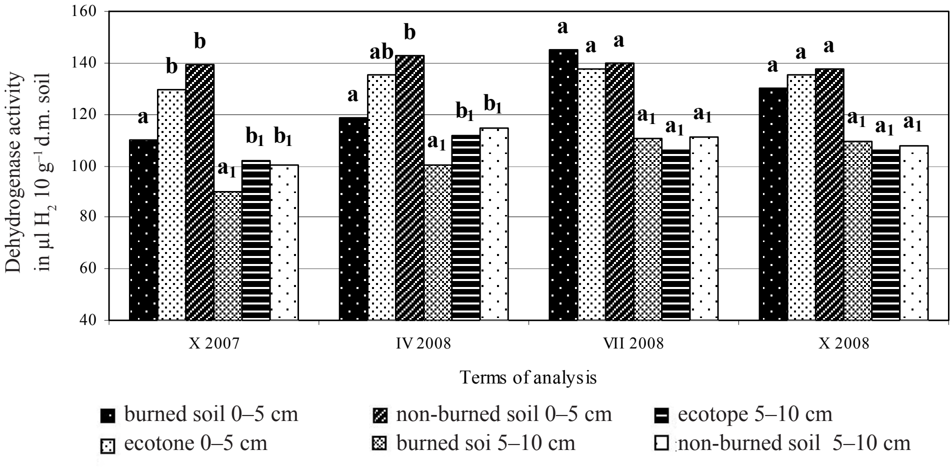

Figure 1. Effect of fire on dehydrogenase activity of soil samples taken from meadow located at Janki ($P = 0.05$)

It was found that microbial biomass content in soils of both studied meadows depended on type of grassland and the date and soil level of sample collections. The same relationship was observed in the case of dehydrogenase activity in both soils (Figures 1 and 2). The organic soil contained higher amounts of microbial biomass and showed higher enzyme activity than mineral soil because of the availability of carbon nutrients. A strong effect of fire on microbial biomass content was observed for all dates of analysis in organic soil in both in surface and subsurface samples. This was probably due to higher biomass of plants on organic soil, so the load and temperature of fire in this condition would also have been higher. In both soils the effect of burning decreased with the

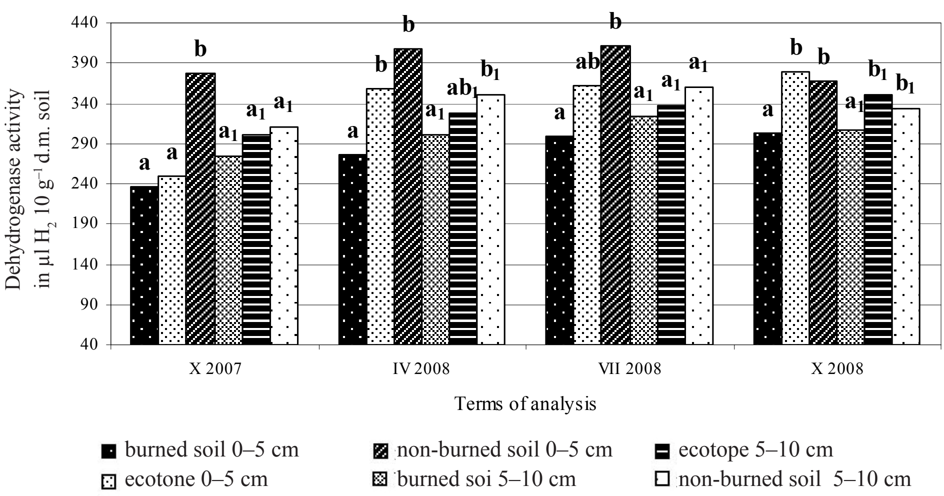

Figure 2. Effect of fire on dehydrogenase activity of soil samples taken from meadow located at Puchały ($P = 0.05$)

course of time. At the end of the studies, the content of microbial biomass returned to levels chracteristic of the control sites.
The effect of fire on soil dehydrogenase activity was smaller than on microbial biomass.
Practically, the influence of fire on dehydrogenase activity was limited to surface layer. There was slightly morer sensitivity to temperature for the dehydrogenase activity in organic soil than in mineral one. The experimental fires were done at the and of autumn. This was at the end of the vegetation season, but water content in soil and atmospheric air was quite high. This may have contributed to the rather small effects of fire on soil biology observed here.
The results indicate the high potential for the restoration of these soils after damage to biological activity caused by fire.

Conclusions

The experimental fires carried out on two meadows, one on mineral soil and the second on organic soils, decreased soil biological activity with the effects being greatest in the soil surface level of the organic soil. The effects, however, decreased with time after burning, indicating that these aspects of soil biology have high restoration potential following fire.

Management of permanent grasslands in North-Eastern Romania

Samuil C.[1], Vintu V.[1], Iacob T.[1], Saghin Gh.[2] and Trofin A.[1]

[1]University of Agricultural Sciences and Veterinary Medicine, Iasi, Romania
[2]Agricultural Research and Development Station, Suceava, Romania
E-mail: csamuil@univagro-iasi.ro

Abstract

From the point of view of the total natural grassland area, Romania is in 5 place in Europe, after France, the United Kingdom, Spain, and Germany. The total area in Romania is 4.9 million ha (Zimkova *et al.*, 2007), of which 3.4 million ha is grassland and 1.5 million ha hayfields, which is an important source of fodder for animal feed. This paper shows the influence of sustainable management, applied in the permanent grasslands found at a height of 120 m, in the forest-steppe zone of Ezareni, Iasi County, on the production and the quality of the fodder obtained. In an experiment carried out at Ezareni, we studied the influence of organic fertilisers, applied at rates of 10–40 Mg ha^{-1}, on the soil background of $N_{50-100}P_{36-72}$, on the fodder content and yield, and on the flower and chemical composition.

Keywords: grassland, manure, *Festuca valesiaca*, fertilisation, yield

Introduction

The reduction of the productive potential of the permanent grasslands of north-eastern Romania, over 65–70% of which are found on slope fields, is caused by erosion, to which unfavourable climatic conditions and their wrong management may be added (Samuil *et al*., 2007). The productive potential of these grasslands can be increased by fertilisation with different rates and types of organic and mineral fertilisers (Cardaşol, 1994). Investigations carried out until today have shown the positive effects of manure, combined with moderate rates of mineral fertilisers, which are applied to grasslands. If applied rationally, they can entirely replace chemical fertilisers (Jeangros *et al*., 2003). Manure has a positive effect on the plant nutrition regime and can improve the thermic and aeration regime of the soil, intensify the activity of the microorganisms in the soil, and have a favourable effect on the development of vegetation. This paper presents the results obtained during 2006–2008, on *Festuca valesiaca* L. permanent grassland, improved by fertilisation with different rates and combinations of organic and mineral fertilisers.

Materials and methods

The trial was carried out on *Festuca valesiaca* L. permanent grassland with a low plant composition, situated at a height of 107 m, on a 10% slope. The soil was cambic chernozem, weakly leached, with a clayey texture, a pH of 6.5–6.7, and a mobile phosphorus content of 25–30 mg kg^{-1} and a mobile potassium content of 300–350 mg kg^{-1}, at a depth of 0–30 cm. The climatic conditions during the testing period were characterised by mean temperatures of 9.5°C and mean total rainfalls of 552.4 mm. We should also mention that at Ezăreni – Iaşi, the year 2007 was extremely dry and the climatic conditions in that year were highly unfavourable to the good development of vegetation on grasslands. The experimental factors were: V_1 – unfertilised control; V_2 – 10 Mg ha^{-1} cattle manure applied every year + N 50 kg ha^{-1} + P 36 kg ha^{-1}; V_3 – 10 Mg ha^{-1} cattle manure applied every year + N 50+50 kg ha^{-1} + P 72 kg ha^{-1}; V_4 – 20 Mg ha^{-1} cattle manure applied every 2 years + N 50 kg ha^{-1} + P 36 kg ha^{-1}; V_5 – 20 Mg ha^{-1} cattle manure applied every 3 years + N 50+50 kg ha^{-1} + P 72 kg ha^{-1}; V_6 – 30 Mg ha^{-1} cattle manure applied every 3 years + N 50 kg ha^{-1} + P 36 kg ha^{-1}; V_7 – 30 Mg ha^{-1} cattle manure applied every 3 years + N 50+50 kg ha^{-1} + P 72 kg ha^{-1}; V_8 – 40 Mg ha^{-1} cattle manure applied every 3 years + N 50 kg ha^{-1} + P 36 kg ha^{-1}; V_9 – 40 Mg ha^{-1} cattle manure applied every 3 years + N 50+50 kg ha^{-1} + P7 2 kg ha^{-1} (N = nitrogen; P = phosphorus). Harvesting was carried out at the time of the formation of the ears of the dominant grasses, and the yield was expressed in dry matter (DM). The changes that took place in the structure of the canopy were determined through the gravimetrical method.

Results and discussion

Analysing the production data, one may notice that in 2006, they varied between 2.30 Mg ha^{-1} DM for the control and 4.66 Mg ha^{-1} DM for fertilisation with 40 Mg ha^{-1} cattle manure, applied every 3 years + N_{50+50} kg ha^{-1} + P72 kg ha^{-1} (Table 1). The highest yields were recorded for fertilisation with 40 Mg ha^{-1} cattle manure, applied every 3 years, combined with mineral fertilisers of 3.90 Mg ha^{-1} DM and 4.66 Mg ha^{-1} DM, respectively. In 2007, the vegetation of permanent grasslands was highly affected by the long-term drought that dominated the testing area of Ezăreni from September 2006 until August 2007. Therefore, the productivity was greatly diminished, resulting in a very low effect of fertilisation on production. In that year, yields varied between 1.52 Mg ha^{-1} DM for the unfertilised control and 2.62 Mg ha^{-1} DM for fertilisation with 40 Mg ha^{-1} cattle manure, applied every 3 years + N 50+50 kg ha^{-1} + P 72 kg ha^{-1} The uniformity of the yields may be noticed, irrespective of the fertilisation level used. The yields obtained in 2008 were higher than those obtained in the previous years, varying between

Table 1. Influence of fertilisation on dry matter production (Mg ha^{-1})

Fertilisation variant	Ezăreni – Iaşi			
	2006	2007	2008	Average
Unfertilised control	2.30	1.52	6.22	3.35
10 Mg ha^{-1} cattle manure applied every year + N_{50} P_{36}	3.40	2.18	8.69	4.76*
10 Mg ha^{-1} cattle manure applied every year + N_{50+50} P_{72}	3.72	2.42	9.44	5.19*
20 Mg ha^{-1} cattle manure applied every 2 years + N_{50} P_{36}	3.50	2.26	8.96	4.91*
20 Mg ha^{-1} cattle manure applied every 3 years + N_{50+50} P_{72}	3.93	2.49	10.27	5.56**
30 Mg ha^{-1} cattle manure applied every 3 years + N_{50} P_{36}	3.92	2.57	8.36	4.95*
30 Mg ha^{-1} cattle manure applied every 3 years + N_{50+50} P_{72}	4.12	2.61	10.31	5.68**
40 Mg ha^{-1} cattle manure applied every 3 years + N_{50} P_{36}	3.90	2.31	9.26	5.16*
40 Mg ha^{-1} cattle manure applied every 3 years + N_{50+50} P_{72}	4.66	2.62	11.26	6.18***
Average	**3.72**	**2.33**	**9.20**	**5.09**

*LSD 5%; **LSD 1% ; ***LSD 0.1%

6.22 Mg ha^{-1} DM for the unfertilised control and 11.26 Mg ha^{-1} DM for fertilisation with 40 Mg ha^{-1} cattle manure, applied every 3 years + N 50+50 kg ha^{-1} + P 72 kg ha^{-1}. The mean yields obtained during 2006–2008 varied between 3.35 Mg ha^{-1} DM for the control and 6.18 Mg ha^{-1} DM for fertilisation with 40 Mg ha^{-1} cattle manure, applied every 3 years + N 50+50 kg ha^{-1} + P 72 kg ha^{-1}. Analysing the mean yields, we found that their augmentation was due to an increase in the rate of manure applied and, especially, to an increase in the rate of mineral fertilisers.

The analysis of the canopy structure shows that the mean recorded values of the presence percentage were 68% for grasses, 13% for legumes, and 19% for other species (Table 2).

Table 2. Influence of fertilisation on the canopy structure (%)

Fertilisation variant	Grasses	Legumes	Others
Unfertilised control	69	10	21
10 Mg ha^{-1} cattle manure applied every year + N_{50} P_{36}	76	13	11
10 Mg ha^{-1} manure applied every year + N_{50+50} P_{72}	59	16	25
20 Mg ha^{-1} cattle manure applied every 2 years + N_{50} P_{36}	70	11	19
20 Mg ha^{-1} cattle manure applied every 3 years + N_{50+50} P_{72}	67	15	18
30 Mg ha^{-1} cattle manure applied every 3 years + N_{50} P_{36}	62	11	27
30 Mg ha^{-1} cattle manure applied every 3 years + N_{50+50} P_{72}	68	16	16
40 Mg ha^{-1} cattle manure applied every 3 years + N_{50} P_{36}	71	12	17
40 Mg ha^{-1} cattle manure applied every 3 years + N_{50+50} P_{72}	69	11	20
Average	**68**	**13**	**19**

The most important changes were found in the plants belonging to the "various" group, which showed significant increases at the same time as the increase in the applied manure rate. In the *Festuca valesiaca* grassland of Ezăreni, a total number of 40 species was recorded, of which six species were grasses, 10 species belonged to the fabaceae, and 24 species to the "other species" category. The species which were found at high percentages were *Festuca valesiaca* (39%), *Bromus commutatus* (5%), *Trifolium pratense* (7%), *Medicago falcata* (3%), *Plantago media* (3%), and *Achillea setacea* (4%).

Table 3. Influence of fertilisation on the chemical composition

Fertilisation variant	CP (g kg^{-1})	CF (g kg^{-1})	Mean yield of RP (kg ha^{-1})
Unfertilised control	9.01	24.22	302
10 Mg ha^{-1} cattle manure applied every year + N_{50} P_{36}	9.06	24.12	431
10 Mg ha^{-1} manure applied every year + N_{50+50} P_{72}	9.22	24.01	479
20 Mg ha^{-1} cattle manure applied every 2 years + N_{50} P_{36}	9.51	23.98	470
20 Mg ha^{-1} cattle manure applied every 3 years + N_{50+50} P_{72}	9.94	23.89	553
30 Mg ha^{-1} cattle manure applied every 3 years + N_{50} P_{36}	10.25	23.88	507
30 Mg ha^{-1} cattle manure applied every 3 years + N_{50+50} P_{72}	10.64	23.78	604
40 Mg ha^{-1} cattle manure applied every 3 years + N_{50} P_{36}	10.38	23.82	536
40 Mg ha^{-1} cattle manure applied every 3 years + N_{50+50} P_{72}	10.55	23.80	652

Table 3 shows the values of crude protein (CP), crude cellulose (CF), and protein yield ha^{-1}. The yield of crude protein was influenced by the percentage of raw protein and the yield of DM, varying between 302 kg ha^{-1} DM for the control and 652 kg ha^{-1} DM for fertilisation with 40 Mg ha^{-1} cattle manure, applied every 3 years + N 50+50 kg ha^{-1} + P 72 kg ha^{-1}.

Conclusions

The DM yields obtained were influenced by climatic conditions and the type and level of organic and mineral fertilisation.
In all the three testing years, the highest yields were obtained for fertilisation with 40 Mg ha^{-1} cattle manure, applied every 3 years + N 50+50 kg ha^{-1} + P 72 kg ha^{-1}.
The obtained results show the positive effects of fertilisation on the productivity, biodiversity, and canopy structure of the permanent grassland that was studied.
The crude protein yield was influenced by the crude protein percentage and by the DM production.

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The influence of white and red clover and wheat cultivation methods on some soil parameters

Sarunaite L., Kadziuliene Z. and Kadziulis L.

Lithuanian Institute of Agriculture, Dotnuva Akademija, Kedainiai, Lithuania
E-mail: lina@lzi.lt

Abstract

An experiment was conducted at the Lithuanian Institute of Agriculture to study the cultivation of cereals and clover in a bi-cropping system and to ascertain the effects of clover on soil properties. The pre-crops for winter wheat were white and red clover and perennial ryegrass. In the autumn of the sowing year winter wheat was sown conventionally and direct-drilled in the clover swards. The concentration of soil N_{min} at a depth of 0–60 cm was the highest in the autumn and at the wheat maturity stage after the clover. The soil bulk density at a depth of 0–10 cm was higher in the wheat bi-cropping system. A better soil aggregate stability was achieved in the autumn when winter wheat had been direct-drilled into the swards. During the whole winter wheat growing season the content of 1 mm soil aggregates tended to increase in the bi-cropping system.

Keywords: clover, mineral nitrogen, soil aggregate, bi-cropping

Introduction

Sustainable agricultural systems have become one of the most important issues, because intensive agricultural activities accelerate the degradation of soil (Pathak *et al*., 2005). Our experimental period was too short to determine significant changes in the soil, which generally take a longer period (Masto *et al*., 2007). The changes and trends depend on many factors, such as soil and climate conditions, the amount of plant residues and their chemical composition, and others. The aim of our experiment was to ascertain the influence of winter wheat pre-crops (red and white clover and ryegrass) and winter wheat sowing methods on the stability of soil properties. The data on the amount of soil N_{min} and structure were analysed. The soil indicators were chosen from the list recommended by Lal (2004) for minimum soil indicators necessary for soil quality description.

Materials and methods

The experiment was conducted during 2004–2005 at the Lithuanian Institute of Agriculture in Dotnuva (55°24'N) on a loamy *Endocalcari-Epihypogleyic Cambisol*. The soil pH varied between 7.3 and 7.5, the humus content was 2.3%, available P 170–182 mg kg^{-1} and K 162–168 mg kg^{-1}. Red clover (*Trifolium pratense* L.), white clover (*Trifolium repens* L.), and perennial ryegrass (*Lolium perenne* L.) were sown in the spring of the first experimental year (Table 1). Winter wheat (*Triticum aestivum* L.) for grain was sown in the autumn of the same year. The clover, prior to winter wheat undersowing, was cut, and the herbage was weighed and spread on the plots.
In the autumn, the wheat was sown conventionally (CD) and among legumes (DD), forming a bi-cropping system. The layout was a randomised block design with four rep-

Table 1. Experimental design

In the 1st experimental year		In the 2nd experimental year	
Wheat pre-crops[1] in the spring		winter wheat sowing method[2] in the autumn in the pre-crops	
White clover	Wcl[1]	conventional drilling	CD[2]
White clover	Wcl[1]	direct drilling (bi-cropping: winter wheat + white clover)	DD[2]
Red clover	Rcl[1]	conventional drilling	CD[2]
Red clover	Rcl[1]	direct drilling (bi-cropping: winter wheat + red clover)	DD[2]
Perennial ryegrass	Pr[1]	conventional drilling	CD[2]

[1]Pre-crops: Wcl – white clover, Rcl – red clover, Pr – perennial ryegrass; [2]Wheat sowing method: CD – conventional drilling, DD – direct drilling

licates. The amount of inorganic soil nitrogen (N_{min}) was measured in the autumn and in the following year during the main wheat growth stages. For analysis, soil samples were taken from the 0–30 cm and 30–60 cm depths. The amount of N_{min} was determined by adding up the amounts of NO_3^- and NH_4^+.

The soil bulk density (BD) was determined according to the Kachinsky method using a 100 cm³ cylinder drill at the soil depths 0–5, 5–10, 10–15, and 15–20 cm, and the soil aggregate water stability was determined according to Savinov's method (Hakansoon, 1990). The dry matter yield was determined on the basis of the total amount of dry matter per plot and calculated as kg DM yield ha^{-1}. The experimental data were statistically processed using analysis of variance and correlation-regression methods. The 'Fisher protected' post hoc test was used.

Results and discussion

N_{min} depended on different pre-crops and growing conditions. A higher N_{min} content in the soil at the 0–60 cm depth was identified in all cases when winter wheat had been sown after the ploughing-in of pre-crops (Table 2).

In all treatments, the content of N_{min} in the soil in spring and at booting and heading was lower than that in the autumn before the sowing of the winter wheat. Although we did not measure the rainfall in detail, it might have had some effect on the lower content of

Table 2. The amount of inorganic nitrogen in the soil at a depth of up to 60 cm in the main wheat growth stages, and winter wheat grain yield

Sown plants[1] + method[2]	Soil $N_{min.}$ pool mg kg^{-1}										Grain yield (kg ha^{-1})
	autumn		spring		booting		heading		maturity		
	0–30	30–60	0–30	30–60	0–30	30–60	0–30	30–60	0–30	30–60	
Wcl – CD	4.71	4.9	2.52	3.76	2.55	2.83	2.54	2.52	4.81	4.24	3,005
Wcl – DD	2.82	2.67	2.76	3.24	2.46	2.20	3.11	2.63	7.33	5.30	1,446
Rcl – CD	3.36	4.52	3.49	4.42	1.91	2.24	2.63	2.56	5.73	4.66	3,660
Rcl – DD	2.42	2.34	2.41	2.79	2.52	2.58	2.98	2.91	5.19	4.30	948
Pr – CD	2.29	2.51	2.22	3.71	1.95	2.39	2.65	2.45	4.53	4.14	1,729
$P < 0.05$	0.94	0.51	0.63	1.05	0.61	0.76	0.43	0.51	1.27	0.50	316.3

N_{min} during the winter. At the maturity stage, before the harvesting of the winter wheat, N_{min} was found to be higher than that during the growing season in all treatments, especially when the clover had been left after the direct drilling of the wheat.

A significantly higher winter wheat grain yield was achieved in the ploughed-in plots after white and red clover than after perennial ryegrass.

The results show that the winter wheat sowing method influenced the soil bulk density (BD). The bulk density was similar in the treatments where clover and ryegrass had been ploughed in Table 3. However, the trend of BD increasing was recorded after the direct drilling of winter wheat into growing clover compared with conventional drilling.

Researchers have highlighted the importance of the physical environment of the soil for plant growth and for the chemical condition of the soil (Drury *et al*., 2003). Our investigations revealed a strong linear correlation ($R^2 = 0.72$) between the wheat grain yield and soil N_{min} at the depth of 0–60 cm (sum of 0–30 and 30–60 cm) in the autumn. The wheat grain yield was higher in the following year, when the crop had been tilled better in the autumn. No correlation was found during intensive wheat growing (booting and heading); this shows that wheat grew better as a result of other factors and utilised more N_{min}. Polynomial regression between BD at the soil depth of 0–10 cm and N_{min} at the depth of 0–30 cm was strong: in spring ($R^2 = 0.87$), at booting ($R^2 = 0.68$), and at heading ($R^2 = 0.70$), when the wheat root system developed intensively and more nutrients were needed for this. In the autumn (at maturity), the regression index showed that the correlation between N_{min} and BD was weaker ($R^2 = 0.46$) and the soil N_{min} and BD were interdependent.

Table 3. The BD of the plough layer and soil aggregate content during the winter wheat growing period

Sown plants[1] + method[2]	Soil depth (cm)	Density of plough layer ($Mg\ kg^{-1}$)			Soil aggregates (mm, %)					
		autumn	spring	autumr	autumn		spring		autumn	
					> 1	> 0.25	> 1	> 0.25	> 1	> 0.25
Wcl – CD	0–10	1.44	1.34	1.48	10.4	60.6	9.7	61.3	14.5	59.6
	10–20	1.40	1.40	1.51	12.3	61.9	12.0	62.8	15.9	61.7
Wcl – DD	0–10	1.38	1.39	1.38	13.7	62.3	12.4	60.3	15.4	56.5
	10–20	1.42	1.38	1.41	14.7	62.9	10.6	59.4	15.9	56.1
Rcl – CD	0–10	1.28	1.28	1.34	10.1	60.1	11.8	59.5	15.7	57.4
	10–20	1.32	1.32	1.49	9.12	57.6	13.0	61.7	17.3	62.7
Rcl – DD	0–10	1.38	1.35	1.38	11.9	63.1	11.0	62.0	22.2	61.8
	10–20	1.43	1.37	1.30	13.4	64.6	8.6	59.0	17.5	61.9
Pr – CD	0–10	1.35	1.32	1.53	9.82	57.7	10.3	59.3	16.0	58.4
	10–20	1.35	1.36	1.49	11.2	59.6	11.6	58.2	21.3	63.4
$P < 0.05$	0–10	0.082	0.045	0.143	1.78	1.82	2.97	1.99	2.26	1.88
	10–20	0.082	0.049	0.074	1.79	1.97	2.72	3.26	1.77	1.70

[1]Pre-crops: Wcl – white clover, Rcl – red clover, Pr – perennial ryegrass; [2]Wheat sowing method: CD – conventional drilling, DD – direct drilling. Autumn – shortly after wheat sowing, spring – upon resumption of vegetation, autumn – at harvesting wheat

Regardless of the soil tillage, the soil structure did not change significantly during the short experimental period, but our data suggested some trends. The amount of soil aggregates > 1 and > 0.25 mm in the soil depended on the pre-crops of the winter wheat. The amount of the above-mentioned soil aggregates exhibited similar increasing trends during the whole winter wheat growing period. In the autumn (shortly after the sowing of the wheat), a higher content of such soil aggregates was found in the bi-cropping system. The amount of soil aggregates > 1 mm in the soil under winter wheat increased throughout the whole growing period and at harvesting it had increased by 1.5–2 times.

Conclusions

A higher amount of N_{min} at the soil depth of 0–60 cm was identified in the treatments where winter wheat had been sown conventionally. Bulk density was higher at the depth of 0–10 cm in the wheat bi-cropping system. Significantly more agronomically valuable soil aggregates were determined in the bi-cropping system compared with the conventional sowing system. The content of soil aggregates > 0.25 or 1 mm increased in the soil in the bi-cropping system compared with that in the conventional system.

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Influence of preparatory cut and harvest date on the yields and quality of perennial grasses

Skládanka J.[1], Nedělník J.[2], Doležal P.[1] and Moravcová H.[2]

[1]*Mendel University of Agriculture and Forestry in Brno, Department of Animal Nutrition and Forage Production, Brno, Czech Republic*
[2]*Research Institute for Fodder Crops, Ltd., Troubsko, Czech Republic*
E-mail: sklady@mendelu.cz

Abstract

The paper compares the quality of *Festulolium*, *Dactylis glomerata*, and *Arrhenatherum elatius* at the end of the growing season under the climatic conditions of Central Europe (Czech Republic) during three years. The parameters assessed are the influence of the date of the preparatory cut (June or July) and the harvest date (October, November, and December) on the yield of dry matter (DM), digestibility of organic matter (DOM), and the contents of crude protein (CP) and crude fibre (CF). *Arrhenatherum elatius* had significantly ($P < 0.05$) higher yields than *Festulolium* and *Dactylis glomerata*. The yields of swards with their preparatory cut in June were significantly higher ($P < 0.01$). *Festulolium* had a low CF content. In contrast, the content of CP was higher in *Arrhenatherum elatius* and *Dactylis glomerata*. The species and date of the preparatory cut and harvest affected the forage quality towards the end of the growing season highly significantly ($P < 0.01$). None of the species can be unambiguously eliminated from a possible extension of the grazing period.

Keywords: *Festulolium*, *Dactylis glomerata*, *Arrhenatherum elatius*, digestibility of organic matter, crude protein, crude fibre, winter grazing

Introduction

Winter grazing is extended mostly in continental overseas conditions but also in the United Kingdom or in Ireland (Hennessy *et al.*, 2006). Whole-year grazing is also possible in the conditions of Central Europe (Deblitz *et al*., 1993). Grass species for swards to be used at the end of the growing season should provide adequate yields and high forage quality for the nutrition of meat cattle breeds or cows without the market production of milk during autumn and winter (Opitz von Boberfeld and Banzhaf, 2006). Interspecific hybrids of *Festulolium* ssp. combine the endurance of the *Festuca* sp. family with the high quality of the *Lolium* sp. family (Casler *et al*., 2002). The use of *Dactylis glomerata* at the end of the growing season is mentioned by Prigge *et al.* (1999). *Arrhenatherum elatius* is a type of drought-resistant vegetation. It finds a particular use in meadow stands and, if it is not given a chance of dropping seeds, its endurance is limited. It is, as a rule, suppressed by intense grazing (Holúbek *et al*., 2007).
The paper compares the quality of *Festulolium*, *Dactylis glomerata*, and *Arrhenatherum elatius* towards the end of the growing season under the climatic conditions of Central Europe (Czech Republic). The use of these grass species for the extension of the grazing period is assessed.

Material and methods

The experiment was conducted at the Research Station of Fodder Crops in Vatín, operated by Mendel University of Agriculture and Forestry in Brno, the Czech Republic (49°31'N, 15°58'E). The small-plot experiment (plot 1.5 × 5 m) in three replications was established in 2004 at an altitude of 560 m a.s.l. The mean annual precipitation is 617 mm and the mean annual temperature is 6.9°C. Three years were monitored. The experimental plots were fertilised with 50 kg ha^{-1} N, 30 kg ha^{-1} P and 60 kg ha^{-1} K. Pure stands of each species were sown with 20 kg ha^{-1} seeds. Evaluated factors and levels are listed in Table 1. Analyses were made of the dry matter weight at 103°C. The samples (1 kg) were taken away immediately after the harvest. Forage samples were analysed for the digestibility of organic matter (DOM) and their crude protein content (CP) and crude fibre content (CF). DOM was estimated *in vitro* by the pepsin-cellulase method. The CP content was established with the Kjeltec 2300 and the CF content with the ANKOM Fiber analyser. The results obtained were analysed using the multi-factor analysis of variance and by subsequent verification based on the Tukey test.

Table 1. Experimental factors and levels assessed

Factors	Levels
Species (S)	*Festulolium* (*Festuca arundinacea* × *Lolium multiflorum*), cv. Felina (FS) *Dactylis glomerata*, cv. Vega (DGS) *Arrhenatherum elatius*, cv. Median (AES)
Preparatory cut (P)	beginning of June (1P) beginning of June and end of July (2P)
Harvest date (H)	beginning of October (OH) beginning of November (NH) beginning of December (DH)

Results and discussion

The average DM yields (Table 2) of *Festulolium* and *Dactylis glomerata* were 1.40 and 1.37 Mg per ha. *Arrhenatherum elatius* reached higher DM yields (1.82 Mg ha^{-1}). Grass species (S) had a significant ($P < 0.05$) influence on DM yields. The preparatory cut (P) had a statistically highly significant ($P < 0.01$) influence on DM yields. The 1P stands showed a higher DM production than the 2P stands. DM yields decreased gradually from October to December. A pronounced fall in the production occurred in December as a rule. The values of DOM (Table 2) were 0.739 to 0.744. The species (S) did not have a significant influence on DOM. The average CP content in *Dactylis glomerata* was 90.8 g kg^{-1} DM. The CP content of *Arrhenatherum elatius* (88.0 g kg^{-1} DM) was comparable with that of *Dactylis glomerata*. The lowest CP content was recorded in *Festulolium* (73.8 g kg^{-1} DM). The CF content was lowest in *Festulolium* (278.2 g kg^{-1} DM). The highest CF content during the survey was recorded in *Arrhenatherum elatius* (299.1 g kg^{-1} DM). The species (S) had a highly significant influence ($P < 0.01$) on the DOM, CP content and CF content. Archer and Decker (1977) observed that in the autumn the CP content of *Festuca arundinacea* was lower than of *Dactylis glomerata*.

Table 2. Effect of species (S), preparatory cut (P) and harvest date (H) on dry matter yields , DOM, and contents of CP and CF in 2005–2007

Factor	DM (Mg ha^{-1})	OMD	CP (g kg^{-1} DM)	CF (g kg^{-1} DM)
Species (S)				
FS	1.40^{a}	0.739^{a}	73.8^{a}	278.2^{a}
DGS	1.37^{a}	0.734^{a}	90.8^{b}	291.1^{b}
AES	1.82^{b}	0.744^{a}	88.0^{b}	299.1^{b}
Significance	0.017	0.539	0.000	0.000
Preparatory cut (P)				
1P	2.28^{a}	0.721^{a}	69.9^{a}	313.3^{a}
2P	0.78^{b}	0,758^{b}	98.4^{b}	265.7^{b}
Significance	0.000	0.000	0.000	0.000
Harvest date (H)				
OH	1.92^{a}	0.782^{a}	93.1^{a}	281.1^{a}
NH	1.65^{a}	0.750^{b}	82.7^{b}	289.0^{ab}
DH	1.03^{b}	0.686^{c}	76.8^{c}	298.0^{b}
Significance	0.000	0.000	0.000	0.000
S × P	0.353	0.236	0.000	0.000
S × H	0.425	0.081	0.011	0.057
P × H	0.005	0.053	0.000	0.948
S × P × H	0.947	0.954	0.140	0.902

Mean values in the same column with different superscripts ($^{a, b, c}$) are significant at a level of $P < 0.05$

However, they considered the difference insignificant. On the other hand, the results presented in this paper point to a significant difference not only between *Festulolium* and *Dactylis glomerata* but also between *Festulolium* and *Arrhenatherum elatius*. A CP content of about 100 g kg^{-1} DM is necessary to meet the demand of pregnant suckler cows (Opitz von Boberfeld and Banzhaf, 2006). The DOM and CP content in the 2P stands were higher than in the 1P stands and the 1P stands had a higher CF content than the 2P stands. A statistically highly significant influence ($P < 0.01$) of the preparatory cut (P) on DOM, CP content, and CF content were observed. The shorter time of grassland sparing was reflected in a higher forage quality at the end of the growing season. These general conclusions are also reported by other authors from other sites and other grassland types (Hennessy *et al.*, 2006; Opitz von Boberfeld *et al.*, 2006). At the end of the growing season, a gradual decrease in the DOM and CP content was observed. The CF content increased gradually from October to December. The harvest date (H) had a statistically highly significant influence ($P < 0.01$) on the DOM value.

Conclusions

On the basis of the content of studied nutrients, none of the species can be unambiguously eliminated from a possible extension of the grazing period. Higher quality with satisfactory yields was achieved in the 2P stands. *Festulolium* and *Dactylis glomerata* could also be used for the extension of the grazing period in continental conditions. The endurance of *Arrhenatherum elatius* remains questionable; it would have to be fostered by the alternate (cutting and grazing) use of the grassland. The question of blights and the related occurrence of mycotoxins would also be far from negligible.

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Properties of *Arrhenatherum elatius* under arable land set aside

Svobodová M., Šantrůček J., Brant V., Urbanec J. and Niňaj M.

Czech University of Life Sciences Prague, Department of Forage Crops and Grassland Management, Prague, Czech Republic
E-mail: svobodoba@af.czu.cz

Abstract

The aim of the experiment was to evaluate the development of *Arrhenatherum elatius* cv. Median sward under extensive exploitation (cut once or three times, mulching once or twice per year) and its effect on the yield of a subsequent crop. The field plot experiment was established in Prague (Czech Republic) in 1996. After seven vegetation years the sward was treated with a total herbicide and reestablished with *Lolium multiflorum* cv Lolita. The dry mass yield (three cuts per year) and the botanical composition were measured during three years. The yield of only *A. elatius* under mulching twice per year was significantly higher by 57% in comparison with the plots that were cut three times per year. The yield of invading wild species was lowest under mulching twice per year – 28–31% of the total DMY. The total DMY of the following crop – *L. multiflorum*, was significantly highest on the plots where the forecrop was cut once per year (8.8 t ha^{-1}), followed by those that had been mulched once per year (10% lower). The proportion of *L. multiflorum* in DMY was significantly highest on the plots where the forecrop was cut three times per year or mulched twice per year (92–96%).

Keywords: *Arrhenatherum, Lolium*, set aside soil, mulching, cutting, forecrop value

Introduction

Changes in agricultural policy and actual conditions on the world market can cause, from time to time, a necessity of setting a part of arable land aside. Leaving it without any treatment causes various problems, especially with weed infestation and other aspects that influence soil fertility. To conserve the soil in good condition, grasses are the best species because of their good winter coverage, organic mass production, a good influence on the soil structure, protection of water against nitrate leaching, etc. (Novák, 1998; Svobodová and Šantrůček, 2005). According to the particular conditions, suitable grass species have to be chosen (Šantrůček *et al*., 2002). Grasses generally have a relatively high demand for rainfall. The optimum Lang's rain factor (LRF) for forage grass cultivation is higher than 120, but the arable land in the Czech Republic is very often exposed to semiarid conditions (LRF = 40–50). Only a few grass species can produce enough phytomass under such conditions with *Arrhenatherum elatius* being one of the best adapted grasses. The aim of the experiment was to evaluate the development of *Arrhenatherum elatius* sward under extensive exploitation and its effects on the yield of a subsequent crop.

Materials and methods

The field plot experiment (3 × 10 m per plot) with *Arrhenatherum elatius* cv. Median was established in Prague (chernozem soil, altitude 281 m a.s.l., average annual precipitation

472 mm, average annual air temperature 9.3°C). The grass was sown as a monoculture without a companion crop in 1996: the sowing rate was 50 kg ha^{-1}. The sward was cut once or three times or mulched once or twice per year. It was not fertilised. Dry mass yields and botanical composition were evaluated. After seven vegetation years the sward was treated with a total herbicide and reestablished with *Lolium multiflorum* cv. Lolita (sowing rate 60 kg ha^{-1}) in late summer to evaluate the forecrop value of *A. elatius*. The dry mass yield (three cuts per year) and the botanical composition were analysed in the second and third vegetation years. The results were evaluated by analysis of variance ANOVA in Statgraphics programme version XV.

Results and discussion

The average yield of the *Arrhenatherum elatius* sward (Figure 1) was 4,300–5,000 kg ha^{-1} in the third and fourth years, but in the fifth year the total yield was lower by 48% in comparison with the previous years. This represented the natural development of the sward under dry conditions (LRF 47-50). In the sixth and seventh year the yields of the sward increased because of higher precipitation (LRF 73 in both the years) especially under mulching twice per year. With this treatment nutrients are returned to the soil and used again if conditions are sufficiently moist. The yield of only *A. elatius* under mulching twice per year was significantly higher by 67% in the last two years in comparison with the plots cut three times per year (simulation of intensive forage exploitation) and by 57% during all the experiment ($D_{\text{min. } \alpha = 0.05}$ = 1,380 kg ha^{-1}). It shows that two harvests are the optimum frequency for such climate conditions from the point of view of the sward yield (Šantrůček *et al*., 2002). The yield of invading wild species (Figure 1) increased under more humid conditions in the 6th and 7th year, and it was lowest under mulching twice per year – 28–31% of the total DMY in comparison with the plots harvested once per year (33–57%) and those cut three times per year (58–64%).

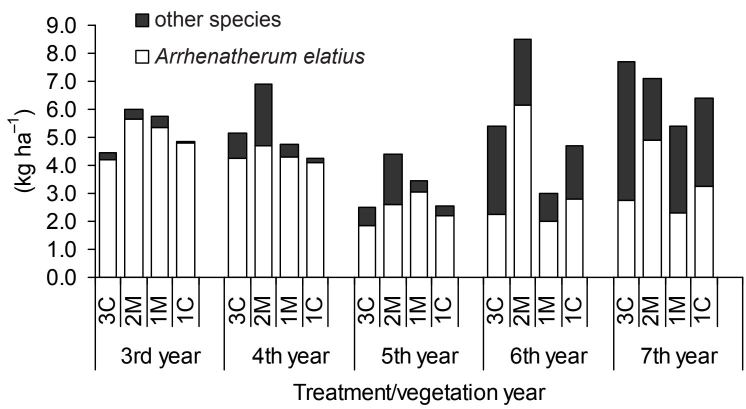

Figure 1. Sward composition of *Arrhenatherum elatius* (t.ha^{-1}) (C – cut, M – mulching)

The average proportion of *A. elatius* in the total DMY calculated from all the experimental years was not significantly influenced by the sward treatment, because in the drier years (the first three ones) there were more weeds on the plots mulched twice per year (Figure 1, Table 1). This parameter was significantly influenced by the age of the sward – the average proportion of *A. elatius* (y) decreased linearly $y = -11.4x + 107.4$ (x = vegetation year – 2), $R^2 = 0.9854$.

Table 1. Proportion of *Arrhenatherum elatius* and other species in the DM yield (%)

Treatment	3rd year		4th year		5th year		6th year		7th year		Average		
	Arrh.	other	Arrh.	other	Arrh.	other	Arrh.	other	Arrh.	other	Arrh.	HG	other
3 cuts	95	5	82	18	73	27	42	58	36	64	65	a	35
2 mulch	94	6	68	32	59	41	72	28	69	31	72	a	28
1 mulch	94	6	90	10	89	11	67	33	43	57	76	a	24
1 cut	99	1	97	3	86	14	60	40	51	49	78	a	22
Average	95	5	84	16	77	23	60	40	50	50	73		27
HG	d		cd		bc		ab		a				

HG – homogenous groups (LSD, α = 0.05); Arrh. – *Arhenatherum elatius*

The other important aim of the experiment was to evaluate the influence of *A. elatius* swards used for setting arable land aside on the development and weed infestation of a following crop. The total DMY of the *L. multiflorum* sward was significantly the highest on the plots where the forecrop was cut once per year (8,800 kg ha^{-1}), followed by those that had been mulched once per year (Table 2) – in both cases the average yields of the forecrop were lower than those with two or three harvests. The yields of only *L. multiflorum* (5,000–6,000 kg ha^{-1}) were not influenced by the treatment of the forecrop, but its proportion in the total DMY was significantly the highest on the plots where the forecrop was harvested twice or three times per year (96 or 92%) and there was significantly more infestation with other species on the plots where the forecrop was harvested only once per year (Table 2). The total DM yield of *L. multiflorum* significantly decreased with the vegetation year and was highest for the first cut in the year.

Table 2. Yield and composition of *Lolium multiflorum* swards

		Total DM yield		DM yield of *Lolium*		Proportion of *Lolium* in DM	
		(kg ha^{-1})	HG	(kg ha^{-1})	HG	(%)	HG
Treatment of forecrop	3 cuts	5,526	a	5,106	a	92.4	b
	2 mulch	6,306	ab	6,039	a	95.8	b
	1 mulch	7,995	ab	5,811	a	72.7	a
	1 cut	8,811	b	5,790	a	65.7	a
Cut	1st	4,140	c	3,581	c	86.5	b
	2nd	2,015	b	1,546	b	76.7	b
	3rd	1,004	a	0,559	a	55.7	a
Year	2nd	9,279	b	8,631	b	93.0	b
	3rd	5,037	a	2,442	a	48.5	a

Conclusion

The results show that weed infestation of a grass sward depends particularly on the persistency of the given grass species and the weed infestation of the following crop does not necessarily correlate with the weed infestation of the forecrop. It also depends on the competitive capacity of the following crop, influenced by the nutrient pool, weather conditions etc.

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Effect of organic fertilisation on quality of lysimetric water

Svozilová M., Otrhálková P., Karabcová H. and Ržonca J.

Agroresearch, Ltd., Rapotín, Czech Republic
E-mail: marie.svozilova@vuchs.cz

Abstract

Grasslands have an impact on the sustainability of nutrition in a country. In this paper the effects of simulated cattle grazing on lysimetric water during a period of three years are presented. The experiment includes two fertiliser types – cow dung with dung-water and semi-liquid cattle manure with a graded load (0.9, 1.4 and 2.0 LU per ha). The soil is sandy-loam, of the cambisol type, with semi-natural permanent grassland. We observed the content of $N\text{-}NH_4^+$ and $N\text{-}NO_3^-$ in the percolate. There was significantly higher leaching of ammonia and nitrate with the load of 2.0 LU and no statistically significant differences were found between the forms of organic manure applied. There were statistical differences between the estimated years. On the basis of the lysimetric water volume found and the concentrations of particular forms of inorganic nitrogen we reveal the annual washing-out of this nutrient from 1 ha; it was 4.9 kg ha^{-1} for 0.9 LU, 4.8 kg ha^{-1} for 1.4 LU, and 6.1 kg ha^{-1} for 2.0 LU per year during the estimated period.

Keywords: grasslands, lysimetric water, nitrogen leaching

Introduction

Most of the grassland in the Czech Republic is situated in less favourable areas (LFA), where grazing and cutting are a more significant and traditional agricultural practice. Grassland management should pay heed to the environment and with the help of lysimeters we are able to control how its management operates. The primary aim of lysimeter measurements on the basis of the analyses of percolated water is the monitoring of nutrient movement, especially concerning nitrogen in soil.

Material and method

In the autumn of 2004 a small-plot trial on grassland with various types of management with animal fertilisation was established at Agroresearch, Ltd., Rapotín, in the Czech Republic. The experiment is located on an east-facing slope 390 m above sea level and it belongs under the Hrubý Jeseník geomorphological division. The geomorphological subgrade is deeper diluvium of mica schist. The soil is sandy-loam, of the cambisol type (horizons Ao-Bv-B/C-C). The mean annual precipitation in the locality is 693 mm, and the average annual temperature is 5.3°C; Table 1 shows data from the relevant season. In the locality there is semi-natural permanent grassland with these predominant species: *Dactylis glomerata, Poa pratensis, Lolium perenne, Taraxacum* sect. *Ruderalia*, and *Trifolium repens*.
Plots with different pasture loads were arranged in a completely randomised block design with four replicate blocks. The plot size was 12.5 m^2. The plots were not grazed (grazing was simulated), but cut according to the grassland load, which was as follows:

A – cow dung + dung-water with a load of 0.9 LU ha^{-1}
B – cow dung + dung-water with a load of 1.4 LU ha^{-1}

Table 1. The precipitation and temperature in Rapotín during the season studied

Year		Month											
		I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.
2005	precipitation (mm)	90.0	45.0	27.5	23.5	76.0	50.0	78.0	69.0	19.0	56	120	74.6
	temperature (°C)	–1.3	–4.5	–0.7	8.9	12.7	15.6	18.3	15.7	13.4	4.9	3.1	–1.7
2006	precipitation (mm)	36.1	63.7	62.7	62.2	63.5	78.1	52.0	110.0	7,2	24.5	59.1	68.2
	temperature (°C)	–8.4	–2.6	–1.8	9.3	12.8	17.0	20.5	15.2	14.5	10.1	8.5	2.1
2007	precipitation (mm)	68.5	49.7	40.0	4.7	66.3	49.2	69.2	68.2	54.2	34.1	67.9	37.2
	temperature (°C)	3.2	2.7	5.0	9.7	11.4	17.7	18.9	17.7	11.0	7.2	1.6	–1,2

C – cow dung + dung-water with a load of 2.0 LU ha^{-1}
D – slurry with a load of 0.9 LU ha^{-1}
E – slurry with a load of 1.4 LU ha^{-1}
F – slurry with a load of 2.0 LU ha^{-1}

(0.9 load unit LU corresponds to 54 kg N ha^{-1} and 2 cuts per year, 1.4 LU corresponds to 84 kg N ha^{-1} and 3 cuts per year, and 2.0 LU corresponds to 120 kg N ha^{-1} and 4 cuts per year).
The cow dung fertilisation was dosed in the autumn, dung-water after the first cut; half of the semi-liquid manure fertilisation was applied in the spring and the second half after the first cut. After every application we analysed the fertilisers and then, on the basis of the nitrogen contents, we counted the actual dosage. The lysimeters were at a depth of 0.4 m in an area of 0.25 m^2, in the four replications. In this paper we estimated the content of N-NH_4^+ and N-NO_3^- in the percolate and the potential risk for the environment.
The statistical analyses were performed with linear mixed models in the nlme and MASS packages in R software.

Results and discussion

The nitrate concentration in the environment is very variable during the year. The nitrate concentration values are shown in Figure 1. Wessolek *et al.* (1994) describe nitrate leaching in sandy soils under different cultures. They show different nitrate concentrations in the root zone: in gardening soils 200–350 mg l^{-1}, in arable land 120–240 mg l^{-1}, and in soil under grassland without fertilisation < 40 mg l^{-1}.

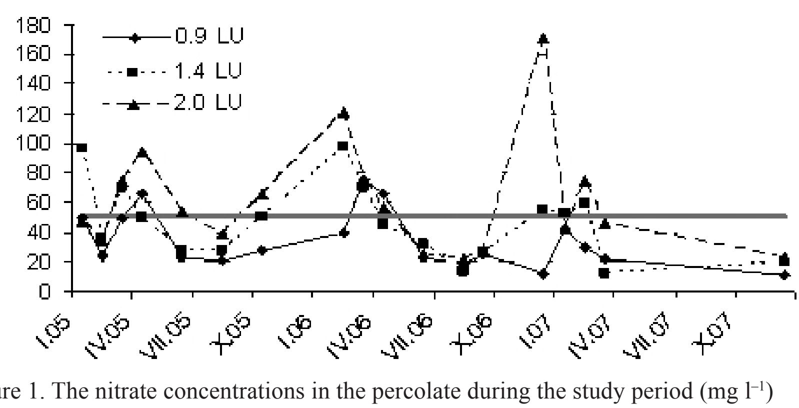

Figure 1. The nitrate concentrations in the percolate during the study period (mg l^{-1})

The values of nitrate concentration in the percolates were variable; from Figure 1 it can be seen that values over the pollution limit for drinking water (50 mg l^{-1}) were exceeded with the load of 0.9 LU only during the spring months. The type of fertiliser had no influence on the nitrate leaching (P = 0.0754). The highest leaching was with the load of 2.0 LU and it was significantly higher (P = 0.0089) than the others. There is variability between the following years; in 2007 nitrate leaching was significantly (P = 0.0001) lower than in the other years, which corresponds to the lowest precipitation during this year (from March to December percolate was not present at a depth of 0.4 m).
The concentrations of ammonia were variable too (see Figure 2). There was higher leaching of ammonia with the load of 2.0 LU (P = 0.0599). Compared to the following years,

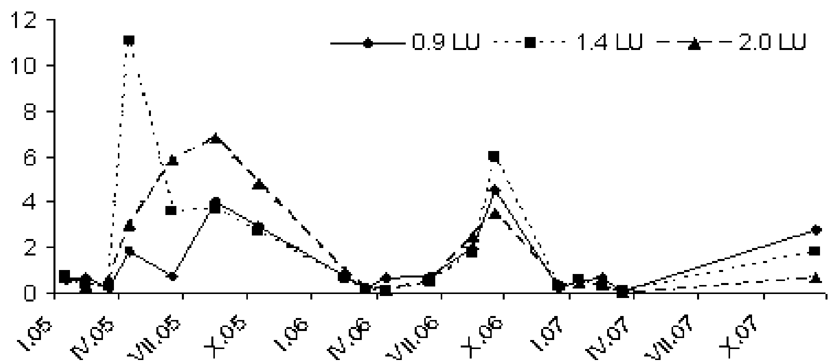

Figure 2. The ammonia concentrations in the percolate during the study period (mg l^{-1})

the leaching in 2005 was significantly higher (P = 0.0442) than in the other years; this could be caused by the high concentration of ammonia in precipitation during this year. We hold the summa of mineral nitrate soil washing as the most telling indicator of the environmental burden, because this value illustrates the nitrate discipline with regard to the water regime. We quantified the annual leaching of mineral nitrogen as being on the level of 4.88 kg ha^{-1} $year^{-1}$ in treatment with a load of 0.9 LU ha^{-1}, 4.77 kg ha^{-1} $year^{-1}$ in treatment with a load of 1.4 LU ha^{-1}, and 6.13 kg ha^{-1} $year^{-1}$ in treatment with a load of 2.0 LU ha^{-1}.

Conclusion

We found no differences in nitrate and ammonia leaching between the estimated forms of organic manure; the highest leaching was with a load of 2.0 LU per hectare. From the environmental point of view grasslands are able to protect ground water against nitrate pollution with a load of 0.9 LU ha^{-1} during the year in our conditions.

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The grass vegetation of watercourses as a biodiversity refuge in an agricultural landscape

Szymura M.[1], Szymura T.[2], Dunajski A.[2] and Wolski K.[1]

[1]*University of Environmental and Life Sciences, Department of Grassland and Landscape Planning, Wroclaw, Poland*
[2] *Wroclaw University, Ecological Station, Institute of Plant Biology, Wroclaw, Poland*
E-mail: magda@ekonom.ar.wroc.pl

Abstract

The quantitative analysis of the vegetation of watercourses in the agricultural landscape in the Odra valley (Poland) is presented. The quantitative participation of a given species was measured by multiplying the length of watercourse sections by the percentage cover of the species. A total of 134 km of watercourses was analysed. Of the 164 plant species observed, 22% were grasses, although their quantitative participation was 39%. The most abundant species were *Calamgrostis epigejos* and then *Phragmites australis.* The majority of grass species were apophytes, and only 12% were antropophytes. The dominance of native species that form specific semi-natural assemblages in this anthropogenically disturbed habitat highlights the potential of riparian vegetation to maintain biodiversity as well as provide ecosystem services in modern agricultural landscapes.

Keywords: biodiversity, *Calamagrostis epigejos,* drainage channels*, Phragmites australis*

Introduction

The industrialisation of agriculture started in the 1950s in the western part of Europe and the 1990s in Poland and has caused a decrease in biodiversity and landscape dysfunction (Baudry *et al*., 2000). One of the aims of contemporary European agricultural policy is to reverse these changes by the promotion of the non-productive functions of rural areas (Billeter *et al.,* 2008). In an agricultural landscape watercourses and adjacent vegetation are important as a result of their influence on water quality, biodiversity, aesthetic values, and their role as ecological corridors (Baudry and Thenail, 2004). Riparian vegetation is also the most frequent semi-natural habitat in agricultural areas (Manhoud and de Snoo, 2003). Analysis of the riparian vegetation in agricultural areas has revealed the importance of grasses among the other plants that are found along watercourses.
In this paper we analyse the quantitative participation of grasses in vegetation associated with watercourses in an agricultural landscape in the valley of the middle Odra. The influence of dominant grass species on biodiversity, as well as their status in the Polish flora, is discussed.

Material and methods

The study was performed in the geomorphological valley of the Odra River, in the region between Brzeg Dolny and Głogów, on three case sites. The study area covered 4.6 thousand hectares. Agricultural land covered an average of 65% (83% arable and 17% grassland) of the area.

The watercourses were divided into homogenous sections with respect to vegetation, channel morphology, and water regime. The cover of dominant plant species (> 5% cover) in vegetation in strips along the watercourses was assessed. All the fieldwork was carried out between June and September 2007.
The quantitative participation of each species was measured by multiplying the length of each section by the percentage cover of a given species. The frequency of sections containing a species and the median of non-zero cover were also computed. The status of species in the Polish flora (apophytes, antropophytes etc.) was defined according to Korniak and Urbisz (2007).

Results and discussion

A total of 134.1 km of watercourses was surveyed, separated into 536 sections. We recorded 164 plant species on the banks of the watercourses, including 36 grass species (22% of the total number of species). However, they generally had a large cover value, and thus their quantitative participation was 39%. Eleven grass species formed the dominant vegetation (> 60% cover) in the sections. They dominated in 27% of the sections and, moreover, showed considerable participation (30–59% cover) in 37% of the sections. The quantitative participation, frequency, cover, number, and percentage of sections in which a given species was dominant are shown in Table 1. This table only shows the grass species with a quantitative participation higher than 0.1% and the most important dicotyledonous species.
Analysis of the status of the grasses in the Polish flora showed that the native species that are associated with human activities (apophytes) make up 78% of the total, while 11% are non-native species (antropophytes) belonging to the archeophyte group. There was also a noticeable lack of invasive Polish grass species. The most important species in the riparian vegetation was reed grass (*Calamagrostis epigejos*). This species, along with *Elymus repens* and *Arrhenatherum elatius*, is able to spontaneously colonise anthropogenically disturbed habitats and to persist there thanks to its high adaptive ability (Prach and Pyšek, 2001). Reed grass was the most distinctive species in the group of vegetation types dominated by grasses and occurred in dense, single-species swards with low biodiversity, especially adjacent to fallow fields, was present in disturbed habitats with *Tanacetum vulgare*, and formed specific assemblages with old oaks (*Quercus robur*) on banks. The second most important species with respect to quantitative participation was *Phragmites australis*. Common reeds show high colonisation dynamics, moving along watercourses and creating dense, single-species stands, which are able to displace other rushes in suitable sites and permanently arrest succession (Milsom *et al*., 2004). The sections dominated by reed forms were characterised by a low average number of species, as well as low Shannon-Wiener indices. Another important grass species, *Phalaris arundinacea*, usually occupies the margins of small, often nutrient-enriched rivers, or occurs in wet grassland on organic soils in large river valleys, where the regular mowing of channels creates favourable conditions for its expansion (Milsom *et al*., 2004). In this study *Phalaris arundinacea* was an indicator of mown sections with high biodiversity, often adjacent to arable land. It was found in assemblages with *Calamagrostis epigejos, Dactylis glomerata, Elymus repens,* and, less frequently, *Arrhenatherum elatius, Phragmites australis*, and *Urtica dioica*. *Deschampsia caespitosa* is an indicator of over-utilised meadows and pastures, together with *Cirsium arvense* growing in wide, wet strips along watercourses, and occurred predominantly next to fallow fields in this study.

Table 1. The quantitative participation (Quan. part.), frequency, cover, number, and percentage of sections in which a given species was dominant

		Quan. part.		Frequency		Cover, %			Dominant	
		(km)	(%)	*N*	(%)	Med.	Min	Max	*N*	(%)
Grasses										
1	*Calamagrostis epigejos*	34.74	13	235	43.8	30	5	90	66	12
2	*Phragmites australis*	18.84	7.1	120	22.4	30	5	100	41	7.6
3	*Phalaris arundinacea*	16.65	6.2	139	25.9	20	5	70	7	1.3
4	*Dactylis glomerata*	8.55	3.2	124	23.1	10	5	60	1	0.2
5	*Bromus inermis*	3.91	1.5	40	7.5	20	5	60	1	0.2
6	*Elymus repens*	3.69	1.4	57	10.6	10	5	50	0	0
7	*Arrhenatherum elatius*	3.48	1.3	51	9.5	10	5	40	0	0
8	*Deschampsia cespitosa*	3.31	1.2	48	9	15	5	70	5	0.9
9	*Dactylis aschersoniana*	2.45	0.9	15	2.8	40	10	80	6	1.1
10	*Poa nemoralis*	2.08	0.8	23	4.3	10	5	50	0	0
11	*Glyceria maxima*	1.84	0.7	34	6.3	10	5	40	0	0
12	*Calamagrostis arundinacea*	1.09	0.4	6	1.1	35	10	90	2	0.4
13	*Poa palustris*	0.6	0.2	5	0.9	10	5	40	0	0
14	*Deschampsia flexuosa*	0.34	0.1	1	0.2	60	60	60	1	0.2
15	*Festuca gigantea*	0.28	0.1	4	0.7	15	5	30	0	0
16	*Millium effusum*	0.26	0.1	2	0.4	33	5	60	1	0.2
17	*Molinia caerulea*	0.25	0.1	3	0.6	10	10	30	0	0
18	*Apera spica-venti*	0.22	0.1	4	0.7	20	5	30	0	0
19	*Alopecurus pratensis*	0.21	0.1	6	1.1	8	5	20	0	0
20	*Agrostis capillaris*	0.21	0.1	7	1.3	10	5	30	0	0
21	*Echinochloa crus-galli*	0.16	0.1	2	0.4	8	5	10	0	0
22	*Lolium perenne*	0.13	0.1	2	0.4	15	10	20	0	0
Major dicotyledons										
1	*Urtica dioica*	25.36	9.5	241	46	20	5	90	36	6.7
2	*Quercus robur*	22.90	8.6	184	35	20	5	80	33	6.2
3	*Prunus spinosa*	23.00	8.6	131	25	30	5	100	51	9.5
4	*Rubus* sp.	8.85	3.3	115	22	10	5	70	4	0.7
5	*Alnus glutinosa*	19.66	7.4	113	22	30	5	90	28	5.2
6	*Cirsium arvense*	4.75	1.8	73	14	10	5	40	0	0
7	*Tanacetum vulgare*	4.05	1.5	73	14	10	5	40	0	0

Conclusions

The results emphasise the quantitative dominance of grass species (*Poaceae* family) in the vegetation of ditches in the agricultural landscape. The maintenance of ditches in land reclamation systems creates anthropogenic habitats occupied by native species, which create semi-natural assemblages that are important for the conservation of biodiversity. The two most abundant and frequent species, *Calamagrostis epigejos* and *Phragmites australis*, are expansive, with a tendency to form single-species stands with low biodiversity if the management of the land reclamation system ceases.

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Using ArcGIS for the evaluation of land use in a grassland area of the Jizerské hory Mts.

Štrobach J., Pavlů V. and Mikulka J.

Crop Research Institute, Department of Plant Ecology and Herbology, Prague, Czech Republic
E-mail: strobach@vurv.cz

Abstract

In the second half of the 20th century many changes occurred in agricultural practices in Central Europe. In the 1950s intensive agricultural management was applied and it lasted till the end of the 1980s. It was usually accompanied by a decrease in grassland area, because many highly productive grasslands were ploughed and transformed into arable land. The goal of our research was to study historical changes in land use on the landscape level in an upland area (280 ha) of the village Oldřichov v Hájích in the Jizerské hory Mts. (Czech Republic) by using theArcGIS® 9 software. The duration of the study was divided into several periods based on important changes in land use. From 1950 to 1968 there was a majority of arable land. During the period 1968–1974 a large part of the arable land was sown with productive grassland mixtures and transformed into intensively managed meadows and pastures. The grasslands were fertilised and renovated in five-year cycles. The period from 1989 to 1992 (after the political changes known as the "Velvet Revolution") was characterised by a successive reduction of the intensive management, reducing the doses of fertiliser and intensity of cutting. After 1993, a dramatic reduction in the number of cattle occurred and many grasslands were without any management or managed by extensive cutting or mulching only. The ArcGIS® 9 software package seems to be a convenient tool for the historical monitoring and analysis of land use.

Keywords: pasture, meadows, land use, Czech Republic, ArcGIS

Introduction

The structure of agricultural land in the Czech Republic (CR) has undergone dramatic changes since the 1950s. It was caused by political changes after World War II (WWII), when large-scale socialist agricultural collectives were built up (Lipský, 2000). Large areas of pastures and meadows were incorporated into arable land or temporary grasslands till the 1980s. After the political changes in 1989 a significant decrease in the number of herbivores (cattle, sheep, and horses) led to the extensification of grassland utilisation or even to the abandonment of the marginal areas. It was estimated that 30–50% of the total grassland area in the Czech Republic consisted of non-utilised meadows and pastures.
The aim of this paper is to analyse changes in land management on the landscape level in the surroundings of the village of Oldřichov v Hájích in the second half of the 20th century.

Materials and methods

The study area was a part (280 ha) of the cadastral area of the village of Oldřichov v Hájích (10 km north of the town of Liberec in the upland of the Jizerské hory Mts. The altitude ranged from 350 m to 450 m above sea level. The average annual precipitation is 803 mm and the mean annual temperature is 7.2°C.

Data about land use and the size of the areas were collected from present farmers, former farmers, eyewitnesses, and other residents. The ArcGIS® 9.1 software was used for the transformation of screening data into polygons on a scale of 1:10,000. The attributes (meadows, pasture, grazed meadows, arable land) were assigned to each polygon according to the type of management. The study period was divided into four periods in which the size and land use of the polygons had been relatively stable: 1950–1968, 1968–1989, 1989–2003, and 2003–2008.

All the data were analysed and visualised with the ArcGIS® 9.1 software.

Result and discussion

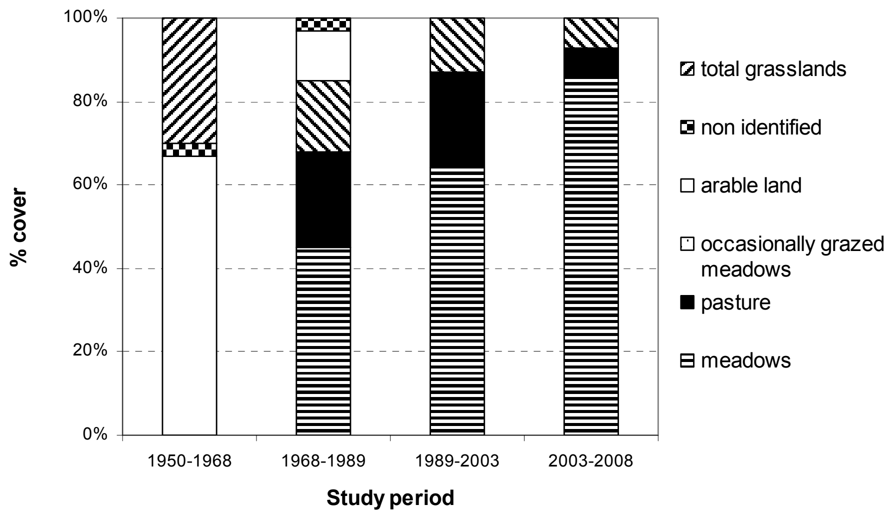

Figure 1. Percentage changes of land use during the four periods of the study

After WWII arable land was the most important part of the agricultural land in the study area (67%), whereas grassland covered only 30% (Figure 1). During the socialist collectivisation era in the 1950s small patches of arable land and/or grassland were connected to larger areas because of the use of mechanisation (Lipský, 2000). However the percentage proportion of land use was similar to the situation after WWII and remained relatively stable till 1968 (Figure 2).

The years 1968–1970 were the breaking point in this area, because a cowshed (for 175 cows), a rearing house for young stock (for 300 young cattle of 100–350 kg) and a pasture farm of 113 ha of grasslands were built. Therefore the arable land area here decreased from 67% to only 12%, whereas on the national level the trend was completely the opposite. The majority of agricultural land here was grasslands, which started to be intensively managed. They were renovated in five-year cycles (ploughed, reseeded, and fertilised) and mineral fertilisers were used to increase forage production. Only those

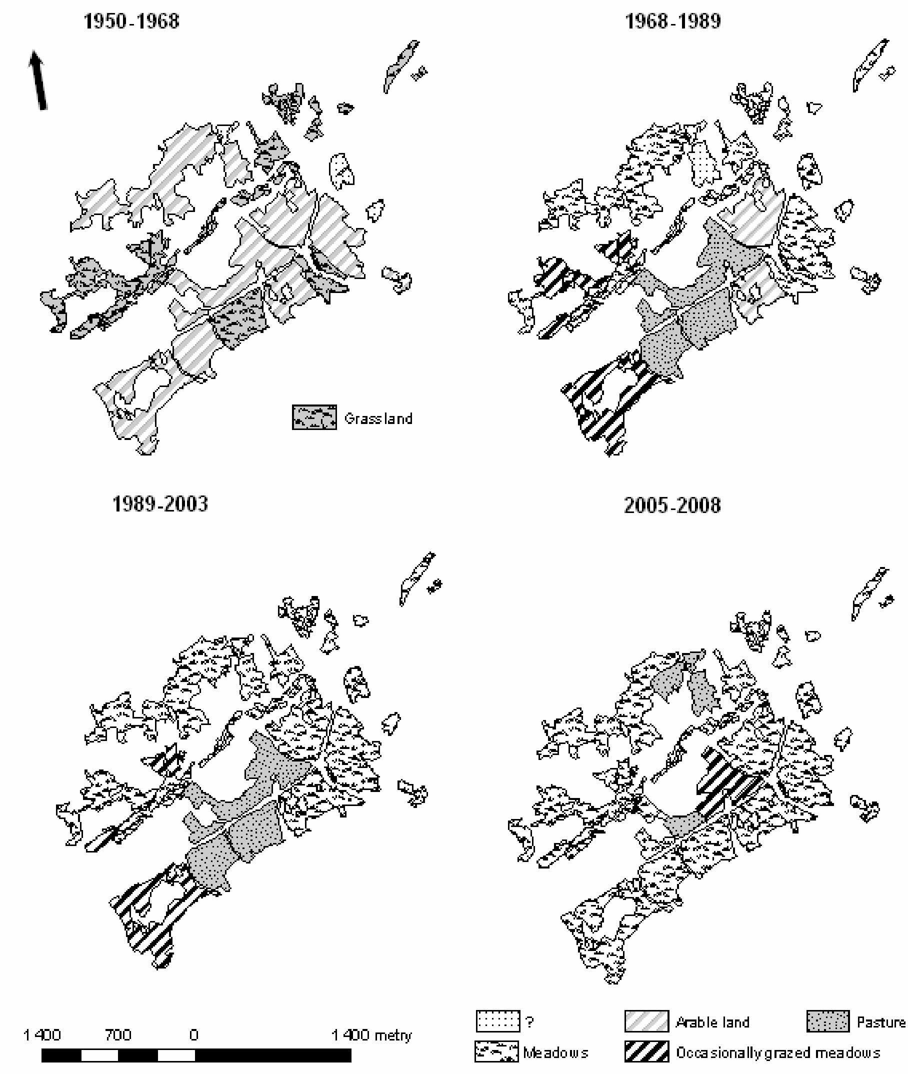

Figure 2. Changes in land use in the study area during the four periods of the study

grasslands that were less accessible for agricultural mechanisation were not renovated and fertilised.

In the 1970s–1980s many grasslands were turned into arable land in the Czech Republic and the grassland area was reduced to less than 20% of the total agricultural land. However, during this period the remaining arable land (12%) in the study area was incorporated into grassland. After 1989, as a result of changes in the structure of the farming industry, the fertilisation was successively reduced and stopped definitively in 1993. After this year the number of cattle (the main herbivore) in the Czech Republic was dramatically reduced to a third of its former level (from 3.36 mill to 1.11 mill; Anonymous, 2007) and the shortage of animals grazing on pastures was revealed. In

2003 the big farm in the study area collapsed and both the cowshed and the rearing house for young stock rearing house were closed. Because of the lack of grazing animals the pasture area was reduced from 23% to 7%. The grasslands were cut only because of a state subsidy once per year.

Conclusions

The structure of land use is strongly affected not only by the socio-economic changes on the state level, but also by the local possibilities and conditions. Historical analyses of land use are important for our understanding of changes in the structure of the landscape (Sklenicka *et al*., 2009) in the context of changes in society. The ArcGIS® 9 software package seems to be a convenient tool for the historical monitoring and analysis of land use.

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Botanical composition of pasture sward influenced by intensity of utilisation and mineral fertilisation

Štýbnarová M.[1], Hakl J.[2], Krhovjáková J.[1] and Pozdíšek J.[1]

[1]*Research Institute for Cattle Breeding, Ltd., Rapotín, Czech Republic*
[2]*Czech University of Life Sciences Prague, Department of Forage Crops and Grassland Management, Prague, Czech Republic*
E-mail: marie.stybnarova@vuchs.cz

Abstract

A long-term pratotechnical trial was established in 2003 on permanent grassland sites in the Rapotín locality. The trial consisted of six treatments with different grazing management (intensity of utilisation and fertilisation). The botanical composition of the swards before the first grazing period was evaluated by means of the projective dominance method. The botanical composition was influenced by time and different management, which explained about 23% of the variability of the botanical composition. Species richness was significantly influenced ($P < 0.05$), mainly by the intensity of utilisation, with increasing intensity of utilisation reducing the total number of species (from 24 to 15 species).

Keywords: grasslands, botanical composition, diversity, grazing utilisation, fertilisation

Introduction

One of the most efficient methods for maintaining grasslands and their natural value with regard to production and non-production functions is cattle grazing. Permanent grassland management for suckler cow breeding appears particularly attractive. Suckler cow breeding has spread in the Czech Republic since 1990 as new and promising branch of livestock production (Pozdíšek *et al*., 2004). The aim of this study was to compare different grazing management approaches, focusing on the botanical composition of the pasture sward.

Materials and methods

A long-term pratotechnical trial was established in 2003 on permanent grassland sites in the Rapotín locality. The altitude is 340 m a.s.l., the long-term temperature and precipitation during the vegetation season is 9.1°C and 481 mm. The dominant species in the sward at the beginning of the trial were: *Achillea millefolium*, *Taraxacum* sect. *Ruderalia*, *Plantago major*, *Agrostis tenuis*, *Poa pratensis*, *Dactylis glomerata*, and *Trifolium repens*.
The trial consisted of three treatments (one plot size: 200 m^2) with different intensities of grazing utilisation (two, three, and four grazing periods per year). The plots were grazed rotationally (paddock grazing system) by suckler cows at a stocking rate of 1.2–1.45 LU ha^{-1}. Each type of utilisation was established in treatment with or without the application of mineral fertilisers ($N_{100}P_{30}$ + K_{60}, pure nutrients). Phosphorus was applied in the form of superphosphate and potassium as potassium salt in one dose in the spring. Nitrogen was applied in two doses (in the spring and after the first grazing) as ammonium salt

with limestone. The botanical composition was estimated before the first grazing period by means of the projective dominance method. Species diversity in a community was measured by Simpson's diversity index (*D*) (Begon *et al*., 1997), modified according to Klimeš (2000):

$$D = \frac{1}{\sum p_i^2}$$

where: p_i – projective dominance of the i^{th} species
S – total number of species (richness)

The equitability (evenness) of the community was calculated according to the formula $E = D/S$. The significance of the differences between the mean values of diversity indexes was tested using the LSD test ($P < 0.05$). Redundancy analyses and variance partitioning were performed using CANOCO for Windows Version 4.5 (ter Braak and Šmilauer, 2002).

Results and discussion

Species richness (*S*) is an important indicator of species diversity. The mean values of *S* for different methods of pasture management during 2003–2008 are given in Table 1. Extensively utilised treatment (two grazing periods per year) without mineral fertilisation showed the highest total number of species (a maximum of 29 species in 2008) in comparison with other utilisation treatments. Furthermore, it was found out that the species richness is higher in unfertilised treatments, especially concerning treatment with two grazing periods per year. These findings are in line with e.g. Mrkvička and Veselá (2002).

Table 1. Species richness (*S*) with different methods of grazing management

Treatment	Number of species with dominance > 1%							Number of species with dominance < 1%						
	2003	2004	2005	2006	2007	2008	mean	2003	2004	2005	2006	2007	2008	mean
P4/0	8	6	11	7	10	12	9	9	8	6	5	5	3	6
P4/NPK	6	7	9	6	11	13	8	12	10	6	8	4	3	7
P3/0	7	11	9	9	13	14	10	16	7	11	8	6	6	9
P3/NPK	7	8	8	7	11	12	9	9	7	9	7	5	3	7
P2/0	13	11	10	11	14	18	13	11	9	14	12	11	11	11
P2/NPK	8	10	8	11	12	13	10	13	7	11	7	6	4	8

P – grazing utilisation with number of grazing periods per year; 0 – no fertilisation; NPK – mineral fertilisation: $N_{100}P_{30} + K_{60}$ (pure nutrients)

Simpson's diversity index (*D*) reflects the species richness and evenness (equitability) of the community (Table 2). In terms of years, we found a significant difference ($P < 0.05$) between treatments utilised in four grazing periods per year and other utilisation treatments. Fertilised and unfertilised treatments also differed significantly from each other ($P < 0.05$). Treatments P2/0 and P3/0 alternated during years in the highest values of the diversity indexes. It indicates better ecological conditions in the case of these grasslands.

On the contrary, a low diversity index value (treatment P4/NPK; *D* = 4.16 in mean of years) indicates the incidence of a stress factor.

Our results correspond with those of Klimeš *et al.* (2007), who studied an analogical pasture trial in the foothills of the Bohemian Forest (at an altitude of 650 m a.s.l.). According to their findings, to ensure the stabilised species diversity of pasture cenosis it is appropriate to manage the pasture sward rotationally in 2 or 3 grazing periods per year by the application of 0–100 kg N ha^{-1} (+PK). If the intensity of utilisation is increased and especially in connection with nitrogen application, species diversity goes down.

Table 2. Diversity parameters with different approaches to grazing management

Treatment	Diversity index (*D*)							Equitability (*E*)						
	2003	2004	2005	2006	2007	2008	mean	2003	2004	2005	2006	2007	2008	mean
P4/0	3.59	4.22	4.31	3.30	5.67	6.49	4.60	0.47	0.81	0.40	0.49	0.57	0.55	0.55
P4/NPK	2.67	3.44	3.62	3.06	5.64	6.55	4.16	0.44	0.54	0.43	0.51	0.54	0.52	0.49
P3/0	4.29	5.95	4.75	4.92	5.22	8.03	5.53	0.66	0.55	0.53	0.54	0.42	0.60	0.55
P3/NPK	3.63	4.88	4.84	3.30	4.14	5.64	4.41	0.57	0.59	0.61	0.45	0.38	0.48	0.51
P2/0	7.17	4.66	4.87	4.84	5.75	7.29	5.76	0.56	0.42	0.50	0.45	0.42	0.41	0.46
P2/NPK	4.22	5.01	4.57	4.50	4.94	4.32	4.59	0.56	0.50	0.58	0.41	0.41	0.34	0.47
LSD 0.05	1.13	0.61	0.35	0.63	0.45	0.95	0.47	0.06	0.09	0.06	0.03	0.06	0.07	0.03

Figure 1 shows trends in the composition of particular species during 2003–2008. The inclusion of environmental variables (time, fertilisation, intensity of utilisation) explains 23% of the variability in species composition after the removal of the block effect. Species composition in our conditions was significantly influenced mainly by the intensity of utilisation (ca 10%) and also by time (7%). The influence of fertilisation was not

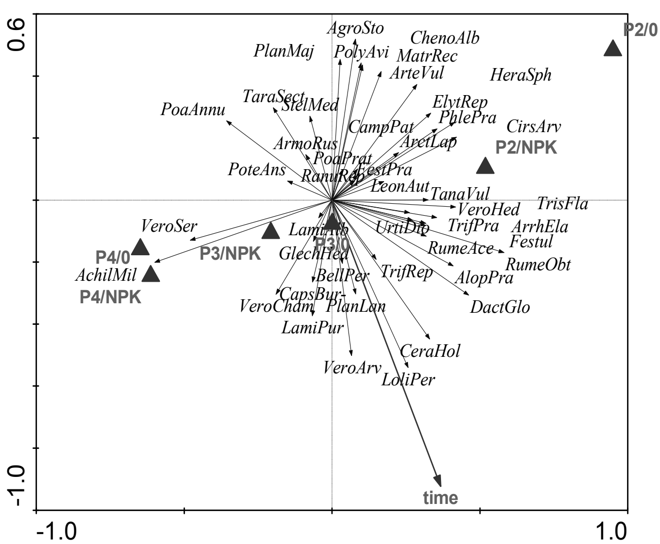

Figure 1. Ordination plot from RDA summarising the effect of grazing management and time upon species composition after the removal of the block effect

significant (2%); however, a significant interaction with grazing management was found, which explains ca 4% of the variability.

Conclusion

The botanical composition of the grasslands grazed by suckler cows was influenced by different management and time, which explained about 23% of the variability in the botanical composition. It is necessary to adjust the pasture management to provide the maintenance of biodiversity, but also with respect to the animals' requirements, which is also largely dependent on the climatic conditions during appropriate seasons. For optimal grassland management it is important to take all relevant factors into account.

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Species development of meadow stand related to yield

Veselá M., Mrkvička J. and Hrevušová Z.

Czech University of Life Sciences in Prague, Department of Forage Crops and Grassland Management, Prague, Czech Republic
E-mail: veselam@zf.czu.cz

Abstract

The influence of different intensities of fertilisation, especially nitrogenous, on the origin growth type *Dactylidetum,* association *Trifolio-Festucetum rubrae* was studied. Four variants were studied: $N_0 P_0 K_0$–$N_0 P_{40} K_{100}$–$N_{100} P_{40} K_{100}$–$N_{200} P_{40} K_{100}$. The occurrence of the species increased significantly with PK fertilisation (from 24 to 35). Fertilisation and the utilisation of the stand caused an increase in its production ability, so PK fertilisation increased yields in comparison with the control treatment by 38% and different doses of N fertilisation by 85, resp. 129%. The average dominance was determined from 76% ($N_0 P_0 K_0$) to 96% D by the plot with an application of 100 kg N ha^{-1} (+ PK). The average yields of dry matter in the years 1976–2005 increased relatively by 129% ($N_{200} P_{40} K_{100}$) compared with the control plot. The yields of dry matter in the experimental variants are significant in their differences (on the 95% level).

Keywords: permanent meadow, fertilisation, species diversity, dominance, yields

Introduction

Meadow stands are multi-componential mixed associations of leguminous and other dicotyledonous species and a dominant grass component (Novák, 2006). The botanic composition and yields result in conservative and progressive factors (Klimeš, 1999). The effect of fertilisation on the phytocenological changes of stands and fodder yields has been documented by Krajčovič (2002), Mrkvička and Veselá (2002), and Jančovič *et al.* (2004) after long-term experiments. According to Michalec and Maťúšová (2002), grass abundance increased in relation to nitrogen fertilisation, whilst the abundance of other botanical groups had a mainly varying tendency. Veselá and Mrkvička (1999), Kasperczyk (2002), and Holúbek (2002) point out the succession changes after long-term fertilisation by N when associations with stoloniferous grasses are created after 5–7 years.

Materials and methods

The experiment was established in 1976 on a plain permanent meadow of mesophytic character at the site of Senožaty (49°33'56"N, 15°12'28"E), which originated in the original grass stand during 1976–2005. The meadow stand is identified from the typological standpoint as *Dactylidetum*, association *Trifolio-Festucetum rubrae.* The altitude is 485 m a.s.l., the average annual precipitation sum 641 mm (402 mm during the vegetation period), the average annual temperature 7.0°C, and Lang's rainfall factor 92. The experiment was arranged by the method of randomised blocks designed with four replications. The area of the experimental parcels is 24 m^2.

Table 1. Fertilisation treatments

Treatments	Signification of variants in following text	Fertilisers/terms of application		
		ammonia saltpetre with limestone/spring	superphosphate/ autumn	potash salt/after first cut
$N_0 P_0 K_0$	1	–	–	–
$N_0 P_{40} K_{100}$	2	–	40	100
$N_{100} P_{40} K_{100}$	3	100	40	100
$N_{200} P_{40} K_{100}$	4	200	40	100

The plant composition of the phytocenosis was always evaluated before the first harvest by the method of reduced projective dominance (D), according to Regal and Veselá (1975).

Results and discussion

In the year of the opening of the research, *Dactylis glomerata* was the dominant species, with the highest degree of coverage. The next concomitant species were *Poa pratensis* and *Festuca rubra*.

Table 2. Frequency of species with dominance D > 1 and D < 1 and total dominance in ten-year stages

Treatments	Years			
	1976	1985	1995	2005
	D > 1/D < 1, ∑ D	D > 1/D < 1, ∑ D	D > 1/D < 1, ∑ D	D > 1/D < 1, ∑ D
1	13/15, 28	12/17, 29	12/13, 25	16/16, 32
2	11/13, 24	14/12, 26	13/12, 25	15/20, 35
3	10/14, 24	12/10, 22	10/13, 23	14/13, 27
4	10/14, 23	8/14, 22	8/14, 22	14/9, 23

A diversity indicator is a number of vascular plant species. Long-term monitoring resulted in the highest number of species within variant 1. Fertilisation, mainly by nitrogen, causes a reduction in the number of species. The dominant species increased their coverage. Regular fertilisation and harvesting of the stand changed the number of species with sporadic occurrence and a dominance less than 1 (D = +), which is documented in Table 2. Similar conclusions were published by Hrabě *et al.* (2002), Mrkvička and Veselá (2006). The grass component had the highest abundance with increased doses of nitrogen fertilisation (Table 3), where *Poa pratensis* (24–27%) and *Festuca rubra* (12, resp. 11%) dominated. Holúbek (2002) verified that the expansion of stoloniferous grasses occurs after 5 to 6 years of regular application of 150 kg N ha^{-1}. Among the bunch-type grass species with the highest coverage were *Dactylis glomerata* and *Arrhenatherum elatius*. The coverage of legumes declined proportionally with the nitrogen doses. The species with the highest coverage were *Trifolium repens* and *Lotus corniculatus*. The highest dominance of other dicotyledonous species was recorded within variants 1 and 2 with *Taraxacum officinale* dominant.

Table 3. Dominance of floristic groups in ten-year stages

Floristic groups	Treatments	Years			
		1976	1985	1995	2005
Grasses	1	55	30	19	37
	2	56	39	50	53
	3	85	61	60	59
	4	90	91	68	73
Legumes	1	25	5	15	29
	2	20	20	10	17
	3	3	6	10	10
	4	1	2	1	3
Other herbs	1	15	27	30	26
	2	5	35	15	20
	3	7	14	15	12
	4	9	5	14	14

The highest average yields of dry matter were reached on plots with the application of N fertilisation (5.2, resp. 6.4 Mg ha^{-1}). Phosphorus and potassium fertilisation increased yields by 38% in comparison with the control plot and nitrogen fertilisation by 85–129% (Table 4). The yield capacity was similar with the variants $N_{100}P_{40}K_{100}$ and $N_{200}P_{40}K_{100}$ (ca 13 kg dry matter per 1 kg N). This stand type is not able to effectively use an elevated dose of nitrogen because of its floristic composition. Similar conclusions were published by Holúbek (2002).

Table 4. Average dry matter yields (Mg ha^{-1}) in decades of years (1976–2005)

Years	Fertilisation			
	$N_0P_0K_0$	$N_0P_{40}K_{100}$	$N_{100}P_{40}K_{100}$	$N_{200}P_{40}K_{100}$
1976–1985	2.66	3.35	5.00	7.00
1986–1995	2.62	3.41	4.53	5.34
1996–2005	3.08	4.82	5.94	6.82
Average 1976–2005	2.79	3.86	5.16	6.39
Relatively in % 1976–2005	100.0	138.4	185.0	229.0

According to the Tukey test the yields of dry mass in experimental variants are significantly different on the 95% level (Table 5).

Table 5. The influence of fertilisation on yields of dry matter (1976–2005)

Variants of fertilisation	Number of cases	Average	Homogenous groups
$N_0P_0K_0$	30	2.792	*
$N_0P_{40}K_{100}$	30	3.864	**
$N_{100}P_{40}K_{100}$	30	4.163	**
$N_{200}P_{40}K_{100}$	30	6.391	*

Conclusions

From the long-term results we can conclude that the application of mineral fertilisers resulted in changes in the succession of species and their dominance and yields on stands of the type *Dactylidetum*, association *Trifolio-Festucetum rubrae.* The coverage of bunch-type grasses (as the less perennial species) decreases, while with nitrogen fertilisation stoloniferous grass species successively expand.

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Variation of structural and functional characteristics of grasslands in the foraging areas of the Eurasian black vulture (*Aegypius monachus* L.)

Vrahnakis M.S.[1], Kadroudi M.[1], Kyriazi E.[1], Vasilakis D.[2], Kazoglou Y.[1] and Birtsas P.[1]

[1]*School of Forestry & M.N.E., TEI of Larissa, Karditsa, Greece*
[2]*WWF Greece, Dadia, Greece*
E-mail: mvrahnak@teilar.gr

Abstract

One of the most crucial attributes of natural grassland functions is their ability to sustain avifauna. This is especially important for protected wild bird species. The Eurasian black vulture (*Aegypius monachus* L.) breeds across southern Europe and Asia, but is endangered throughout its European range. One of its southern-eastern limits of expansion is the Dadia-Lefkimi-Soufli National Park (Dadia NP) in north-eastern Greece. The present research explores the relation between the structural and functional characteristics of grasslands adjacent to the Dadia NP integrated in the foraging areas of the Eurasian black vulture. The research was conducted in June 2007 and included field measurements of vegetation cover, plant species composition, floristic diversity, and above-ground dry biomass. It was found that the Eurasian black vulture forages over grasslands that are characterised by: (a) approximately 40% bare ground cover, (b) a 3:2:1 ratio of Graminae: Umbeliferae: Compositae, (c) high floristic diversity, and (d) low (440 kg ha^{-1}) and medium (611 kg ha^{-1}) above-ground biomass.

Keywords: raptors, grassland structure, diversity ordering diagram, Dadia National Park

Introduction

The Eurasian black vulture (*Aegypius monachus* L., Accipitridae) is one of the largest raptors in the world and is presently distributed in a few Mediterranean countries and Central Asia. It usually breeds in dense *Pinus*, *Juniperus*, or *Quercus* forests at altitudes of 1,000–2,000 m, nesting in trees or occasionally on cliff edges. Its populations have declined severely over most of its former range in the Western Palearctic in the last 200 years as a result of persecution, habitat loss, poisoning by bait put out to kill wolves and other predators, and higher hygiene standards that have reduced the amount of carrion available; it is currently listed as near threatened (NT) (Snow and Perrins, 1998; IUCN, 2008). Recently, various conservation programmes have resulted in the recovery of specific populations, particularly in Spain, where numbers had increased to about 1,000 pairs by 1992 after an earlier decline to 200 pairs in 1940–70, as well as in the Dadia NP, Thrace, NE Greece (Snow and Perrins, 1998; Skartsi *et al*., 2008).
Generally, natural and semi-natural grasslands sustain high avifaunal biodiversity, e.g. 173 "priority" bird species in Europe are associated with low-elevation grasslands and plain agricultural lands (Tucker and Evans, 1997). Natural grasslands are one of the best foraging habitat types for the Eurasian black vulture in terms of food availability (Carrete and Donázar, 2005; Vasilakis *et al*., 2008). Nevertheless, little is known about

the structural and functional characteristics of the grasslands that sustain Eurasian black vultures. The purpose of the present research was to define the floristic cover and composition, the floristic diversity, and the productivity of the grasslands that attract the Eurasian black vulture.

Study area and methods

The Eurasian black vulture is the flagship species of the protected area of the Dadia NP (Natura Site GR-1110002), an area legally protected since 1980 and consisting of two nucleus zones of absolute protection (922 ha and 6,368 ha) and one peripheral zone (35,710 ha), expanded in an elevation range of 3–651 m. The forest consists of pure and mixed *Quercus* spp. as well as other broad-leaved species. The area sustains 219 bird species (including 36 out of the 38 raptors of Greece), 40 reptiles and amphibians, and 48 mammals. Studies of population size have shown that the colony of Eurasian black vultures increased from 25 individuals in 1979 up to 89–100 in 2001, thanks to various conservation measures that included the operation of a feeding station in 1987, but nowadays it is considered rather stable with 19–20 breeding pairs (Skartsi *et al.*, 2008). The optimal nesting habitat is mature trees surrounded by openings or with low-height vegetation located on steep slopes (Poirazidis *et al*., 2004). Their foraging areas include their nesting zones and coincide with the neighbouring extended livestock husbandry areas, mostly shrublands and grasslands.

In June 2007 three grassland areas were distinguished in terms of intensity of use by Eurasian black vultures according to a range use study carried out in the year 2004 by means of radio-tracking (Vasilakis *et al.*, 2008). The grassland in the area of Kechros received a high number of visits, that of Nea Sanda a medium number, and that of Fillyra a low number. Three plots (0.1 ha each) were randomly located in each grassland area. For cover and floristic composition three 20-m transects were randomly set on the ground in each plot and the first contacts of an 80-cm metal stick, placed vertically on the transect line at 20-cm intervals, were recorded. For floristic diversity five metal quadrats (50 cm × 50 cm) were placed randomly on the ground in each plot, and plant species and the number of individuals per species were recorded. For above-ground biomass production three similar quadrats were placed randomly on the ground in each plot, and the above-ground biomass was selected and oven-dried to determine its dry matter production.

For cover/composition percentages and the above-ground biomass production of the three grasslands: (a) typical descriptive statistics were calculated, (b) the Levene test of homogeneity of variance and the one-way ANOVA were applied, and (c) a post-hoc statistical comparison test of the means took place for an $\alpha = 0.05$ level of significance. Initial percentage values were prior arc-sin transformed. For the floristic diversity of the three grasslands the Renyi diversity ordering diagram was constructed in order to explore the diversity comparability of the three grassland communities and their ranking according to a family of diversity indices. Information on the use of the Renyi index can be found in Vrahnakis *et al*. (2005).

Results and discussion

The exploration of the structural components of the three grasslands revealed that the Eurasian black vulture used the grassland with high rock/bare ground cover (Kechros) and low vegetation cover more intensively (***$P < 0.001$) (data not shown). The rate of the three dominant botanical families in this grassland was approximately 3:2:1 for Graminae:Umbeliferae:Compositae, while there was not any clear pattern of cover by botanical families in the grasslands that received medium or low use by the Eurasian black vulture. For all the grasslands, these three botanical families add up to over 50% of the total vegetation cover. *Cynodon dactylon* is the dominant species in all the grasslands, while spine-leaved species, such as *Eryngium campeste* and *Notobasis syriaca*, characterise the canopy of these grasslands. The above-ground dry matter production of the grassland with high use by the vultures (420.2 kg ha^{-1}) is not statistically different (NS, $P > 0.05$) from that of the grassland with medium use (611.2 kg ha^{-1}), while both are significantly lower (*, $P < 0.05$) than that of the grassland with low use (1,053.5 kg ha^{-1}) (data not shown).

The Renyi diversity ordering diagram, for a range of diversity indices, revealed that the grassland of Kechros is more diverse compared to those of Nea Sanda and Fillyra, since the Kechros diversity line superimposes the lines of Nea Sanda and Fillyra; the latter two are not comparable in terms of diversity, since their diversity lines are intersected (Figure 1).

Generally, the abandonment of traditional livestock husbandry practices leads to changes in the composition of vegetation, thus resulting in the reduction of landscape diversity, with negative consequences for avifauna (Tucker and Evans, 1997). The present results stress the need to retain grasslands and open habitats in the foraging areas of the vultures. In this sense, it is not only the Dadia NP, but also the neighbouring grasslands in the species' foraging areas that need to be included into a management scheme. Additionally, the restoration of traditional livestock husbandry practices, to control shrub encroachment, will be beneficial not only for the "flagship" Eurasian black vulture (Vasilakis *et al.*, 2008), but also for other wildlife and the local economy.

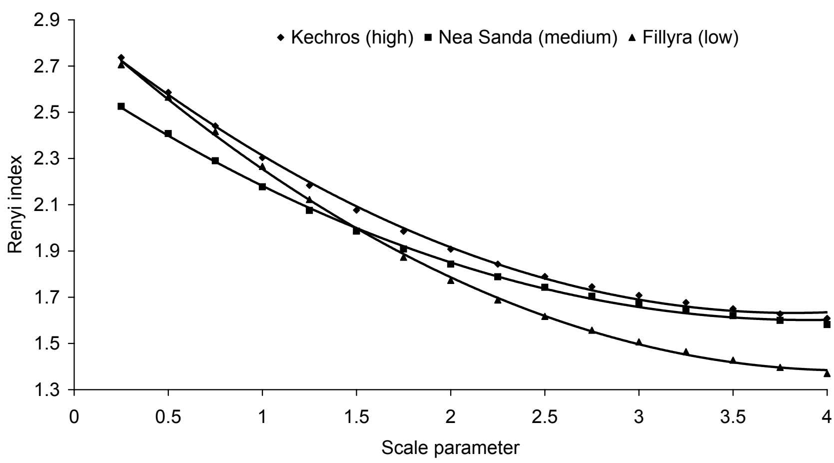

Figure 1. Renyi diversity ordering diagram for the three grasslands

This study is a first approach. It has to be taken into account that not only the structural and functional characteristics of the grasslands but also other factors, such as the relief, the topography, land use, and human disturbances affect the selection of areas for foraging (Vasilakis *et al.*, 2008). Further research on these can provide valuable information about the best conservation management practices.

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Sustainable approaches to small-area grassland and barren management with respect to flora and insect diversity

Vymyslický T.[1], Fabšičová M.[2] and Musil Z.[3]

[1]Research Institute for Fodder Crops, Ltd., Troubsko, Czech Republic
[2]Institute of Botany, Czech Academy of Sciences, Department of Ecology, Brno, Czech Republic
[3]Agency for Nature Conservation and Landscape Protection of the Czech Republic, Moravian Karst Protected Landscape Area Administration, Blansko, Czech Republic
E-mail: vymyslicky@vupt.cz

Abstract

This study is devoted to the determination of sustainable ways of increasing flora and insect diversity in meadows through the establishment of barren sites and fallows, which help many ephemeral plant species to reproduce from the soil seed bank. We tested the optimal time for the duration of a fallow and it seems to be 3–5 years; after this old fallows should be renewed. Significant differences were observed in the number of species and their coverage between nutrient-poor and nutrient-rich areas. No massive occurrence of invasive and expansive species was found. Species commonly found in cultivated landscapes, field margins and balks prevailed. In the warm eastern part of the Podyjí NP we found plant species that had been missing there for many years.

Keywords: barrens, fallows, grasslands, diversity, management

Introduction

A decrease in the biodiversity of semi-natural grasslands, hedges, hollows and minute steppe plots is connected with changes in the landscape as a result of the intensification of agriculture and abandonment of traditional management practices in the last century. Habitat fragmentation leads to the loss of patch connectivity, which has a strong impact on the decrease in the richness of species as a result of changes in soil nutrient availability, an increase in litter deposition, and a reduction of light availability at the community level (Soons, 2003). At the population level, it leads to a decrease in seed production and seed viability and the low availability of pollinators as a result of genetic erosion inside small populations. Such changes cause soil seed bank depletion because of the absence of seed rain and the senescence of buried seeds, which consequently lose their viability and are unable to germinate. The age and management history and the isolation of grasslands from human influence play a crucial role in the recent state of species richness both above ground (in actual vegetation) and below ground (in the soil seed bank). During the last century natural grasslands in Europe have faced a loss of area and increased isolation of their remaining fragments, the cessation of proper management, and an increased load of nutrients (Pärtel *et al*., 2005). In the last 20 years some plots became abandoned because of changes in the land property and a reduction in the use of biocides. The spreading of some extensive agricultural countryside species into the substitutive biotopes of barren sites and fallows has been observed. Only a few works related to these problems have been produced (Chytrý *et al*., 2001; Hofmann and Isselstein, 2004).

The nomenclature of plant names in the paper was unified according to Kubát *et al*. (2002).

Material and methods

The Podyjí National Park was chosen as the study site, because both its history and the management of its area are well known. The National Park was created in 1991 and its area is about 62 km^2. In the year 2000 the Thayatal National Park was created in Austria and both parks now form a bilateral protected area. The River Dyje makes the axis of the area and forms a deep river valley with well-developed river phenomena. The altitude ranges from 207 to 536 m a.s.l. The geology of the area is very complicated. We can find loess, limestone, slate, granite and other types of rock. The whole area is divided into a warm part in the south-east (mean annual temperature 8.8°C) and into a slightly warm part in the west (mean annual temperature 7°C). The whole area is located at the boundary of the Pannonian and Hercynian floristic regions (Culek *et al*., 1996) in a dry climate with precipitation from less than 500 to 620 mm. The flora of the national park is well known; about 1,300 plant species have been recorded there. 84% of the total area is covered by forests. The eastern part was deforested and used for grazing for several hundred years. The central and western part is covered by forests, mainly natural oak-hornbeam and acidophilous oak forests.

In the year 2004 the active creation of fallows started, especially in the eastern part of the NP and in its buffer zone. Experimental plots were selected for the first time in 2006. In the eastern part of the Podyjí NP there are more xerothermic fallows with a mosaic of grasslands, heathlands and ruderal stands. In the western part and in the deep valley of the River Dyje there are more mesophilous fallows. Twelve localities of different vegetation types – dry grasslands (*Koelerio-Phleion phleoidis* Korneck 1974) and mesic ones (*Arrhenatherion elatioris* Koch 1926) – were chosen. In these localities the composition of plant and animal communities and changes in the succession of the initial vegetation types are investigated every year after the autumn ploughing.

Important note on terminology: Fallows are abandoned overgrown former fields, but barren sites are in general parcels without agricultural management (former fields, meadows, gardens, etc.). Barrens very often form a transitional zone between plots with semi-natural (meadows) or natural (steppes) vegetation and field cultures.

Results and discussion

Since 2007, species changes in the vegetation and invertebrate communities of the barrens and fallows in the Podyjí NP have been monitored. In general, the rapid development of a herb layer was observed, depending on climatic conditions (e.g. a drought during the vegetation season of the year 2007). A significant difference was observed in the number of species and their coverage between nutrient-poor and nutrient-rich areas. No massive occurrence of invasive and expansive species was found. Species commonly found in cultivated landscapes, field margins and balks prevailed. In moist places perennial species growing through turf which had not decomposed after the autumn ploughing prevailed. Barren sites and especially fallows can help many ephemeral plant species to reproduce from the soil seed bank. Rare and endangered species were observed only occasionally. After the ploughing of meadows endangered missing plants that had survived in the soil seed bank appeared again: *Thymelaea passerina, Adonis flammea, Bupleurum rotundifolium, Adonis aestivalis, Valerianella rimosa, Tordylium maximum, Filago lutes-*

cens, Alcea biennis, Ajuga chamaepitys, Hyoscyamus niger, Centaurea cyanus. Some *Coleoptera* (*Meloe proscarabaeus* L., *Dorcadion pedestre* (Poda, 1761), *Ophonus ardosiacus* (Lutshnik, 1922), *Netocia hungarica* (Herbst, 1790), and *Curculionoidea* species (30% of 585 recorded species in that area are on barren sites – *Psallidium maxillosum* (Fabricius, 1792), *Asproparthenis punctiventris* (Germar, 1824), genus *Ceutorhynchus*) were found to be typical for barren sites.

Table 1**.** Numbers of plant species found in established fallow plots in 2007 and 2008

Locality	2007	2008	Locality	2007	2008
1. Jejkal	11	37	7. Kraví hora	27	47
2. Hamry	11	39	8. Konice	24	30
3. Galis	7	44	9. Behind Fladnitz cottage	23	37
4. Sobes	20	51	10. Below Fladnitz cottage	12	45
5. Masovice	5	42	11. Hnanice apiary	13	60
6. Masovice pasture	9	51	12. Hnanice forest margin	25	55

Increasing the diversity of the landscape is possible as a result of one or more disturbances of the soil surface taking place and the acceleration of an increase in biodiversity during the succession of plant and animal communities. From the point of view of agricultural praxis these communities are often considered as potential sources of dangerous weed species diaspores. Biotopes of ruderal and barren vegetation occurring in the vicinity of towns offer a refuge, for example, to 50% of the hymenoptera insects and over 35% of the beetles considered in Great Britain as rare and local. The total is 12–15% of the invertebrates (Eversham *et al*., 1996; Small *et al*., 2003). These biotopes are used by *Carabidae* beetles as a refuge, from which they search for food in their surroundings. They act as an important tool for the biological control of pests in a fragmented agricultural landscape. We believe that an appropriate period for the duration of a fallow on one site is 3–5 years. After this period old fallows should be renewed: one part of the fallow is ploughed again and the other one is left as the plant and animal species pool for the next year. Subsequently we should reach a state in which we have all the development phases of fallows at each locality. This approach is very important for the maintenance of the continuousness of the occurrence of the invertebrates. The long-term keeping of the plots under the influence of succession leads to the creation of dense sward and later shrubs. A lot of barren sites have been established randomly in the frame of extensive culture, fields, vineyards, the uncovering or embankment of substrate, etc. Biological belts also play a very important role in such a landscape. These can be lines – roadsides, fields, vineyards, individual grooves, excavations or foxholes. They are often very small – only points – regarding species protection. Some problems need to be solved when fallows are established. First of all, expansive and invasive plant species (*Calamagrostis epigejos, Robinia pseudacacia, Ailanthus altissima*, etc.) can be potentially very dangerous. When there are fields in the surroundings, we have to protect against the influence of pesticides by the creation of field margins.

Conclusions

Barren sites and fallows enable ephemeral plant species to reproduce from the soil seed bank. In the warm eastern part of the Podyjí NP we found plant species that had been missing there for many years. The rapid development of a herb layer was observed, depending on climatic conditions. Significant differences were recorded in the number of species and their coverage between nutrient-poor and nutrient-rich sites. Species commonly found in cultivated landscapes, field margins and balks prevailed, while invasive and expansive plants were suppressed when fallow management is used.

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Chemical composition analysis of harefeeding base

Wolski K., Gawęcki J., Dradrach A. and Kazimierska N.

Wrocław University of Environmental and Life Sciences, Department of Grassland and Landscape Development, Wroclaw, Poland
E-mail: karol.wolski@up.wroc.pl

Abstract

The aim of this work was to estimate the results of the analysed chemical composition of a hare's diet. The investigation was carried out at the Forest Environment and Farm of the Game Breeding Research Centre in Zlotowek. The subjects of the examination were mainly grasses, dicotyledons, and crop plants. The research revealed that the animals' forage has a highly diversified chemical composition.

Keywords: chemical composition, forage, hare

Introduction

There has been a considerable decrease in the size of the *Lepus europeus* population within the last ten years in the whole country, ranging up to 90%. Apart from diseases, parasites, and the high number of predators threatening this species, its feeding base is of no less importance. Forest grasslands constitute areas with permanently formed sod and, when utilised in an appropriate way, they provide small game and deer with fodder of high botanical value. Forest grasslands feature a specific microclimate and phenological, edaphic, and hydrological conditions. Shaded spots, originating from the direct influence of the forest, can lead to the impoverished botanical composition of this kind of sod. Yet, when appropriately utilised, forest grasslands do not differ in their nutritive value from field grasslands and they are able to provide a rich feeding base for small game and deer (Krupka, 1989; Trzaskoś, 1993, 1997; Janicka and Kwiecień, 2004). In the areas featuring diverse management and farm-size reduction the decrease in hare productivity is three times lower than on those characterised by large-scale farming. The latter, as well as large areas of barren land, cause a worsening of the genetic information flow within the hare population (Jezierski, 2004a, b, c).
The aim of this work was the assessment of the chemical composition of the feeding base on a hare (*Lepus europaeus*) breeding farm.

Material and methods

The examinations were conducted at the Forest Environment and Farm of the Game Breeding Centre at Wroclaw University of Environmental and Life Sciences in Zlotowek, Zawinia district, Lower Silesian Voivodship. The base is hunting ground No. 36, with an area of 7,655 ha, of which forest accounts for 72.5%. In the area of the forests forest meadows can be found whose total area amounts 12.93 ha. These are the home of several species of game. The most numerous species are represented by roe deer (*Capreolus capreolus*) and wild pigs (*Sus scrofa scrofa*), while the least numerous are partridge (*Perdix perdix*) and hares (*Lepus europaeus*).

The investigation was conducted at a hare breeding farm (8.282 ha), including forest (6.587 ha) which represents 79.5% of the total farm area. Meadow areas represent 7.3%, ploughland 8.6%, and the remaining part – 4.6% – belongs to a forest nursery. 35 ha were let in for the purpose of breeding. The most characteristic and representative plants were selected and designated, then plant samples were collected to be subjected to chemical analysis. Observation of plants was undertaken from the point of the view of beeing crunched by the hares, as well as observation of the behaviour of the hares themselves, including their feeding preferences. The examinations also involved the chemical composition of the forage.
In order to assay the chemical composition of the plants, samples were collected on two dates: 28th June 2005 and 21st October 2005. No significant difference was found in the contents of particular components (organic and mineral) between the plants collected on different dates. The data regarding the average contents of particular chemical components were tabulated (Tables 1 and 2).

Results and discussion

Plant species were divided into three groups: layer I – forest ground cover 0–50 cm in height; layer II – undergrowth 50 cm-1/3 the height of the trees, and layer III – the forest floor. In layer I 13 plant species were designated, including 8 grass species. Out of eight types selected from layer I the largest area was occupied by *Vaccinum myrtillus* – 68.68%. The second largest area was the domain of a meadow – 7.92% – with such species as *Calamagrostis arundinacea*, *Molinia coerulea*, *Deschampsia caespitosa,* and *Carex* sp. The highest contribution to the meadow sward was that of sedge and blue moorgrass. The most advantageous composition of species featured a grass-sedge type that included sedge (*Carex* sp.). *Poa pratensis*, and *Anthoxanthum odoratum*. Its area ranged over 0.656 ha and it spread along a watercourse. In the forest area, *Deschampsia caespitosa* occurred in more sunny spots, which occupied 1.45% of the breeding farm area. Layer II – the undergrowth – was dominated by *Prunus padus* shrubs. This was included in 4 out of 6 designated types of undergrowth, alternately with

Table 1. Organic and mineral composition of plant species included in the feeding base of *Lepus europaeus* (% of DM)

Inventory	Total protein	Crude fibre	Crude fat	Crude ash	P	K	Ca	Mg	Na
Holcus lanatus	15.16	31.50	2.71	8.46	0.21	1.91	0.70	0.23	0.19
Pteridium aquilinum	11.63	32.74	1.77	7.93	0.10	1.39	0.60	0.55	0.11
Avena sativa	10.79	31.37	2.00	7.38	0.20	1.97	0.49	0.17	0.12
Milium effusum	12.94	36.36	2.21	7.42	0.12	1.45	0.31	0.18	0.03
Deschampsia caespitosa	10.01	32.87	1.55	4.54	0.12	0.48	0.39	0.21	0.05
Deschampsia flexuosa	7.42	39.67	2.45	3.98	0.12	0.95	0.16	0.13	0.01
Poa pratensis and *Anthoxanthum odoratum* type	12.11	34.12	1.45	7.45	0.17	1.94	0.36	0.22	0.03
Calamagrostis arundinacea	10.92	36.50	2.45	5.74	0.18	0.92	0.27	0.19	0.06
Molinia coerulea	11.75	35.60	1.73	5.53	0.10	1.12	0.17	0.14	0.01
Carex sp.	11.91	28.28	1.80	7.94	0.11	0.56	0.43	0.27	0.07
Mean	11.46	33.90	2.01	6.64	0.14	1.27	0.39	0.23	0.07

Table 2. Organic and mineral composition of plant species included in the feeding base of *Lepus europaeus* (% of D.M.)

Inventory	Part of plant	Total protein	Crude fibre	Crude fat	Crude ash	P	K	Ca	Mg	Na
Vaccinium myrtillus	all plant	8.36	32.87	2.24	3.69	0.08	0.33	0.63	0.26	0.03
Betula pendula	shoots	11.81	24.76	10.20	3.15	0.11	0.39	0.62	0.18	0.03
Prunus padus	bark	3.93	25.31	1.51	2.84	0.04	0.12	1.22	0.13	0.04
	shoots	12.50	16.42	4.46	5.44	0.10	0.62	0.83	0.31	0.03
Rubus sp.	all plant	11.51	26.91	2.34	3.75	0.09	0.47	0.86	0.26	0.03
Viburnum opulus	shoots	9.52	24.76	6.83	7.76	0.08	1.00	1.70	0.35	0.06
Rubus ideaus	all plant	12.59	30.10	1.51	5.39	0.12	0.92	0.78	0.29	0.04
Alnus glutinosa	bark	9.18	27.09	3.94	4.20	0.07	0.29	1.67	0.10	0.07
	shoots	15.51	16.66	8.29	5.09	0.11	0.30	1.26	0.18	0.05
Prunus spinosa	bark	3.99	22.10	3.29	9.65	0.04	0.14	2.42	0.12	0.06
	shoots	4.04	36.52	1.88	3.54	0.06	0.16	0.79	0.13	0.03
Mean		9.35	25.91	4.22	4.93	0.08	0.43	1.16	0.21	0.04

Pinus sylvestris, *Betula pendula*, and *Alnus glutinosa*, as well as *Sorbus aucuparia* and *Larix decidua*. The largest area – 4.249 ha – was occupied by *Prunus spinosa* and *Prunus padus* (16.30%), while the smallest one (0.06%) was occupied by young *Malus domestica* planted in 10 "nests" numbering 10 plants each, along the forest wall. The vegetation was relatively poor in protein as its average value for grassland amounted to 11.46% (DM) and for shrubs and trees it represented 9.45% (DM). The lowest protein value was that of *Deschampsia caespitosa* – 7.42% (D.M.) and the bark of shrubs such as *Prunus spinosa* and *Prunus padus*, while the highest amount of protein was that of *Holcus lanatus* (15.16% DM) and the shoots of *Alnus glutinosa* (15.51% DM).

The crude fibre content in the sward reached quite a high level, exceeding 30% of DM. A lower content of crude fibre was assayed in the shoots and bark of trees and shrubs, amounting to 25.91% of DM Among grasses the highest content of protein – 39.67% (DM) – was found in *Deschampsia caespitosa* and among shrubs – the shoots of *Prunus spinosa* – 36.5% (DM). Low fibre content, in comparison to other species contained in the sward, was found in *Carex* sp. – 28.28% (DM) – and among trees and shrubs – the shoots of *Prunus padus* – 16.42% – and *Alnus glutaminosa* – 16.66% of DM. The crude fat content in the sward represented a relatively low level and it amounted to 2.01% of DM; trees and shrubs contained more crude fat, reaching 4.22% of DM.

The crude ash content of the sward amounted to 6.64% of DM. Shrubs and trees contained less ash – 4.93% of DM. The average phosphorus content in the sward equalled 0.14% of DM, while for trees and shrubs that value was 0.08% of DM. The potassium content in the grassland was 1.27% of DM; less potassium was found in trees and shrubs – 0.43% of DM The calcium content in the grassland was 0.39% of DM, and much more calcium was assayed in trees and shrubs – 1.16% of DM. The magnesium content in the grassland equalled 0.23% of DM, and similar amounts of magnesium were found in trees and shrubs – 0.21% of DM. The average content of sodium in the sward was 0.07% of DM, while its content in the shoots and bark of trees and shrubs was of an even value and it amounted to 0.047% of DM.

The highest quantity of this component was in *Holcus lanatus* – 0.19% of DM. The lowest amounts of sodium were in *Deschampsia caespitosa* and *Molinia coerulea* – 0.01% of DM.

Conclusions

1. Analysis of the forage chemical composition included in the diet of hares *Lepus europaeus* was highly diversified regarding the contents of particular components.
2. Among grasses *Holcus lanatus* featured the highest content of total protein and mineral components, while the lowest content of components was found in *Deschampsia caespitosa*.
3. The ground cover of a forest, as well as the shoots and bark of trees and shrubs, contained a highly diversified content of chemical components. The bark of *Prunus padus* and *Prunus spinosa* featured 4% total protein, while the shoots of *Alnus glutinosa* contained more than 15.5%.
4. The relatively low content of nutrients in the plants growing on the hare breeding farm should be supplemented by additionally provided forage.

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Water-use efficiency of grassland differing in diversity

Wrage N.[1], Ebenau A.[1], Jarzmik A.[1], Steude K.[2], Peter K.[2], Thies C.[2] and Isselstein J.[1]

[1]*University of Goettingen, Department of Crop Sciences, Goettingen, Germany*
[2]*University of Goettingen, Institute of Agroecology, Goettingen, Germany*
E-mail: nwrage@gwdg.de

Abstract

Plant diversity in grassland may lead to increased water-use efficiency as a result of complementary use of the rooting zone. An indicator of the water-use efficiency of C_3 plants is their natural abundance of the carbon isotope. When enough water is available, the plants can keep their stomata open, enabling them to use a large pool of carbon dioxide. Thus, they can fractionate more against the heavier ^{13}C, leading to a depletion of the plant material. When less water is available, they need to use more ^{13}C because of the smaller C pool available with the shorter opening times of the stomata. This causes an enrichment of the plant material. We have used this principle to investigate the water-use efficiency of grassland differing in diversity. Sods of grassland with or without forbs were cut and incubated in pots with normal water application or experimental drought. Differences between water treatments were clearly visible in ^{13}C values. However, there were no differences between differently diverse swards. This was probably due to the cutting of the sods, which destroyed deep roots.

Keywords: plant diversity, water-use efficiency, deep root

Introduction

With climate change, the occurrence of droughts is likely to become more frequent and rainfall more erratic (IPCC, 2007). To make possible sufficiently large production, agricultural management needs to be efficient not only with respect to nutrients and energy, but also to water use. It has been suggested that plant diversity influences the water use of a sward. The different rooting depths of coexisting species have been found to increase the water use of more diverse grassland systems (Caldeira *et al.*, 2001), thus potentially increasing the vegetation's resilience to water stress. So far, experiments have been conducted on experimental grassland under conditions that are not readily comparable to agricultural situations.
In this manuscript, we describe work that was carried out as a student practicum with sods from long-term grassland. The influence of water stress was measured with stable isotopes. When sufficient water is available and the stomata are open, CO_2 can be exchanged with the ambient air and plants preferably use the lighter $^{12}CO_2$. Under drought conditions, the stomata are closed for longer periods and plants have fewer chances to fractionate. Thus, their tissue is gradually enriched with the heavier isotope ^{13}C (Figure 1).

Material and methods

Sods were cut to a depth of 20 cm on long-term grassland of the experimental farm at Relliehausen, University of Goettingen, from two plots of the BIOMIX experiment

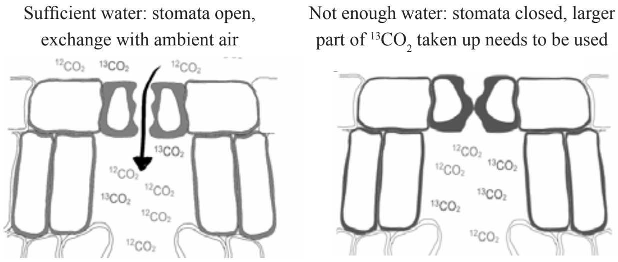

Figure 1. With open stomata, CO_2 can be exchanged between intercellular space and ambient air. The substrate pool for photosynthesis is larger and plants can fractionate more, i.e. use more depleted CO_2 than when the stomata are closed. The tissue contains less $^{13}Co_2$; it is depleted

(40 sods). Two years previously, one part of the grassland had been treated with herbicides against dicots. Thus, the sods of the treated grassland were dominated by *Dactylis glomerata, Poa pratensis, Agrostis tenuis, Lolium perenne*, and *Lolium remotum*. The untreated grassland also contained *Taraxacum officinalis, Galium rotundifolium, Ranunculus repens, Trifolium repens, Poa annua*, and *Poa trivialis*. The sods were potted and incubated in an open-air hall under ambient conditions. The pots were arranged with alternating grass-only (G) and forb and grass (F) sods. They were left for three weeks to regenerate from the sod cutting. After this time, the plant biomass was cut to a height of 10 cm. Then, half of the pots were protected from rain by transparent plastic foil (drought treatment, D). This foil reduced the light transmission by 25 to 40% on a shady and sunny day, respectively. As the incubation took place in May and June 2008, when rainfall was scarce, the unprotected pots were watered regularly (control, C). The amount of rainfall was measured with a gauge. The drought treatment did not receive water.

After 26 days, the vegetation was harvested (cutting height 10 cm). It was dried (60°C), weighed, milled, and samples measured for ^{13}C on an isotope ratio mass spectrometer (Delta plus Finnigan MAT, Bremen, Germany) that was coupled to an elemental analyser (NA2500 CE Instruments, Rodano, Milano, Italy) via an interface (Conflo III Thermo Electron Cooperation, Bremen, Germany). Isotopic values are given as $\delta^{13}C$ values:

$$\delta^{13}C\ (‰) = (^{13}C/^{12}C_{sa} - {}^{13}C/^{12}C_{std})/(^{13}C/^{12}C_{std}) \times 1{,}000$$

where: sa – sample; std = standard (V-PDB)

The treatment effects were evaluated with ANOVA (biomass data) or the Kruskal-Wallis test in cases of non-normal distribution (isotopic values) ($n = 10$, $\alpha = 0.05$). Values are given as means plus/minus standard deviations.

Results

After the three-week recovery period, there was no significant difference in harvested biomass between the treatments. After the incubation period, the biomass in the drought plots was significantly less than in the controls. There were no significant differences between the sods with or without forbs. In CF, 66% of the biomass consisted of grasses, 27% of legumes, and 7% of forbs. The biomass of forbs and, especially, legumes decreased more than that of grasses in pots with drought stress compared to the controls. While the grass biomass was, on average, in DF 32% of CF (thus making up 93% of the biomass), that of forbs was 12% and that of legumes only 2% of that in CF. In DG, the grass biomass was 30% of that in CG and no forbs or legumes were found.

There were significant differences in δ^{13}C between D and C. There were, however, no differences between G and F (Table 1). Individual analysis of the functional groups yielded the same results.

Table 1. δ^{13}C values (‰) of the different treatments (n = 10, given are means and standard deviations)

	D (‰)	C (‰)
G	–28.6 ± 0.4	–29.7 ± 0.2
F	–28.2 ± 0.3	–29.6 ± 0.6

D – with experimental drought, C – control with sufficient water, G – sward contained only grasses, F – sward contained grasses, forbs, and legumes

Discussion

The drought led to shifts in the proportion of functional groups, with grasses in our conditions generally coping better with the stress. After extreme heating events, White *et al*. (2000) found a larger surface cover of C_4 species in grassland. Three years of elevated temperatures increased forb production in another experiment, however without significantly changing overall diversity (Zavaleta *et al.*, 2003). It should be kept in mind that such changes in the relative proportions of grasses and forbs also affect fodder quality and livestock production. Kahmen *et al*. (2005) did not find changed species numbers, but observed increased below-ground production in more species-rich plots after a simulated drought, which may affect the recovery of the vegetation, thus potentially also increasing resistance to drought.

In this experiment, we also tested differences in δ^{13}C values as indicators of water stress in grassland with different proportions of grasses and forbs. Our hypothesis that more species-rich grassland should be better able to use water resources and, therefore, have more negative δ^{13}C values could not be verified. This might have been due to the cutting of the sods, as we were only able to take the upper 20 cm of the soil and roots. Thus, we had to cut the deep roots, which might have annihilated the advantage of swards with more coexisting species that might also be rooting at greater depths. This would also have influenced biomass production. We therefore suggest repeating the experiment in the field.

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Session 2

Alternative use of grassland

Life-cycle analysis of heat generation using biomass from semi-natural grasslands in Central Europe

Tonn B., Thumm U. and Claupein W.

University of Hohenheim, Institute of Crop Production and Grassland Research, Stuttgart, Germany
E-mail: btonn@uni-hohenheim.de

Abstract

Combustion for bioenergy generation is an alternative use for semi-natural grasslands. These constitute low-yielding, but low-input systems for biomass production. A life-cycle analysis (LCA) was used to assess the overall energy efficiency, global warming potential and acidification potential of hay combustion in comparison with heat generation from fossil fuels. Four scenarios were compared (grassland cut once or twice a year, with and without N fertilisation) together with sensitivity analyses to assess the effect of biomass yield. The combustion of grassland biomass was found to be carbon negative and to provide net energy gains even at low biomass yield levels. At a yield of 3.8 Mg DM ha^{-1}, energy use efficiency was 8.7 GJ GJ^{-1} and thus comparable to that of other herbaceous biofuels. Increased yields under N fertilisation or a two-cut regime could not compensate for the higher energy input and, while increasing net energy yield, decreased energy use efficiency. Acidification potential of all biomass scenarios was higher than that of the fossil fuel scenario due to high SO_2, NO_x, and HCl emissions during combustion. With technological solutions to reduce these emissions and local networks to collect dispersed residual biomass from different sources, semi-natural grasslands can constitute an important biomass potential for bioenergy generation.

Keywords: bioenergy, combustion, grassland conservation, acidification potential, global warming potential, energy use efficiency

Introduction

Heat generation from grassland biomass

Semi-natural grasslands are ecosystems of high biodiversity and characteristic elements of many European landscapes. A large proportion of them are listed in Annex I of the EU Habitats Directive as natural habitat types of Community interest (EC, 1992). Technological changes in the agricultural sector and increased quality requirements for animal feeds due to improvements in animal performance have led to a dramatic reduction in their area over the last decades (Emanuelsson, 2008). The same developments make it increasingly difficult to utilise the remaining semi-natural grassland areas for forage production. Alternative uses for grassland biomass are being sought. This is of particular importance for those parts of Europe where semi-natural grasslands are dominated by mown grasslands that are difficult to conserve by grazing. Even where these grasslands are still managed under agri-environmental or conservation schemes the disposal of the harvested biomass may pose considerable problems. The growing importance of bioenergy production seems to offer new solutions to these problems (Elsäßer, 2003).

In theory, a variety of conversion technologies can be used for bioenergy generation from grassland biomass. Electricity and heat production through anaerobic digestion of biomass has acquired a great importance predominantly in Germany and Austria. High conversion efficiencies, however, can only be achieved when young, highly digestible grass is used. Mature grassland biomass from extensively used grasslands shows substantially lower specific methane yields (Prochnow *et al.*, 2008). A considerable number of technologies designed specifically for energy production from cellulosic substrates, such as wood or straw, are currently in different stages of development. These include, among others, biomass-to-liquid technologies, gasification, and cellulosic ethanol production (Hamelinck *et al.*, 2004, 2005; Hamelinck and Faaij, 2006; Wang *et al.*, 2008). So far there are still very few operating plants, and it is not yet clear what kind of substrates will be eligible for these technologies from a logistic point of view. Because of these uncertainties, the present work focuses on combustion as the currently most promising conversion technology for mature grassland biomass. Using furnaces already available for the combustion of straw, it combines a high conversion efficiency with the possibility for using small, decentralised units (Obernberger, 1998).

The importance of assessing the energy efficiency and overall environmental impact of different biofuels has recently been stressed by several authors (Tilman *et al.,* 2006; Hill, 2007; Petersen, 2008). Compared to other crops, semi-natural grassland requires only a small energy input for cultivation, as neither soil cultivation nor, in most cases, application of mineral nitrogen fertilisers are required. Starting to use grassland biomass for energy production does not imply land-use change with associated CO_2 emissions from soil carbon and aboveground biomass destruction (Fargione *et al.*, 2008). On the other hand, yields are low, and the low density of hay leads to a large transport volume. Both are factors with a negative influence on energy efficiency. The chemical composition of grassland biomass also leads to higher emissions of nitrogen oxides (NO_x) and hydrogen chloride (HCl) during combustion compared to wood or straw (Obernberger, 1998).

Life cycle analysis

A suitable tool for the evaluation of the overall environmental impact of grassland biomass combustion is the technique of life cycle analysis or life cycle assessment (LCA). An LCA considers potential environmental impacts of a product on a cradle-to-grave base, including raw product acquisition, production and disposal. According to ISO norm 14040:2006 (CEN, 2006) it comprises the four distinct steps detailed below.

The first step in an LCA is the goal and scope definition. It clearly states the intended application of the study, describes the product system to be studied and its functions as well as the system boundaries. It also defines the reference unit, the so-called 'functional unit', to which inputs and outputs are related. Several functional units can be used in the same LCA. This is often the case in LCAs of agricultural production systems, where both the environmental impact per product unit and per unit land occupied are of interest. The second step of an LCA is the compilation of a life cycle inventory. It consists in collecting and calculating relevant inputs and outputs of the production system. Inputs include resources and energy, outputs may consist in emissions to air, water and land. This step is followed by a life cycle impact assessment. Many approaches are possible here. A standard procedure is to classify inventory data into impact categories. These include, for example, global warming potential (aggregating CO_2, CH_4, NO_2 emissions; unit: CO_2 equivalents) or acidification potential (aggregating SO_2, NO_x, NH_3 and HCl emissions; unit: SO_2 equivalents). There are many other impact categories pertaining to both environmental impacts and impacts on human health. LCAs of agricultural production systems have to take account of the fact that land will inevitably be used for some purpose. Results are therefore often presented in comparison to a reference scenario considering a different land use. In LCAs of bioenergy production the reference scenario will generally include energy provision by a fossil fuel alternative. The forth and final stage of an LCA is the life cycle interpretation. It summarises the results of the life cycle impact assessment to come to conclusions and recommendations.

The goal and scope definition and the documentation of inventory data are crucial as there is no one single approach to an LCA. Different assumptions may be taken about elements of the production chain. System boundaries can be set to include or exclude human labour and supply chains such as production and maintenance of machines and infrastructure used. Depending on the intended application depth and detail of the study may vary. The quality of the data used also differs widely and may impose serious limitations to the study. Due to regional differences and technological developments different spatial and temporal scopes of LCAs may introduce further variation. If results are expressed in comparison with a fossil fuel scenario, the choice of this reference system strongly influences the results. All these factors have therefore to be taken into account when comparing LCAs following different methodologies.

Objectives of this paper

Among LCA studies of biomass combustion, very few have included semi-natural grassland biomass as a fuel. This paper presents the results of an LCA adressing the following questions:

- What is the environmental impact and energy use efficiency of heat generation from semi-natural grassland biomass under a very extensive management schedule (one cut per year, no N fertilisation)?
- How does an increased yield through a more intensive management (two cuts per year, application of N fertiliser) change these parameters?

Within the limitations described above, these results are compared to those of other LCAs on grassland biomass combustion. Differences between the studies and uncertainties in the underlying models are discussed. The results are also set into perspective by considering the environmental impact of other conversion strategies for grassland biomass as well as that of dedicated biofuels for combustion.

Materials and methods

An LCA was done according to ISO norm 14040:2006 (CEN, 2006) with the aim to assess the environmental impact of heat production from grassland biomass. The impact categories considered were cumulative energy consumption, global warming potential and acidification potential. The equivalence factors for the emissions contributing to global warming and acidification potential were taken from IPCC (2001) and Heijungs (1992), respectively. The functional unit was 1 GJ heat energy produced at the heating plant. Energy use efficiency (EUE) was calculated as the quotient of energy yield at the heating plant and total energy input. A fossil fuel scenario was used to normalise the environmental impacts. In this scenario the grassland sites are mulched and the heat energy is supplied using light heating oil. The assumed bioenergy production system is represented in Figure 1. Full supply chains for machines, diesel fuel, heating oil, N fer-

tiliser and electricity were taken account of. Those for infrastructure, such as roads and buildings, were excluded. Time and diesel fuel needed to perform machine operations were derived from KTBL (2005a). A 40% allowance was added to these data for all field operations. This acounts for increased time and fuel demand in the management of semi-natural grasslands due to steep slopes, stones, trees and other obstacles (KTBL, 2005b). The electricity demand of the biomass and fossil fuel heating plants was assumed to be 1.4% and 0.5% of the fuel heating value, respectively (Kaltschmitt and Reinhardt, 1997; Heinz *et al.*, 2001). The thermal efficiency was set as 84% for the biomass heating plant and 92% for the oil heating plant (Kaltschmitt and Reinhardt, 1997).
Inventory data for the supply chains of machines, diesel fuel, and electricity were taken from Gaillard *et al.* (1997) and Kaltschmitt and Reinhardt (1997). Emissions through the combustion of diesel fuel follow Borken *et al.* (1999). The emissions of N_2O and NO_x from N applied as fertiliser or mulch were calculated based on Bouwman (1996) and Yan *et al.* (2003). During the combustion of grassland biomass 16% of fuel Cl and 46% of fuel S were assumed to be emitted as HCl and SO_2, respectively, with constant CH_4 emissions of 9.0 mg MJ^{-1} and N_2O emissions of 6.6 mg MJ^{-1} (Becher, 1997). NO_x emissions were modelled using data published by Nussbaumer (1997) to derive the following function:

$$NO_x = 0.526 \text{ mg MJ}^{-1} \times LHV \times N^{0.43} \times 426.6 \text{ (mg m}^{-3}\text{)}$$

where: NO_x – NO_x emissions (mg kg^{-1}), LHV – lower heating value (MJ kg^{-1}), N – N content of the grass (%)

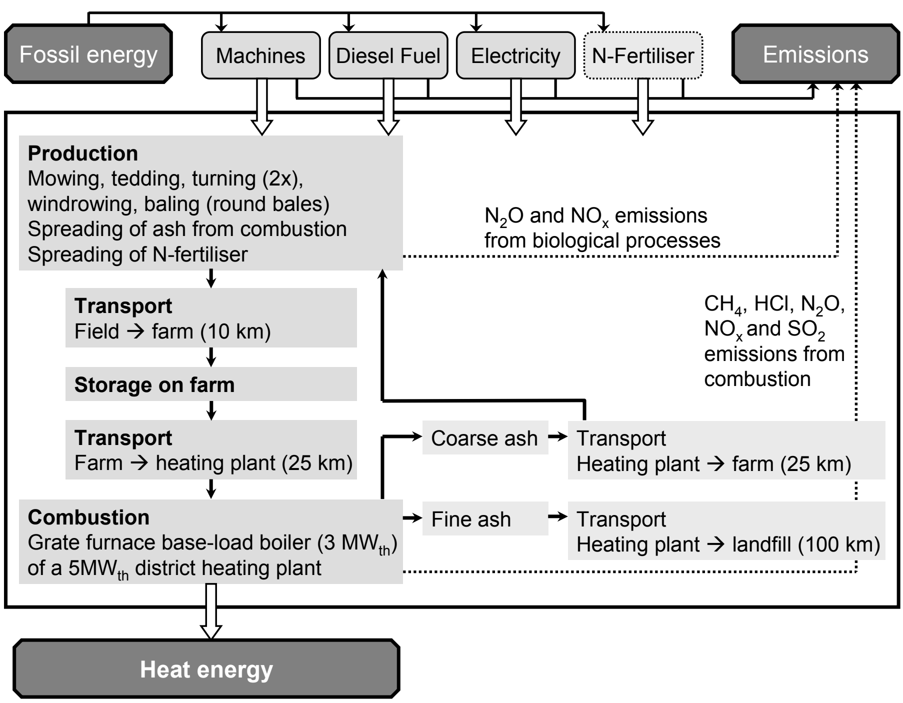

Figure 1. Simplified life cycle of heat generation from semi-natural grassland biomass

Data from the last eight years of a 17-year field experiment of the Bildungs- und Wissenszentrum Aulendorf was used to derive biomass yields, ash and N content of semi-natural grassland under different management schemes (Elsäßer and Briemle, 2002). This field experiment was run on a stagnic luvisol at the experimental station Aulendorf (590 m a.s.l., average yearly precipitation 910 mm, average yearly temperature 7.9°C). Treatments considered in the LCA are one or two cuts per year, either with or without fertilisation. Fertiliser was applied as liquid cattle manure. The LCA stipulates no P and K fertilisation apart from the coarse ash returned to the field. As P and K fertilisers show no direct yield effects in grassland on soils well provided with these nutrients (Øgaard *et al.*, 2002; Gallet *et al.*, 2003) the following assumption were made: (*i*) the lack of ash applications on the unfertilised experimental treatments were assumed not to have decreased yields, (*ii*) the higher P and K inputs through liquid manure in the fertilised experimental treatments were assumed not to have increased yields in comparison with the system underlying the LCA. Accordingly, only the N fertiliser application was bilanced. One kilogram of liquid manure N was supposed to be equivalent to 0.75 kg N applied as ammonium sulfate. The experimental treatment of mulching once a year is included in the fossil fuel reference scenario of the LCA.
S and Cl content were not analysed in the field experiment. Using data from Whitehead (2000) they were set to 5 mg g^{-1} Cl for all cuts and to 1.5 and 1.8 mg g^{-1} S for the first and second cut, respectively. The experimental yields (Table 1) are higher than the net yields that would be achieved by conventional haymaking. For the LCA, net biomass yields were calculated assuming 20% mechanical and respiratory losses and additional pick-up losses of 0.15 t ha^{-1} following the literature reviewed by McGechan (1989). The biomass delivered at the heating plant is reduced by another 3% of storage and transport losses. In addition to the LCA for the four biomass scenarios and the one reference scenario, several sensitivity analyses were conducted to assess the influence of biomass yield, transport distance and amount of N fertiliser on the outcome of the analysis.

Table 1. Treatments in the field experiment underlying the LCA

Treatment	Cutting date	Fertiliser input (kg $ha^{-1}a^{-1}$)	Average yield (Mg DM $ha^{-1}a^{-1}$)
1 cut, no N fertiliser	01. 09.	–	4.89
2 cuts, no N fertiliser	20. 07./20. 10.	–	6.08
1 cut, N fertiliser	01. 09.	N: 113 / P: 19 / K: 94	6.68
2 cuts, N fertiliser	20. 07./20. 10.	N: 163 / P: 30 / K: 135	10.01
Fossil fuel reference	01. 09. (mulching)	–	6.62

Results

Proportional to their biomass yields, energy yields of the four biomass scenarios ranged from 45 to 92 GJ ha^{-1} or 1.1 to 2.2 tonnes of oil equivalent (Table 2). The energy input was 5.2 GJ ha^{-1} for the unfertilised treatment at one cut. A second cut increased the energy demand by 48%, N fertilisation more than doubled it. EUE was highest at one cut and no N fertilisation. Even under N fertilisation, more than five times as much bioenergy was produced than fossil energy invested.

Table 2. Net biomass yield, energy yield, energy input and energy use efficiency for the four biomass scenarios

	No N fertiliser		N fertiliser	
	1 cut	2 cuts	1 cut	2 cuts
Net biomass yield (Mg DM ha^{-1})	3.76	4.71	5.20	7.86
Energy yield (GJ ha^{-1})	44.9	54.5	62.0	91.9
Energy input (GJ ha^{-1})	5.2	7.6	10.8	16.8
Energy use efficiency (GJ GJ^{-1})	8.71	7.17	5.73	5.47

The dependence of the EUE on biomass yields is shown in Figure 2a. Under one cut and without N fertilisation it is still considerably higher than 1 GJ GJ^{-1} even for very low biomass yields of less than 2 Mg ha^{-1}, while it rises above 10 GJ GJ^{-1} when net biomass yields exceed 6 Mg ha^{-1}. Transport distance considerably affects EUE, particularly at high biomass yields (Figure 2b). Increasing the distance between farm and heating plant from 25 to 100 km reduces EUE from 10.0 to 7.3 GJ GJ^{-1} at a net biomass yield of 6 Mg ha^{-1}.

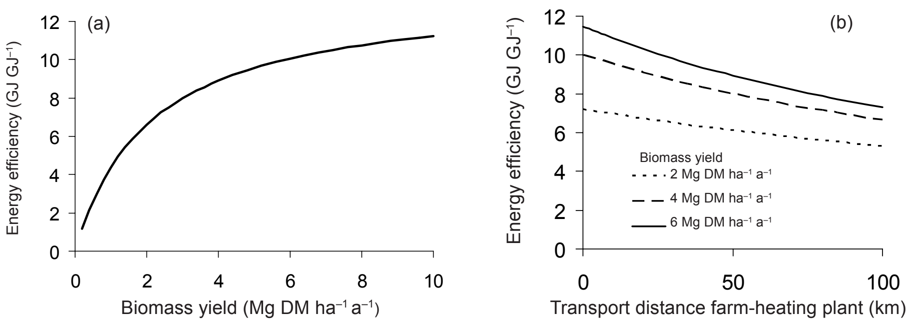

Figure 2. Sensitivity graphs showing the influence of (a) net biomass yield and (b) transport distance between farm and heating plant on the energy use efficiency (EUE) of heat generation from grassland biomass

How much the EUE is decreased by a second cut or by the application of N fertiliser depends on the baseline yield and on the yield increase obtained through these measures. If a second cut can increase biomass yield by 2 Mg ha^{-1} on a grassland site yielding 4 Mg ha^{-1} under a one cut regime, the energy efficiency of the two cut regime will be 91% of that of the one-cut regime (Figure 3a). At a baseline yield of 6 Mg ha^{-1} the same yield increase would mean an EUE of only 83% compared to a one-cut regime.

To simply offset energy needed to produce N fertiliser, comparatively low yield gains are sufficient. The EUE, on the other hand, is strongly affected even under moderate N fertilisation (Figure 3b). The yield increases that may be realistically expected through N fertilisation are not sufficient to achieve the same EUE as the unfertilised system.

Non-renewable energy consumption of heat production from grassland biomass was 9% to 15% of that needed in the fossil fuel reference scenario (Figure 4a). For the unfertilised treatment without N fertilisation the electricity demand of the heating plant made up the greatest share in the total energy demand. In the fertilised treatments the production of N fertiliser contributed more than a third of the total energy demand.

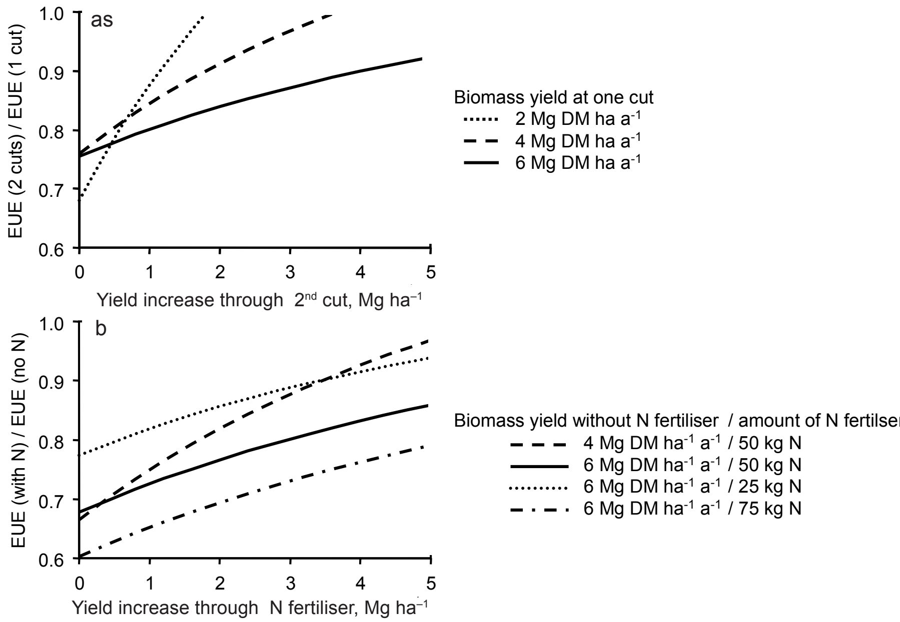

Figure 3. Sensitivity graph showing the ratio between the energy use efficiencies (EUE) a) of grassland land cut once or twice a year, b) of grassland with and without N fertilisation

The emission of greenhouse gases is not directly proportional to the use of fossil fuels, as there are several other processes that result in the emission of greenhouse gases, particularly of CH_4 and N_2O. Both gases are emitted during combustion. N_2O is set free in the course of N fertiliser production and through denitrification following its application. Consequently, global warming potential rises to more than 30% of that of the fossil fuel scenario in the two fertilised treatments (Figure 4b). If the yield increase through N fertilisation is below 0.02 Mg per kg N fertiliser, even the net greenhouse gas saving per ha will be lowered.

While grassland biomass combustion showed both lower energy consumption and global warming potential than the fossil fuel scenario, the acidification potential was more than doubled for all four biomass scenarios (Figure 4c). Emissions during the combustion process most strongly contributed to the acidification potential. Of these, 49% of the SO_2 equivalents were due to NO_x, 35% due to SO_2 and 16% due to HCl emissions.

Discussion

Acidification potential

The most critical aspect of grassland biomass combustion was identified to be its high acidification potential. This would be most efficiently reduced by lowering the emissions contributing the highest amount of SO_2 equivalents, namely N_2O and SO_2 emitted during combustion. Decreasing the biomass N content can contribute little to the achievement of that goal: according to the emission model used in this study, even reducing biomass N content by half only leads to a 25% decrease of N_2O emissions. The biomass S content is difficult to influence in semi-natural grassland biomass. Technical primary and secondary measures to lower boiler emissions will thus be necessary. For example, fuel staging has the potential to reduce boiler NO_x emissions by up to 80% (Nussbaumer, 2003), thus reducing total acidification potential by about 30%.

Management influence on EUE and global warming potential

As electricity needed for combustion has a large share in the total energy consumption, the influence management practices have on the EUE are comparatively small. Moreover, in many cases conservation objectives will decide whether one ore two cuts will be taken and if N fertiliser may be applied at all. There are, however, cases where the management aim is not primarily to preserve a given botanic composition, but rather to keep the landscape open and prevent shrub-encroachment and re-forestation (Moog *et al.*, 2002). In these cases, management should optimise net energy production, EUE and greenhouse gas saving potential.

When grassland is cut twice instead of once a year the EUE will be reduced by only 10–20% in the majority of cases. If therefore the botanical composition is best preserved by two cuts, this is not too disadvantageous from an energetic point of view. Monetary costs will be more likely the limiting factor of such a practice unless farmers are paid an adequate compensation for this management. Another problem of a two-cut regime is the lower biofuel quality of the second regrowth. Its higher N content will lead to higher NO_x emissions; a higher K content will increase corrosion and furnace slagging (Obernberger, 1998).

Mineral N fertilisation will not be considered at all on many oligotrophic semi-natural grasslands. Mesotrophic grasslands, on the other hand, constituting a majority of the traditional

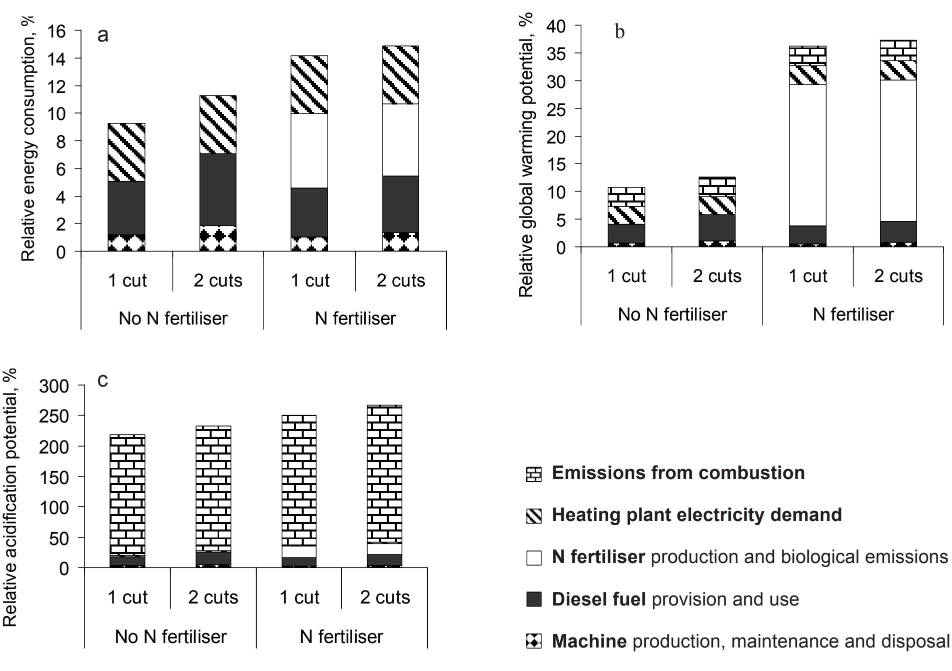

Figure 4. Cumulative energy demand, global warming potential and acidification potential of heat generation from grassland biomass relative to the fossil fuel scenario

hay meadows, require a partial replacement of the nutrients removed. This is traditionally done by the application of stable manure. For P, K, Mg and trace elements such a nutrient recycling takes place by returning most of the fuel ash to the field. N may be supplied by legumes, though grasslands with a high proportion of legumes are less suitable for combustion due to their higher biomass N content. If N is applied as mineral fertiliser on these sites, this will be both decreasing the EUE and increasing the relative global warming potential.

Comparison of LCAs

The comparability of LCAs following different methodologies is limited, as explained above. This makes it difficult to compare the environmental impact of grassland biomass combustion with that of other biofuels. Lewandowski and Schmidt (2006) and Angelini *et al*. (2005) balanced energy yield and consumption for the cultivation of miscanthus, reed canary grass, triticale and giant reed at different N fertilisation levels (Table 3, production systems 1 and 2a–c). They calculated the EUE as the quotient of gross bioenergy yield and energy consumption for crop production only. At this calculation basis, the EUE was 34.5 and 22.4 GJ GJ^{-1} for the unfertilised scenarios of the present study, while the fertilised scenarios had an EUE of 14.9 and 14.0 GJ GJ^{-1}, for the one- and two-cut treatments, respectively. All these values are well within the ranges reported by Lewandowski and Schmidt (2006) and Angelini *et al*. (2005), showing that biomass

Table 3. Biomass yield and energy use efficiencies (EUE) in published LCAs of different biomass crops and biomass use scenarios

Production system	Biomass yield, Mg DM $ha^{-1}a^{-1}$	EUE, GJ GJ^{-1}
Angelini *et al.* (2005)		
1. Giant reed (*Arundo donax*), N fertiliser 0 and 200 kg ha^{-1}	22.8–29.1	23–102*
Lewandowski and Schmidt (2006)		
2a. Miscanthus (*Miscanthus × giganteus*), N fertiliser 0, 70 and 140 kg ha^{-1}	8–38	8–51†
2b. Reed canary grass (*Phalaris arundinacea*), N fertiliser 0, 50, 100 and 150 kg ha^{-1}	2–12	2–36†
2c. Triticale (*Triticosecale*), N fertiliser 0, 70 and 140 kg ha^{-1}	3–12	17–39†
Rösch *et al.* (2007)		
3a. Semi-natural grassland, unfertilised, one cut per year, field size 5 ha, round bales, combustion in 89 kW_{th} whole-bale straw-gasification boiler	3.9	13.6‡
3b. Intensely used grassland, 2 and 4 cuts per year (accounting for 10 and 90% of the substrate), electricity production by anaerobic fermentation, 100 kW_{el} biogas combined heat and power plant (CHP)	6.4/10.0	5.3‡
3c. Maize (*Zea mays*), N fertiliser 111 kg ha^{-1}, electricity production by anaerobic fermentation, 100 kW_{el} biogas CHP	15	4.3‡
3d. Poplar (*Populus trichocarpa*), no N fertiliser, combustion of wood chips in a 40 kW_{th} boiler	9.4	9.8‡

* EUE = biomass dry matter yield *higher heating value/energy consumption for crop production
† EUE = fresh biomass yield *lower heating value of fresh biomass/energy consumption for crop production
‡ EUE = heat energy delivered at heating plant/energy consumption for crop production and energetic use

production from semi-natural grassland can compete with the cultivation of dedicated biofuels for combustion as regards EUE.

A study of Rösch *et al.* (2007) (see also Rösch *et al.*, 2009) compared the combustion of grassland biomass with anaerobic fermentation of grass and maize and with the combustion of poplar wood chips (Table 3, production systems 3a–d). The study was similar in goal and scope to the one presented in this paper. The grassland biomass combustion scenario (3a) had a considerably higher EUE than the one-cut, unfertilised treatment of this study in spite of comparable net biomass yields. Rösch *et al.* (2007) consider a small-scale on-farm boiler that makes transport between farm and heating plant unnecessary and also has a considerably lower electricity demand. This largely accounts for the observed difference in the EUE. The disparity between the two scenarios is far greater for the global warming potential. Rösch *et al.* (2007) found it to be 5.6 kg GJ^{-1} CO_2 equivalents for their scenario 3a, compared to 12.9 kg CO_2 equivalents GJ^{-1} for the one-cut unfertilised scenario of the present study. The difference is mostly caused by Rösch *et al.* (2007) not supposing that biomass combustion leads to N_2O and CH_4 emissions. With 326 compared to 416 g SO_2 equivalents GJ^{-1}, acidification potential was also lower in the LCA of Rösch *et al.* (2007). They assumed lower NO_x emissions and only 13% of the HCl emissions during combustion that were calculated for the one-cut unfertilised scenario of this paper.

Within the frame of their LCA Rösch *et al.* (2007) found combustion of grassland biomass in round bales to have the lowest relative energy consumption and relative global warming potential of all the scenarios under investigation. Fossil energy consumption was 5.3, 6.4, 7.9 and 7.4% of the fossil fuel reference scenario for scenarios 3a, 3b, 3c and 3d, respectively. The relative global warming potential of anaerobic digestion of grass and maize was as high as 19 and 25%, compared to 5.4 and 7.0% for grass and wood chip combustion. This difference was to a great extent caused by N_2O emissions arising from the application of fermentation residue as fertiliser in scenarios 3b and 3c. Due to high NH_3 emissions also caused by spreading of the fermentation residue, the relative acidification potential of those two scenarios was also by far the highest (1,040 and 610%). Here, only wood chip combustion had lower emissions of SO_2 equivalents than the fossil fuel reference. An aspect not considered by the study is the change of carbon bound in soil organic matter caused by the assumed change from permanent grassland to cultivation of maize or poplar in scenarios 3c and 3d. Semi-natural grassland, on the other hand, shows relatively stable soil carbon contents even when aboveground biomass is removed without replacement over a course of many years (Werth *et al.*, 2005).

The above comparisons have been made on a product, not on an area base. Due to their lower biomass yields semi-natural grasslands have lower net energy gains and net greenhouse gas savings per hectare than those bioenergy crops. This is a disadvantage only where there is a direct competition between different land uses. For semi-natural grasslands, this is often not the case. With their contribution to biodiversity – and landscape aesthetics – they fulfill functions not measured by the impact categories used here, which make their conservation an aim in itself and exclude dedicated biomass cropping as an alternative option.

Conclusions

Energy yield and energy consumption of grassland biomass combustion can be assessed with satisfactory accuracy. Considerable uncertainties exist, on the contrary, for estimations of the global warming and acidification potential. Major sources of these uncertainties are

the emissions caused by the combustion of both biomass and fossil fuels, as well as the NO_x and N_2O emissions arising from mulching material, mineral and organic fertilisers.
In spite of this incertitude the following conclusions can be drawn:

- The combustion of grassland biomass is carbon negative and provides a net energy gain even at very low biomass yield levels. Its EUE is competitive with that of other biofuels for combustion or that of electricity production by anaerobic fermentation of grassland biomass or maize.
- The main environmental challenge of grassland biomass combustion is related to the N content of the biomass. Unlike the other plant nutrients, which are largely returned to the soil in the coarse ash, N is lost to the ecosystem when grassland biomass is burnt. This loss takes place mostly in the form of NO_x, contributing to a high acidification potential. Legal limits for NO_x and HCl emissions from combustion existing in some countries may also be exceeded. A reduction of these emissions by appropriate secondary measures is thus a prerequisite for environmentally sustainable grassland biomass combustion.
- In spite of higher biomass yields more intensive management, especially application of N fertiliser, reduces EUE and considerably increases the relative global warming potential. It is therefore not to be recommended from the perspective of bioenergy generation.

A crucial question in this connection is that of economic viability. The special adaptions necessary in grassland biomass boilers increase the cost of heat generation in comparison with that of other less problematic biofuels, such as wood. Fuel costs have only a comparatively small share in the overall energy costs (Rösch *et al.*, 2007). Small, decentralised combustion plants using locally available grassland biomass will probably have to rely on subsidies which might be given as part of conservation projects. If sufficient biomass is available, combustion in larger heating or even CHP plants can lower the energy generation costs making use of the economies of scale.
In summary, grassland biomass combustion can be regarded as an opportunity to put semi-natural grasslands of conservation interest to an economic use as well. In spite of comparatively low biomass yields, these grasslands constitute a substantial biomass potential due to the area they cover. Regional logistic networks to collect residual biomass of dispersed origin from agricultural production, landscape maintenance and private households could further improve utilisation perspectives. Leading to higher amounts of locally available biomass residues, such networks would make larger and more profitable heating and CHP plants possible. They would also provide opportunities for the use of new conversion technologies working at larger scales. Otherwise unutilised biomass sources could then appreciably contribute to alleviating the competition between food and energy production on agricultural land.

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Alternative use of grassland biomass in Ireland: Grass for biorefinery

O'Keeffe S.[1, 2], Schulte R.P.O.[1] and Struik P.C. [2]

[1]*Teagasc, Johnstown Castle, Ireland*
[2]*Wageningen University, Department of Crop and Weed Ecology, the Netherlands*
E-mail: rogier.schulte@teagasc.ie

Abstract

In Ireland approximately 3.8 million hectares are devoted to grassland (silage, hay and pasture). With maximum yields ranging between 12−18 t DM ha^{-1}, grass has the potential for energy production or other purposes. An alternative use of grassland could be Green Biorefinery. It is an integrated refinery concept using green biomass (pasture) as raw material to produce high value biochemicals from the grass liquid fraction and lower value products such as building material or energy generation from the grass fibre fraction. Using the biorefining experiences of various European countries as a benchmark, the potential for establishing a Green Biorefinery system in Ireland was reviewed. The research required to bridge the knowledge gaps was identified. A blueprint for Green Biorefinery in Ireland was developed, through a combination of field work and conceptual modelling. This conceptual blueprint is being verified using six case studies around Ireland.

Keywords*:* grass, Ireland, Green Biorefinery

Introduction

Nowadays in Europe, but also worldwide, the need to reduce atmospheric CO_2 emissions is one of the main driving forces to use renewable resources for energy and chemicals (Danner and Braun, 1999). Biomass can be used to replace fossil based raw materials for applications such as heat, electricity, transport fuels and chemicals; together, these four uses comprise the bulk of the western worlds total fossil consumption (Sanders, 2005). Green Biorefinery could theoretically be used for all four. It is an integrated refinery concept using green biomass (pasture) as raw material. High value biochemicals can be extracted from the grass liquid fraction (press juice). These could be potential substitutes for petrochemicals, such as lactic acid, which can be used as a building block for plastic production in the form of polylactic acid (PLA). Proteins and amino acids can be extracted for applications such as animal feed or cosmetics. The grass fibre fraction can be utilised for lower value products such as building materials or energy generation via biogas (heat or electricity) (Kromus *et al.*, 2004). The residual grass slurries or 'side streams' can then be fed into an anaerobic digester (AD) to produce biomethane gas, which can be compressed and used as a transport fuel (Murphy and Power, 2008). To make the process sustainable, all fractions of a crop should be converted into valuable products without leaving any waste materials (Neureiter *et al.*, 2004). During the last ten years the activities in the field of biorefinery systems have grown, particularly in the Green Biorefinery concept, which is currently in an advanced stage in many EU countries. The concept has been successfully demonstrated in Germany (Geveke, 2009), Austria (Van Den Berg and Rademakers, 2007), Switzerland (Grass, 2004) and Denmark (Thomsen *et al.*, 2004). Table 1 provides an overview of the available peer reviewed literature on the conceptual and technological advancements made by the predominant European countries interested in Green Biorefinery.

This paper aims to summarise the European advancements in the Green Biorefinery concept and to identify the factors that catalysed the interest in developing this technology. Using the various European countries as a benchmark, the potential for establishing a Green Biorefinery system in Ireland will be reviewed. We assess the Irish technological and socio-economic strengths and weaknesses for Green Biorefinery advancement, relative to other EU member states, and identify the knowledge gaps which need to be addressed in order to develop an Irish Green Biorefinery concept.

A review: European countries and the driving forces which led to the Green Biorefinery concept

Denmark – Green crop drying industry

In 1990, the Green Biorefinery initiative began in Denmark with the research by Kiel (Kromus, 2002). The green crop drying industries were generating large quantities of 'Brown juice' or waste plant juices, during green pellet production. This brown juice was being used as a fertiliser (high potassium and nitrogen); however land application was restricted to autumn (Thomsen *et al.,* 2004). The rising disposal costs and environmental restrictions catalysed the research into alternative solutions for 'Brown juice'. The high protein content of the juice gave it the potential to be used as a substrate for fermentations and this is what catalysed the advancement of the Green Biorefinery concept in Denmark. The aim was to convert a simple drying industry to a whole crop utilisation factory, with lysine being produced from the plant juice streams (Kromus, 2002). The related research is outlined in more detail in Table 1. In 2002, Agro Ferm A/S developed a facility in Esbjerg using the waste 'Brown juice' from the pellet generation as a growth medium for lysine production (see web link in references). The Danish Green Biorefinery encountered two problems that required research. The first was quality control due to the variability (seasonal, weather) of the plant juice and the second was the storage of the plant juice as it was only available in the growing season of grass, i.e. from May to November. A conservation process was developed which used the untreated fresh 'Brown juice' directly as a lactic acid fermentation medium (Andersen and Kiel, 2000).

The Netherlands – Combining potato and grass refining

The desire to enhance the viability of the potato refining industry for starch production was the driving force for the Netherlands. Potato refining was restricted to potato availability (August to March); therefore processing grass from April to August meant the plant could be in operation all year (Sanders, 2005). The Dutch 'Prograss consortium' fractionated grass into three process streams of protein, fibres and grass juice, at their pilot plant in Foxhol (Groningen). Four tonnes of fresh grass material were processed per hour with the central part of the process being a mechanical refiner as used in the pulp industry. The Dutch found grass fibres to be of most interest and focused on advancing macerating or primary separation technologies as outlined in detail in Table 1. They concluded that grass input should only cost the factory about 50–80 € per tonne grass (DW) to make the processes economically viable (Sanders, 2005).

Table 1. Summary of European research activity on Green Biorefinery

EU country	Focus	Raw material used	Fresh/Ensiled	Raw material of interest	Potential product	Processing technologies	Process stage	Scale	Information source
Austria	Press juice	1st/2nd cut grass silage from local farms	Ensiled & inoculated with LA bacteria	Lactic acid (LA)	Polylactic acid (PLA)	Electrodialysis	Purification	Lab	Danner *et al*. (2000)
		N/a	N/a	Lactic acid	PLA	Electrodialysis	Purification	Lab	Madzingaido *et al*. (2002)
		N/a	N/a	Lactic acid	PLA	Integrated membrane bioreactor systems coupled with electro-dialysis	Purification	Lab /pilot	Danner *et al*. (2002)
		L. perenne; Medicago sativa subsp. *sativa*	Fresh	Protein concentrate	Animal feed	Heat coagulation/centrifugation; Ultrafiltration	Purification	Lab	Koschuh *et al*. (2004)
		Silage collected from local farms	Ensiled	Lactic acid Amino acids: isoleucine, alanine, lysine	(PLA) Animal feeds	Electrodialysis	Purification	Lab	Thang *et al*. (2004)
	Press cake	Grass/clover mix *D. glomerata* Permanent pasture	Both (Ensiled in lab)	Hemicellulose Sugar fractions: glucose, xylose, arabinose	Fermentation medium PLA	Dilute acid hydrolysis	Extraction process	Lab	Neureiter *et al*. (2004)
	Press juice	Silage collected from local farms composed of *T. repens, L. perenne*	Ensiled (in lab)	Lactic acid Amino acids: Aspartate, Asparagine, Alananine, Phenylallanine, Leucine, Lysine	PLA Animal feed	Nanofiltration Fine-ultrafiltration	Purification	Lab	Koschuh *et al*. (2005)

Table 1 to be continued

EU country	Focus	Raw material used	Fresh/Ensiled	Raw material of interest	Potential product	Processing technologies	Process stage	Scale	Information source
Austria	Press juice	Silage collected from local farms composed of *T. repens* *L. perenne*	Ensiled	Lactic acid	PLA	Chromatography separations using Neutral polymer resins	Purification	Lab	Thang and Novalin (2008)
	*Process supply chain	–	–	Silage	Fibres Lactic acid Amino acids	Fractionation (Screw press) purification	Full system	Industrial	Halasz *et al.* (2005)
Denmark	Press juice	Green and brown juice from: *L. multiflorum,* *L. perenne,* *Medicago sativa*	Fresh	Lactic acid Carbohydrate Organic acids	Fermentation medium PLA	Fermentation	Production /extractions	Lab	Andersen and Kiel (2000)
		Brown juice of green crop drying industries	Fresh	L-Lysine	Fine chemicals	Fermentation	Production	Pilot Lab	Thomsen *et al.* (2004)
		Brown juice of green	Fresh	Lactic acid	PLA	Fermentation – bacteria and enzyme	Production	Lab	Thomsen and Guyout (2007)
Germany	Press juice	Green juice from wild grass mix *Medicago sativa*	Fresh	Carbohydrate content	Substrates for green chemistry	n/a	Quality assessment	Lab	Starke *et al.* (2000)
	Whole crop	1st cut *L. perenne, D. glomerata, A. pretensis* 2nd cut silage mix	Fresh/ensiled	Carbohydrate	Biogas	Anaerobic digesters	–	Lab scale	Mähnert *et al.* (2005)

Table 1 to be continued

EU country	Focus	Raw material used	Fresh/Ensiled	Raw material of interest	Potential product	Processing technologies	Process stage	Scale	Information source
Switzerland	Press cake/ press juice	Grass from permanent pasture	Fresh	Fibres	Insulation materials Paper Combustion pellets Natural fibre re-enforced plastic	Full biorefinery chain	Full process chain	Plant scale	Grass (2004)
				Protein	Animal feed				
				Carbohydrates	Biogas generation				
	Liquid residues	Residues from biorefining of grass & silage	Fresh/ensiled	Carbohydrate (C:N)	Biogas generation	Upward flow anaerobic blanket reactors (USAB)	Treatment of residues (waste streams)	Pilot scale	Baier and Delavy (2005)
	Liquid residues	Residues from biorefining of grass & silage	Fresh/ensiled	Carbohydrate (C:N)	Biogas generation	Upward flow anaerobic blanket reactors (USAB)	Treatment of residues (waste streams)	Pilot scale	Baier and Delavy (2005)
The Netherlands	Press cake/juice	*L. perenne* *P. pratensis* *L. multiflorum* *D. glomerata* *F. pratensis*	Fresh	Fibres Protein	Soft board Hardboard Chipboard MDF; HDF Composites Insulation Soil conditioner	Defiberising applying technologies used by the pulp and paper	Mechanical fractionation of press juice from press cake		Hulst *et al.* (2004)

Germany and Austria: Biogas production

An Austrian study noted that 'biorefineries are always dependent on biogas and as long as the situation is positive for green energy then Green Biorefinery has good opportunities at the preliminary stages' (Popa-CTDA, 2005). Both Germany and Austria have state-of-the-art biogas technologies already in place accredited to The German Renewable Energy Sources Act (2000) and the Austrian Eco-Power Act (2003). These policies proved to be crucial for supporting the development of biotechnologies as they assured a fixed income for biogas producers connected to the grid for a specified period. The guaranteed fixed incomes from electricity sales encouraged farmers to start producing biogas and in addition to become familiar with the related technologies; expansion into other biomass technologies was the next progressive step. Both countries have examples of 'Green Biorefineries', at various stages of technological implementation. An example from Austria is the biomethane gas station for cars in Eugendorf. The vehicle gas fuel is a blend of 20% CO_2-neutral biogas and 80% natural gas. The biogas is generated from the fermenting of smooth meadow-grass (*Poa pratensis*) and all the grass is converted into a useable fuel and organic fertiliser (Van Den Berg and Rademakers, 2007).

The establishment of the basic biorefining infrastructures (biogas plants) in Austria and Germany has allowed researchers from both countries to focus on the more advanced downstreaming technologies for processing the press juice, as outlined in Table 1. These technologies will determine the success of a Green Biorefinery, as they will determine the capital investments needed for a Green Biorefinery (Kamm *et al.*, 2000; Reimann, 2006). The heterogeneous nature of the green feedstock requires delicate unit operations in order to produce an end product of acceptable quality, which is expensive. Without such processing, the products will be restricted to low-grade (and lower value) applications such as animal feeds and lactate salts used as road de-icers during the winter months. On the supply side, both countries noted the need to improve the technical and economic attributes of silage production, for it to be used as a potential substrate for industrial chemicals (Danner *et al.*, 2000). Mähnert *et al.* (2005) noted that the quality of biogas produced was also influenced by quality of the silage.

Switzerland: A unique example

The Swiss biorefinery model is of interest to Ireland, as the Swiss biorefinery plant was built in 2000 without the advantage of any pre-existing green industry and in conditions comparable to Ireland's current day situation. Switzerland – with a high dependency on fossil fuels for energy production and renewable electricity generated from hydropower or nuclear power – had a minimum emphasis on generating biogas from biomass (Jegen and Wustenhagen, 2001). The Swiss researcher (Grass, 2004) noted that, as Switzerland is a country which did not have many biomass biogas plants, it appeared to be lacking the policy framework to support a biorefinery initiative. The full scale industrial pilot plant demonstrated the practical application of grass biorefinery and managed the issues of handling grass (summer-autumn) and silage (winter-spring) (Baier and Grass, 2001). The main products included technical fibres and biogas from grass, which was used in a combined heat and power (CHP) plant. In 2003, the biorefinery plant ceased operations, as it was not economically viable, predominantly due to the fact that production of biogas and power required high investment and generated a low value product for the overall plant.

Despite this, the Swiss have imparted many valuable insights into the Green biorefining process. These include:

– Small-scale operations were more advantageous than large-scale operations, as a smaller plant means lower levels of investment, increasing financial viability and enables easier organisation of plant operation and management.
– Determining the value added of a potential product from a biorefinery and having an adequate plant design is crucial for success. The related yield per tonne of raw material and the marketability of the product on a large scale are also vital parameters to be considered (Grass, 2004).

Ireland's current scenario relative to Europe: Challenges for an Irish Green Biorefinery
Unlike in other European countries, there has been a historic under-investment in energy networks and an absence of a coherent energy policy in Ireland. The result has been the slow development of the biofuels industry, predominantly attributable to the lack of fiscal incentives and lack of transparency in grid access to boost the commercial viability of biofuels (EU and Irish Regions Office, 2006). In comparison to continental Europe, Ireland currently lacks the basic technological infrastructures which have allowed for the European advancements in Green Biorefinery. These include green crop drying factories (there is only one Irish operation) and anaerobic digesters for biogas production. Digester technologies are facing major stumbling blocks in Ireland and have been reported as having a much lower potential for development than other renewable energy technologies in the country. However, in an attempt to adhere to the guidelines of the Kyoto protocol (2005) and the EU Biofuel Directive (2003/30/EEC), the Irish government introduced the REFIT (Renewable Energy Feed in Tariff) scheme in 2006. This is a policy framework similar to the policies in Germany and Austria outlined above, with the aim to provide financial incentives for alternative energy sources (EU and Irish Regions Office, 2006) and move Ireland in line with the European expertise of biomass to bioenergy. Another issue for Ireland is the societal acceptance and support for these new bioenergy technologies as they have not been widely demonstrated or proven to be viable in the long-term for Ireland. This lack of knowledge could have an impact on market confidence, as well as farmer's willingness to supply biorefineries.

With livestock reductions due to CAP (Common Agricultural Policy) reforms potentially generating a large surplus of grass, and farmers already familiar with the techniques and equipment of grass husbandry, grass could be one of Ireland's most valuable biomass resources for the future. The most efficient means of utilising grass needs to be investigated and this includes assessing the feasibility of 'Green Biorefinery'. Ireland is now in the advantageous position to assess its green biomass options, and using the key findings of Europe as a benchmark, we can now invest in research to bridge the data gaps identified, before the implementation of an Irish Green Biorefinery concept.

European Biorefinery findings for Ireland to consider

The two key European findings which could hold significance for an Irish Green Biorefinery concept are:

(1) Knowledge of the quality and quantity of the green feedstock available and the marketability of the biorefinery products was the guiding principle of the Swiss biorefinery model, as this helped to develop and design a viable biorefining concept (Grass, 2004).

(2) Socio-economics and sustainable agriculture were the foundation of the Austrian biorefinery approach in order to create an efficient and cooperative supply chain management. The Austrians highlighted the need to identify potential catchment areas, where conditions are optimal to support a biorefinery system. Such areas should have good grassland and farmers who would be interested in guaranteeing a supply of green biomass (grass or silage) to a biorefinery.

The rest of this paper will outline the approach taken to develop a conceptual blueprint for a Green Biorefinery system in Ireland. A literature review was carried out to identify the relevant knowledge gaps associated with the supply side of an Irish Green Biorefinery chain management system. The blueprint for Green Biorefinery in Ireland was developed, through a combination of field work and conceptual modelling. This conceptual blueprint is being verified using six case studies around Ireland.

Available data and known knowns

Knowledge of green biomass (pasture) – quantity

Agricultural land is approximately 61% of the total land mass of the Republic of Ireland and approximately 90% of the agricultural area is devoted to grassland farming (O'Mara, 2008), which is dominated by dairy and beef systems, as grass is the cheapest feed available (O'Riordan *et al.*, 1998). The large amount of grassland area is due mainly to climatic conditions (Keane, 1986) and national soil characteristics (Gardiner and Ryan, 1969). Maximum grass yields are estimated to range between 12–18 t DM ha^{-1} yr^{-1}, giving grass the potential for energy production or other purposes (McGrath, 1991). The prediction that global warming will result in elevated grassland yields (Jones *et al.*, 1996) makes grass an even more attractive bio-resource for Ireland.

Knowledge of green biomass (pasture) – quality

Grassland species vary in their ontogeny (e.g. changes in components of leaves or stem during ageing) and ontogeny has a dramatic effect on quality, both in grass species and in herbs (Bruinenberg *et al.*, 2002). In Ireland, improved grassland (*Lolio-Cynosuretum* (GA1) – Irish Heritage classification) makes up the largest proportion of Ireland's productive farmland, which are fertilised regularly and can be heavily grazed or used for silage making. This type of management results in species-poor grassland with perennial ryegrass (*Lolium perenne)* usually abundant, sometimes entirely dominating the sward and often in association with white clover *(Trifolium repens)*. Sward quality varies depending on soil type, fertility, drainage and management. Other prominent grasses include meadow-grasses (*Poa* spp.), timothy *(Phleum pratense)*, crested dog's-tail *(Cynosurus cristatus)* and Yorkshire-fog *(Holcus lanatus)*. Among the more frequently occurring 'agricultural' herbs are dandelion (*Taraxacum* spp.), creeping buttercup *(Ranunculus repens)*, plantains (*Plantago* spp.), nettle *(Urtica dioica)*, thistles *(Cirsium arvense, C. vulgare)* and docks (*Rumex* spp.) (Fositt, 2000).

For Green Biorefinery, there needs to be a thorough understanding of the relationship between the quality of the end product and the raw material (green biomass) (Grass, 2004). Table 2 provides an insight into the potential grass fractions from a range of selected grass species and herbs associated with Irish improved grasslands and silage fields. For the Swiss biorefinery model which produced insulation board and protein feed pellets for animals, Grass (2004) determined the most important quality parameters for assessing a grass feedstock, are the fibre and protein contents.

Table 2. Overview of potential grass fraction yields from common silage field species

Species	Yield, (t DM ha^{-1})	NDF, (kg t DM^{-1})	ADF, (kg t DM^{-1})	CP, (kg t DM^{-1})	WSC, (kg t DM^{-1})
Lolium perenne	2.38–11.94 *Fr,H, M, P*	348–548.6 *C, Dm, T1, Wl, Wr*	221–310.6 *C, Dm, T, Wc*	120.6–244.37 *Fr, C, H, T, Wc, Wr*	114–179.36 *M, Wc,Wr*
Agrostis sp.	2.63-10.05 *Fr, P, S*		272 *Wc*	137.5–218.75 *Fr, H, Wc*	87 *Wc*
Poa sp.	1.49–10.16 *Fr, H, P*	433–716 *B, HL, Wr, Z*	196.7–422 *B, HL, Wc, Z*	135–227.5 *Fr, H, Hl, Wc, Wr*	92–149 *Wc, Wr*
Holcus lanatus	3.68–10.56 *Fr, H*	426–593.6 *C, Hr, Wr*	253–336 *C, Hr, Wc*	124–220.06 *C, Fr, H, Wc, Wr*	114–142 *Wc, Wr*
Trifolium repens		229 *Wr*		272.52–275 *Fr2, Wr*	83 *Wr*
Rumex sp. *obtusifolius*	0.71–8.8 *Dm, Hu*	128.9–286 *Dm, Fb, Hp, Wr*	165 *Dm*	193–298.13 *Fb, Hp, Wr*	76–208 *Wr, Hp*
Ranunculus sp. *bulbosus*		152.8 *Fb*		250.06 *Fb*	

Subscript refers to the peer reviewed literature, from which the ranges of values were sourced.
Figures reported in this table have been modified to kg t^{-1} DM

Brief description of experimental background for results referred to above:

B (Baron *et al.*, 2004) 3 year mean, regrowths harvested mid April, mid Sept (*Poa* spp. = *P. pratensis*).
C (Chaves *et al.*, 2006) the averaged sum of the individual plant parts, summer harvest (leaf, stem, flower).
Dm (Derrick *et al.*, 1993) samples harvested on the 28th Oct. *Lolium perenne* was leafy (results were reported in % DM).
Fb (Fairbairn and Brynmor, 1959) *Rumex sp.* = flowering stage. *Ranunculus* sp. at pre-flowering stage. Figure refers to crude fibre content calculated from absolute dry matter.
Fr (Frame, 1991) 3 years meaned at an annual rate of 0, 120, 240, 360 kg N ha^{-1}, respectively. Monoculture plots (*L. perenne* cv. = perma*, Agrostis* spp. = commercial*, Poa* = *P. pratensis*).
Fr2 (Frame *et al.*, 1997) figures for CP derived from N content (N × 6.25).
H (Haggar, 1976) primary growth yields. CP derived from N content (N × 6.25), Monoculture plots (*Poa* spp. *= Poa trivialis, Agrostis* spp. *= A. stolonifera, L. perenne = S23*) fertiliser rate 400 kg N ha^{-1} a^{-1}.
Hl (Holman, 2007) mean of two years, *P. pratensis* in R_0 (booting stage), R_4 (anthesis) pooled across cvs.
Hp (Hejduk and Doležal, 2004) crude fibre content of 2nd cut forage (6 weeks after first).
Hr (Harper *et al.*, 1999) mean values from one growing season (results reported as % DM).
Hu (Humphreys, 1995) under a three cut silage system.
M (McGrath, 1991) mean of 3 years of medium heading *L. perenne* cvs., first cut in early May. Monoculture plots.
P (Peeters and Decamps, 1994) yield values for the 24 April, 27 May, 9 June respectively, at a rate of 100 kg N ha^{-1} during the first growth cycle in spring (*Poa* spp. *= Poa trivialis).*
S (Sheldrick *et al.*, 1990) annual dry matter production for 3 consecutive years, at an N rate of 200 kg N ha^{-1}.
T1 (Turner *et al.*, 2006), mean values of *L. perenne* at 3 leaf stage.
Wc (Wilson and Collins, 1980) results 3 years meaned.
Wl (Wilman and Altimimi, 1996) to the mean result of 3 cuts over 3 years.
Wr (Wilman and Riley, 1993) meaned pot results (n = 4) (*Poa* spp. *=* *P. annua*).
Z (Zenmenchik *et al.*, 2002) values the mean of 3 years (3 cut system) fertilised at two rates of 56 kg N ha^{-1} and 224 kg N ha^{-1}.

Identification of potential location for a supply chain driven by socio-economics

The socio-economics of an area will determine the most appropriate location for a Green Biorefinery industry, as the catchment region can be seen as the production site. The different supply chains and process structures will depend on the natural and agricultural setting of the biorefinery catchment region, but this also introduces regional economical factors influencing the overall process structure (Halasz *et al.,* 2005). It is important for Ireland to recognise the most suitable regions and those 'socio-economic' factors which would support a Green Biorefinery.

Hynes *et al.* (2006) used the Simulation Model for the Irish Local Economy (SMILE) to statistically match the more detailed data from the National Farm Survey (NFS) to the Census of Agriculture. The result is a geographical output which enables the socio-economic development and policy changes in farming enterprises at a local level, electoral division (ED) across Ireland to be analysed. These SMILE simulations highlight Irish farm income to show a very distinctive Northwest/Southeast divide (Figure 1). This broad division of farming in Ireland into marginal farming areas in the North and West and more commercial farming in the South and East has also been illustrated in the geographic study by Crowley *et al.* (2007). Their detailed empirical analysis of the geographic of farm structures, farming systems, agricultural measures and part-time farming were synthesised into a typology of five farming zones or five different agro-geo-climatic zones within Ireland (Figure 2). The three zones in the North and West of Ireland include: the Purple Zone with main characteristics of high nature value farmland, Blue and Green Zones with main characteristics of agricultural sustainability through part-time farming. The two zones in the South and East are the Orange Zone of Commercial agriculture and the Red Zone of threats to agricultural sustainability as the main characteristics (Crowley *et al.*, 2007). Both the SMILE model and the agro-geo-climatic zones are essential tools to determine the most suitable locations for a Green Biorefinery plant.

Conceptual blueprint for an Irish Green Biorefinery

From the literature review and experiments a hypothesis was developed to describe the most suitable biorefinery type to begin operations in the short term in Ireland, taking into consideration available technologies, socio-economics and green biomass.

Technologies

The European peer-reviewed literature was used to assess the availability and robustness of current and emerging biorefinery technologies. The Swiss biorefinery model was determined to be the most suitable as the Swiss took a gradual approach to developing the refining processes, first implementing the basic extraction technologies. Starting with the most basic technology would be a good starting point for an idealised nascent Irish Green Biorefinery. The products of the Swiss system include fibre for insulation material and protein to be used as an animal feed. There is also the potential for producing biogas or heat, depending on market conditions. Identifying the reasons which led to the failure of the Swiss biorefinery model and finding the potential solutions to these problems under Irish conditions could prevent a similar eventuality in Ireland.

Socio-economics-centralised or decentralised?

Most European studies emphasise the importance of a decentralised approach, because of the decentralised nature of the raw material. The aim of a decentralised concept is to have a direct impact on the economic structure of rural regions, supporting the sustainable development of such areas (Grass, 2004; Kromus *et al.*, 2004). Therefore we hypothesis that the Irish biorefinery should be decentralised and based in the centre of a rural catchment using small-scale operations which were deemed as more advantageous by Grass (2004) for a number of reasons, the main one being ease of operation and flexibility.

Green biomass

Both silage and grass were used in the Swiss system to ensure year round operations. This system of both grass and silage will be analysed in order to determine if either or both would be more suitable under an Irish context.

To summarise, the optimum conceptualised Green Biorefinery system in Ireland should be a small scale decentralised plant located in a catchment area which is experiencing declining livestock numbers and hence increased surplus of green biomass (pasture). The processing plant should be situated in reasonable proximity to rural settlements, so that there is the future potential of supplying local amenities with heat or electricity from the plant. The products potentially produced by this processing plant will include insulation boards from the fibre grass fraction, and biogas produced from anaerobic digestion of the fibre slurries. The biogas produced could be used to supply the biorefinery plant with its own electricity, and heat for drying the press cake. The grass juice could be used to produce protein pellets for animal feed. The residual material remaining after the anaerobic digestion could be used as fertiliser and supplied back to the associated farmers in order to maintain an adequate nutrient cycle within the supply chain. This blueprint for an Irish Green Biorefinery model will be evaluated using the six case studies from across the country (Figure 2).

Knowledge gaps and actions taken to develop a blueprint for Irish Green Biorefinery

Green biomass quality

Herbage maturity influences forage quality more than any other single factor, but geo-environmental and agronomic factors modify the impact of herbage maturity on forage quality: year-to-year and seasonal variation, as well as geographical location also affect forage quality, even when harvested at the same stage of development (Buxton, 1996). The variations in grass quality can be seen in the range in values for the different fractions of each species as outlined in Table 2. Grass (2004) suggested that price schemes for grass delivered to a Green Biorefinery should be established with respect to the raw material characteristics (e.g. fibre content) required to achieve the expected end product yield and quality parameters. Therefore the ability to predict the quality of grass/silage feedstock would be beneficial in determining the best grassland management for supplying a biorefinery. Knowledge of the green biomass variability would also allow a biorefinery system to modify processing as required.

In an attempt to try and bridge the knowledge gaps of green biomass quality for a Green Biorefinery, we measured various quality parameters over two years harvesting seasons for a range of grass species common to Irish silage fields, *Lolium perenne, Agrostis* spp.*, Poa* spp.*, Holcus lanatus, Trifolium repens, Rumex* spp.*, Ranunculus* spp. These quality measurements are being used to model the potential raw materials for Green Biorefinery from mixed pastures as a function of their botanical composition, age, metrological con-

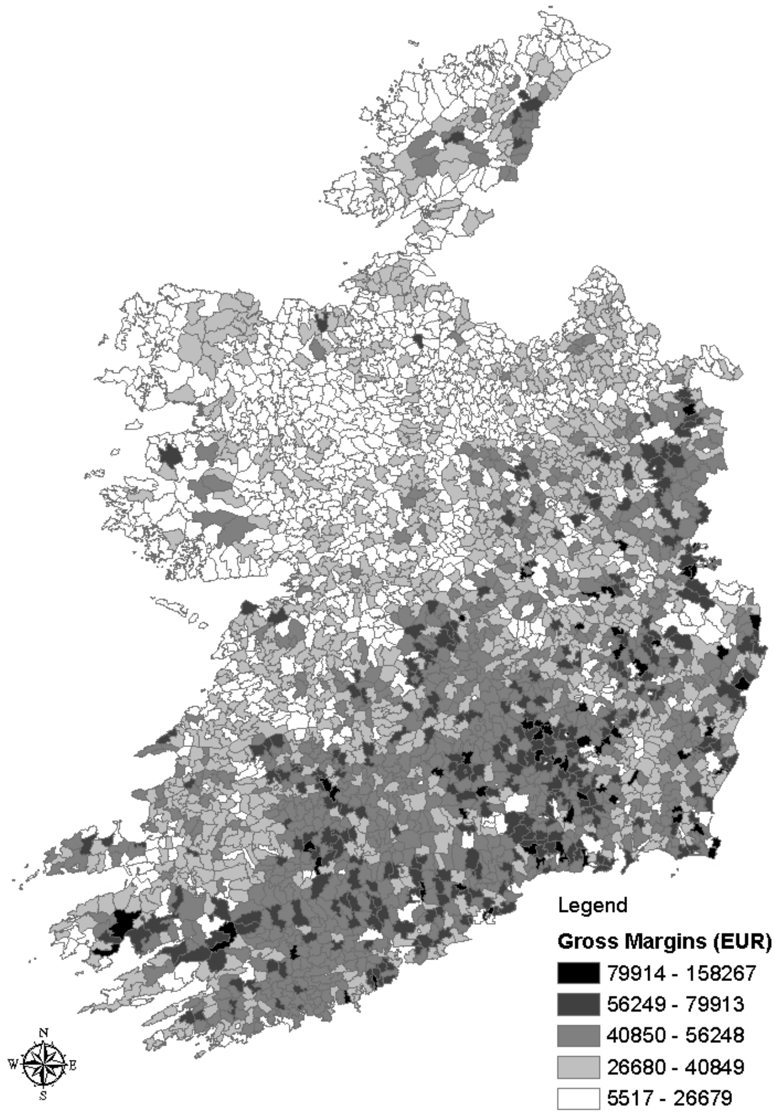

Figure 1. Distribution of Irish farmers gross margins

ditions and soil type. This quality prediction model will be verified using six locations around the country with varying botanical compositions (Figure 2).

Socio-economical data used to identify the optimum locations

To try and determine the most suitable locations for an Irish Green Biorefinery, the SMILE geographic simulations will be queried using a predetermined list of driving forces derived from the literature. These include: (1) identifying regions with declining livestock numbers resulting in a potential excess of grass which could be supplied to a biorefinery; (2) identifying regions where the gross margins (Figure 1) of livestock farming systems are currently low; (3) locations with higher percentages of part time

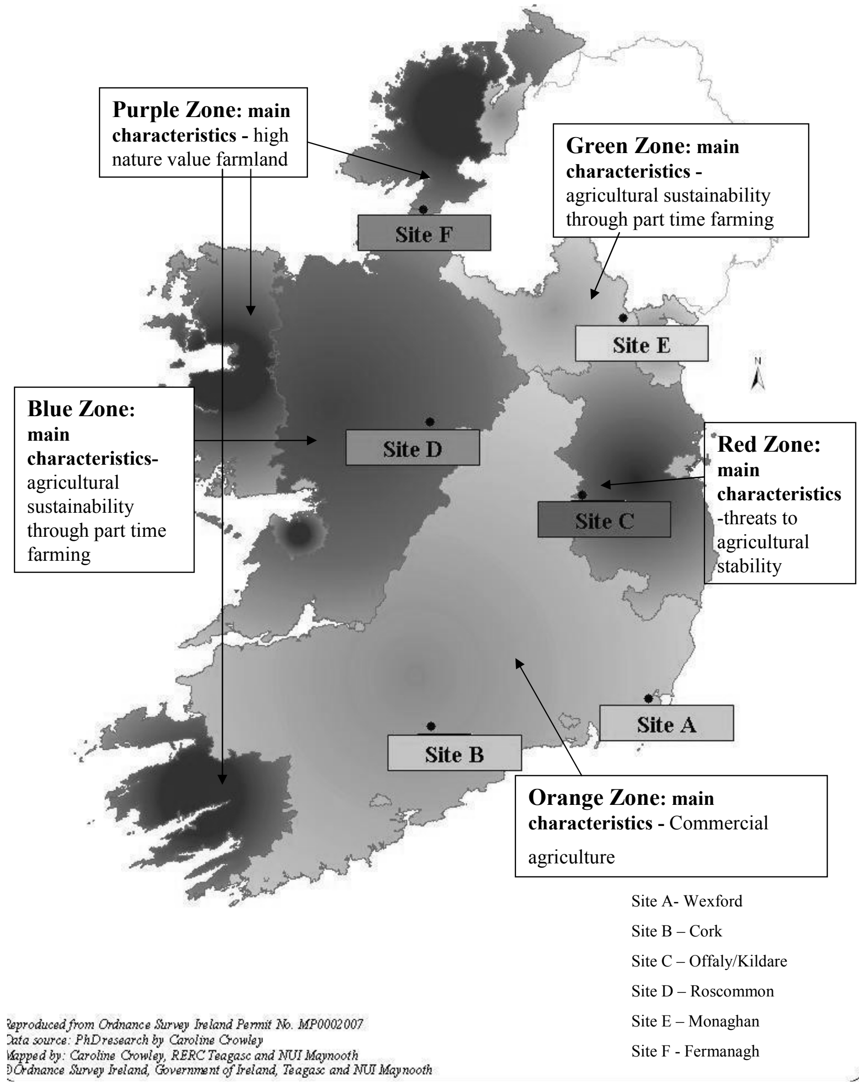

Figure 2. Agro-geographic climatic zones

farmers as these farmers would have less time to devote to livestock production and may prefer the less labour intensive option of supplying a Green Biorefinery; (4) the logistics involved in a supply chain management will also be considered.
The information generated from this desk study will be combined with field trial data from around the country in each of the agro-geo-climatic zones (Figure 2) and will be used to identify potential catchment areas around Ireland for biorefinery.

Environmental-nutrient cycling

Nutrient cycling (N, P) is very important in order to maintain system efficiency, environmental neutrality and a healthy green biomass supply. The environmental implications related to a Green Biorefinery and the cycling of N and P in the system will be assessed using nutrient mass balances with data derived from the national field trial sites. Nitrogen in particular is of interest, as this also could have an influence on the economics of the supply chain. Existing nutrient grassland models (€riN) (Schulte *et al.,* 2009) will be used to develop a potential N mass balance of the system. The modelled data will be used to generate an EIA (Environmental Impact Assessment) in determining how sustainable the operation will be in relation to N usage and the recycling back into grasslands.

Conclusions

Despite the endemic reasons for each European country to pursue the concept of Green Biorefinery, it is very clear that policy is one of the major impetuses providing the foundations and support for such advancements. Without the political infrastructure the basic physical infrastructures, such as the green pellet industries, starch refining or biogas technologies would never have materialised or given the opportunity to advance towards a Green Biorefinery concept.

The conceptual blueprint for an Irish Green Biorefinery is envisaged to be *a small scale decentralised plant, located in a catchment area which has a surplus of green biomass (pasture) and farmers willing to supply the processing plant. The idealised products include from the grass fibre fraction: insulation boards, heat and energy from anaerobic digestion of fibre slurries. From the grass juice fraction: protein pellets for animal feed. The process will be optimised to ensure the nutrient equilibrium of the system.* This hypothesised blueprint for an Irish Green Biorefinery model will be evaluated using the six case studies from across the country.

The aim of this PhD research was to begin bridging the two main knowledge gaps identified by the various European projects: (1) predicting quality of green feedstock and (2) to identify the optimum catchment areas for plant locations.

In an attempt to try and bridge the knowledge gaps of green biomass quality for a Green Biorefinery, a simple empirical model is being developed to model the potential raw materials for Green Biorefinery from mixed pastures as a function of their botanical composition, age, meteorological conditions and soil type. This quality prediction model will be verified using six locations around the country with varying botanical compositions (Figure 2).

To identify potential catchment areas with optimal social and economic conditions to support a Green Biorefinery plant, two geographic models will be queried with a list of driving forces derived from the literature and the results of the spatial studies combined with data from national field trials will be used to identify potential catchment areas.

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Economic assessment of biogas production from landscape management grass in the Lower Oder Valley National Park

Blokhina Y.[1], Prochnow A.[1], Plöchl M.[2], Luckhaus Ch.[2] and Heiermann M.[1]

[1]*Leibniz-Institute of Agricultural Engineering Bornim, Potsdam, Germany*
[2]*BioenergieBeratungBornim GmbH, Potsdam, Germany*
E-mail: aprochnow@atb-potsdam.de

Abstract

A rising demand for feedstock due to the increasing number of biogas plants in Germany and problems with utilisation of grass from landscape und nature protection areas lead to considerations to exploit landscape management grass as a feedstock for anaerobic digestion. However, late harvesting periods and adverse concentration of important substances lead to low methane yields. Therefore it is preferable to co-digest landscape management grass with other input material. A regional economic assessment for the Lower Oder Valley National Park was conducted to determine if biogas production from landscape management grass can be profitable. Based on grassland area, harvesting periods and livestock numbers, four different variants of biogas production were developed. Subsequently expenditures and revenues were calculated. As a result the first variant with five autonomous biogas plants is profitable, with the use of liquid manure making an important contribution to profitability. Two variants with local biogas production on each farm and central biogas use via biogas micro-grid or biogas feeding into the natural gas grid turn out to operate at a deficit. The central anaerobic digestion of landscape management grass and maize without liquid manure would yield a profit, provided there is effective use of the thermal energy produced.

Keywords: biogas, grass, landscape management, economic assessment, Germany

Introduction

The production of biogas is a promising alternative for utilisation of landscape management grass. It helps to mitigate ecological problems and also to increase revenues of farmers practicing landscape management through electrical energy sales. The low quality of landscape management grass for anaerobic digestion can be improved by addition of other feedstock into the digester. Currently bioenergy recovery from grassland is not widespread due to the high costs of supply and application of grass in a biogas plant as well as low methane yields of landscape and nature protection material. The methane yields depend greatly on the harvesting period, vegetation and weather conditions. From the point of the highest possible methane yields per unit area the optimum cutting period of landscape management grassland are August and September (Prochnow *et al.,* 2005). This may be a good opportunity for many nature reserves, which have problems with utilisation of cut grass from late managed areas. The Lower Oder Valley National Park is such a nature reserve. This 105 km^2 park is situated in north-east Brandenburg, on the German-Polish border. Half of the park areas are total reserves and designated for unrestricted natural development. On the remaining areas agricultural management is allowed in compliance with regulations. Selective measures, like prescribed periods and method (mowing/pasturing) of use aim to protect the endangered bird and plant species. The grassland vegetation is mainly represented by plant communities of field meadow foxtail, reed canary grass and sedges. Using the example of grass from the Lower Oder Valley National Park, four variants of biogas production from landscape management grass are described and economically assessed.

Materials and methods

Biomass and methane yields from grassland in the National Park were estimated for the harvesting periods from June to October. Supply costs of landscape management grass, comprising costs for harvest, storage and handling, were calculated from the guideline values of the Association for Technology and Structures in Agriculture (KTBL, 2006). The analysed mix and volume of input material for biogas production are presented in Table 1. Variants 1–3 include combined anaerobic digestion of liquid manure, landscape management grass and maize. Five dairy farms close to the National Park are considered as locations for biogas plants (identified with A–E). Their livestock numbers vary from 150 to 450 heads. In variant 1, biogas is converted into electricity and heat in five separate block heat and power plants at the point of origin. There is no external use of thermal energy since the costs of a heat distribution system would exceed possible revenues from heat sales. Variants 2 and 3 are aimed at local biogas production on each farm and delivery of the produced biogas to one central block heat and power plant in the city of Schwedt. In variant 2 the biogas transportation is carried out via a biogas micro-grid. In variant 3, biogas is upgraded to natural gas quality and fed into the natural gas grid. Variant 4 performs the central anaerobic digestion of landscape management grass and maize without liquid manure. About 10% of digestate is fed back into the digester to ensure pumpability of input material. The biogas plant is assumed to be located in the vicinity of Schwedt.

Table 1. Mix and volume of input material for model biogas plants

Parameter	Variants 1, 2, 3					Variant 4 Schwedt
Location of biogas plant	A	B	C	D	E	
Liquid manure, Mg a^{-1}	4,237	4,647	9,603	5,649	12,710	–
Landscape management grass, Mg a^{-1}	516	566	1,147	708	1,511	13,383
Maize, Mg a^{-1}	558	612	1,287	724	1,710	12,858

In all variants the electricity produced from biogas is fed into the public grid and paid for according to the Renewable Energy Sources Act (Anonymous, 2008). Extra gains are possible through use of waste heat from electricity generation. Hence, the profitability of biogas production in variants 2–4 is calculated for 20%, 30% and 50% of use of the thermal energy. Further revenues result from subsidies for land management in the National Park and cultivation of energy maize. Annual costs arise from providing input material, production and application of biogas and usage of digestate. Calculations of conversion costs are based on data from the Agency for Renewable Resources (FNR, 2006a, 2006b), Leibniz-Institute of Agricultural Engineering Potsdam-Bornim and BioenergieBeratung BornimGmbH.

Results and discussion

Supply costs of landscape management grass from the National Park vary between 31–39 € Mg^{-1} free on biogas plant and are considerably affected by biomass yields and haul distances. Besides the costs of input material the profitability of biogas production depends on chosen plant concept, incurred investment costs and value of subsidies. Table 2 shows the results of profitability calculations.

Variant 1, with five autonomous biogas plants, is profitable even if the surplus heat is not used. Modifications in the recently adopted Renewable Energy Sources Act, in particular the introduction of the liquid manure bonus, add to commercial success of this scheme of biogas production. Variant 2 turns out to be inefficient. Profit is possible only in the case of the complete usage of thermal energy (above 96%), which in practice is hardly feasible. The cause of economic failure is the high investment costs for the 26 km biogas micro-grid.

Table 2. Profitability of four variants of biogas production by different rate of thermal use

Parameter	Rate of thermal use	Unit	Variant 1 (five autonomous biogas plants)	Variant 2 (biogas micro-grid)	Variant 3 (natural gas grid)	Variant 4 (one central biogas plant)
Electric power of block heat and power plants	–	kW_{el}	67–206	499	489	1,018
Total investment costs	–	€	2,122,653	4,595,164	4,184,366	3,677,153
Annual costs	–	€ a^{-1}	913,078	1,069,973	1,111,113	1,734,391
Annual revenues	0%	€ a^{-1}	1,048,371	–	–	–
	20%	€ a^{-1}	–	852,972	834,456	1,642,966
	30%	€ a^{-1}	–	881,735	862,643	1,701,632
	50%	€ a^{-1}	–	939,260	919,018	1,818,966
Profit/loss	0%	€ a^{-1}	135,293	–	–	–
	20%	€ a^{-1}	–	–217,001	276,658	–91,425
	30%	€ a^{-1}	–	–188,238	–248,470	–32,759
	50%	€ a^{-1}	–	–130,713	–192,096	84,575
Emerging electricity costs	–	cent kWh^{-1}	18.14–20.98	27.18	28.95	19.34

Variant 3 with feeding of biogas into the natural gas grid is highly unprofitable under the given circumstances. The reasons are the small capacities of the biogas plants and the long feed lines (15 km). Crucial for the profitability of the central biogas plant in variant 4 is the rate of thermal use. A profit may be expected if heat consumption exceeds the threshold of 36%. So there is a necessity to attract consumers who need heat all the year round.

Conclusions

Profitable use of landscape management grass as a feedstock for biogas production is possible under certain circumstances. Supply costs of this input material depend especially on biomass yields and haul distances. In addition to subsidies for land management and feed-in tariffs of the Renewable Energy Sources Act, the chosen biogas plant concept is of great importance for economic viability of biogas production.

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New technologies of phytomass processing and utilization

Kužel S., Kolář L., Frelich J., Peterka J. and Maroušek J.

University of South Bohemia, Faculty of Agriculture, České Budějovice, Czech Republic
E-mail: kuzel@zf.jcu.cz

Abstract

Phytomass can be seen as an energy source, a source of fuels and a basic raw material for the chemical industry. New technologies are characterized by a complex use of phytomass. They are based on the requirement to process lignocellulose phytomass into basic sugar raw material for biotechnologies and cellulose-lignin phytomass into pyrolysis gases by thermic conversion. In products of hydrolysis there are biotechnological, enzymatic processes using microorganisms, often genetically modified, such as fungi, micromycetes, yeasts, wood-destroying fungi, bacteria and other microorganisms. Enzyme engineering by stabilization of enzymes and increasing their activity plays a crucial role. Agriculture in less-favoured areas gives an interesting possibility for the use of phytomass as a raw material basis for chemical, power engineering, cosmetics, pharmaceutical as well as food industry. 'Complex waste-free processing of clover in a green biorefinery' and 'Complex waste-free processing of oats' are our patent protected examples of solutions to phytomass processing.

Keywords: complex technology of processing, waste-free, *Trifolium pratense, Avena sativa*

Introduction

We do not consider biomass in general, and phytomass specifically, only as a source of energy, as a source of fuels, but as a new basic raw material for the chemical industry. Technologies of phytomass processing can be economically efficient in practice only when the processing and utilization of phytomass are complex. For example, if someone's effort is aimed only at the production of ethanol from cereal starch as an additive to engine fuels, such an effort will be a forlorn hope. Cereals contain about 65% of starch, and losses will be incurred during saccharification, during fermentation, ethanol isolation, etc. It may easily happen that only a quarter of the raw material will be utilized in an efficient way. Therefore biofuels should not be the only product, but one of a number of products of the complex processing of phytomass. Phytomass contains two main components: cellulose, which is a polysaccharide, and lignin (derivative of α-phenylpropane), which was previously also called 'wood'. Obviously, plants grown by farmers – grasses, herbs – are lignocellulose materials while tree species are cellulose-lignin materials. Phytomass processing is somewhat different depending on whether a dominantly cellulose material or more or less lignin material is processed. Phytomass processing is based on the conversion of the basic raw material. It is done either by hydrolysis or thermically. Two methods of thermic conversion can be used: gasification when the heat necessary for a thermic reaction is generated by partial combustion of the raw material and pyrolysis when the heat for the start of the own thermic reaction is completely supplied from an extraneous source.

All old and new methods of phytomass processing are based on these three basic conversions of phytomass as the basic raw material. However, the method of execution of these conversions may be either obsolete or up-to-date or a new promising one. Phytomass hydrolysis is taken as an illustrative example. It can be executed by the use of strong acids at a high temperature and under high pressures. This is a conventional, costly and inconvenient method, so it is an obsolete method. For starch hydrolysis it is also possible to use malt diastase like in any distillery, or mould or bacterial amylase. Sugar solutions are obtained only from starch, not from cellulose. It is a newer method but it is also rather unprofitable. It is however the method used at present. If the hydrolysis of the main component of cellulose phytomass, i.e. cellulose, is done enzymatically using technical cellulase, phytomass utilization will almost double, to produce a promising method. No matter whether cellulase was produced by a strain of bacteria or moulds or the classical *Trichoderma viride* (reesei), a limiting element will be the capacity of cellulase to hydrolyse cellulose in an efficient way. Obviously, wider utilization of phytomass as the basic raw material will naturally improve the economic aspect of production. If we manage to isolate from phytomass another utilizable product that is commercially interesting, it is increases the probability of a promising solution.

Methods

The utilization of agricultural products for non-food purposes is among research priorities of University of South Bohemia in České Budějovice, Faculty of Agriculture. In the framework of Development Programme MSM 6007665806 of the Ministry of Education, Youth and Sports of the Czech Republic 'Sustainable Methods of Farming in Hilly and Mountain Areas Aimed at Harmonization of their Production and Non-production Utilization' our research is focused on the optimization of agricultural production in less-favoured areas (LFA). The outcome of research is 'Complex Waste-free Processing of Red Clover' with the output of seven products. These procedures are protected by two accepted utility models (Kolář *et al.*, 2007b, c) and two submitted patents (Kolář *et al.*, 2006, 2007a). Waste-free processing of oats is another objective of our research. Along with red clover it is a crop of extraordinary potential importance in agricultural production of LFA if its can be processed for effective and, if possible waste-free, utilization, independent of its sale in food and feed sectors. Currently, it is possible to make 22 products from oats (*Avena sativa*) while more than a third of them are intended for non-food use. At the present time this technology 'Complex Waste-free Processing of Oats' is protected by seven accepted utility models (Kužel *et al.*, 2008b, c, d, e, f, g, h) and two submitted patents (Kužel *et al.*, 2008a, b; Kolář *et al.*, 2008a).

Discussion

From green juice from forages we get at first genistin, genistein, Na-Cu-chlorophyllin, pheophytins and carotenes. Genistin is a standard in organic analytics and a substrate for genistein production for pharmaceutical industry. Genistein is an active ingredient in pharmaceuticals to relieve women's menopause symptoms. Na-Cu-chlorophyllin is a green colouring for cosmetic industry and for dyeing some foods. Pheophytins are a brown vegetable dye with different uses. Carotenes are a colouring for food industry, free radical quencher – a component of functional foods. When processing red clover (*Trifolium pratense* L.) or oats by enzymatic hydrolysis, using cellulase prepared by means of *Trichoderma viride* (reesei), a certain quantity of sugar solutions is obtained. They are a suitable raw material mainly for the biotechnological industry, because a number of alcohols can be produced from sugars by fermentation processes and these may be the original raw materials for many other technologically important substances. Sugar solutions can be used as a source of energy in the feed industry. Currently, feeds contain enough nutrients and fibre but often their energy value is insufficient. If the ferment cellulase is applied to feed several hours before its use, cellulose splitting will take place and animals will get necessary energetic sugars. Sugar solutions can also be used for the production of biofuels: bioethanol or biobutanol. Bioethanol is not the best variant for the Czech Republic; it is advisable to produce biobutanol from sugar solutions. It is a more expeditious process because wort can be fermented within 36 hours. It is possible to produce a quantity higher by a third from the same material while biobutanol may be added to oil and petrol at a larger amount – up to 15% without adjustment of the engine. It is also preferable from the aspect of safety but its production is rather complicated. Currently, wort can be prepared from any material – from potatoes, maize or cereals or even from forage crops. Our philosophy of the solution to agricultural production is based on an assumption that farmers should grow what they are able to grow. This production can then be processed to non-food products or it should be used as a raw material for various industries.

Conclusion

Currently, we are working on the complex technology of barley (*Hordeum* L.) processing. We are considering also other agricultural crops in line with our philosophy. Let farmers do what they are able to do. Let them grow agricultural crops both on Moravian or Polabí fertile soils in the framework of intensive precision farming and in LFA within the sustainable farming system. The processors should adapt themselves to them as to producers of raw materials and process their products to foods or non-food products according to market requirements using large-scale or small-scale technologies.

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Biomass of cocksfoot and tall fescue as a substrate for biogas production

Tilvikiene V., Kadziuliene Z. and Dabkevicius Z.

Lithuanian Institute of Agriculture, Akademija, Kėdainiai District, Lithuania
E-mail: vita@lzi.lt

Abstract

Biogas production is a way to utilise the surplus of herbage and produce bioenergy for heating and fuel. When the natural biomass of grasses is used as a substrate or co-substrate for anaerobic digestion, the main variable factor determining the biogas quality and the methane yield is the chemical composition of the substrate. The first cut of grasses is very important for the quantities of chemical indicators determining biogas production, because the biomass yield of the first cut can account for 70% of the annual biomass. Field and laboratory experiments were carried out at the Lithuanian Institute of Agriculture in Dotnuva (55°24'N) to estimate two perennial grasses – cocksfoot (*Dactylis glomerata* L.) and tall fescue (*Festuca arundinacea* Schreb.) – for biogas production, with a special focus on the variation in their chemical composition when cut at the heading and flowering stages. The findings from the first experimental year showed the quality of biomass prepared for biogas production to be better at the heading stage than at the flowering stage.

Keywords: cocksfoot, tall fescue, biomass, chemical composition

Introduction

Anaerobic digestion is becoming more and more popular in producing bioenergy. One of the substrates recently used for biogas production in European countries is grass and grass silage. The substrate of grass is common for its digestibility, but the greatest attention should be given to its changeable chemical composition, which depends on the growing conditions, the species of sward, the cutting time, and other factors (Butkutė and Paplauskienė, 2006). The main chemical elements, which influence the biogas yield and quality, are crude protein, nitrogen, carbon, water-soluble carbohydrates (WSC), cellulose, hemicelluloses, lignin, microelements, and metals.

In Lithuania, the biomass yield of the first cut of most perennial grasses can account for from 47% to 65% of the annual biomass yield when cut at the heading stage and about 6–10% more when cut at the flowering stage (Kanapeckas *et al*., 1999). The difference in the biomass yield between the heading and flowering stages is not very marked, but the variation in the chemical composition of the biomass is obvious.

The aim of the present study was to estimate the chemical composition of grass biomass grown for biogas production in relation to the timing of the first cut.

Materials and methods

Field and laboratory experiments with cocksfoot (*Dactylis glomerata* L.) and tall fescue (*Festuca arundinacea* Schreb.) were carried out at the Lithuanian Institute of Agriculture in Dotnuva (55°24'N). The soil of the experimental site is characterised as *Apicalcari*

– Endohypogleyic Cambisol, light loam. Non-fertilised swards of the second year of use were cut at the heading and flowering stages.
Laboratory experiments were conducted to determine the chemical composition of the biomass. The samples for chemical analysis were cut into 3–5-cm-sized pieces, and then fixed in an oven at a temperature of 105°C for 15 minutes. After fixing, the grass samples were dried at a temperature of 65 ± 5°C. The total nitrogen and organic carbon were determined using the Dumas method (DIN/ISO 13878). Acid detergent fibre (ADF), neutral detergent fibre (NDF), and lignin (ADL) were estimated using the van Soest methodology of fibre fraction, and then the quantities of cellulose, hemicellulose, and crude proteins in the biomass were measured by counting: cellulose = ADF-ADL, hemicellulose = NDF-ADF, crude proteins = N × 6.25 (Rinne *et al*., 1997; Faithfull, 2002).

Results and discussion

The weather conditions were difficult for grass growing in 2008. The lack of soil humidity was the main reason for the low biomass yield. The dry matter yield of the cocksfoot was almost four times as high as that of the tall fescue and amounted to 5 t ha^{-1} at the heading stage and 5.5 t ha^{-1} at the flowering stage.
Biogas, with the main components being methane and carbon dioxide, is a product of the microbiological degradation of organic matter. In our experiments the dry organic matter content did not differ much between the biomass cut at the heading and flowering stages. No significant differences were found between the species (Table 1).

Table 1. The variation of chemical composition in tall fescue and cocksfoot

Cutting time	Indicators (g kg^{-1} DM)					
	DOM	crude protein	WSC	C:N	NDF	ADF
Cocksfoot						
1st cut, at heading	920	70.0	208	39	537	322
1st cut, at flowering	944	58.2	140	48	649	380
Tall fescue						
1st cut, at heading	926	123.0	237	22	492	245
1st cut, at flowering	944	38.5	171	71	660	393

DM – dry matter; DOM – dry organic matter; WSC – water-soluble carbohydrates; C:N – carbon-to-nitrogen ratio; NDF – neutral detergent fibre; ADF – acid detergent fibre

It is known that biomass with a lower water-soluble carbohydrate concentration has a higher buffer capacity (Raclavská *et al*., 2007). The content of water-soluble carbohydrates in the cocksfoot and tall fescue biomass was 1.4 times higher at the heading stage compared with that cut at the flowering stage (Table 1).
The substrate of grass in the process of biogas production is food for anaerobic bacteria. Bacteria cannot produce enough enzymes necessary for carbon assimilation when there is not enough nitrogen in the biomass (Wilkie, 2005). Many authors have reported that the optimal carbon-to-nitrogen ratio (C:N) for anaerobic digestion is from 20 to 30 (Gunaseelan, 1997). In our research, the optimal carbon-to-nitrogen ratio was in the tall fescue biomass at the heading stage. The biomass contains more carbon and less nitrogen at the flowering stage than at the heading stage, and therefore C:N is higher.

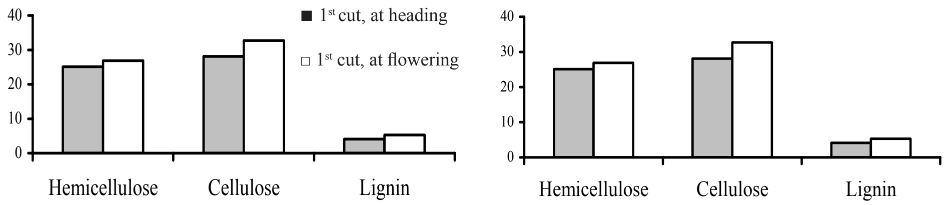

Figure 1. The variation of the ratio of structural biopolymers in the fibre of the biomass of grasses

After the degradation of readily fermented elements, micro-organisms begin to digest such components as cellulose and hemicellulose. The quantities of these fibres were more dependent on the time when the grass was cut than on the grass species (Figure 1).

One of the elements limiting the intensity of anaerobic digestion is lignin, which is not a digestible component and which reduces the digestibility of cellulose and hemicellulose (Casler *et al.*, 2008). The content of lignin in biomass mostly depends on the vegetation period of grasses; when it is higher than 15% DM, the anaerobic digestion is sharply inhibited (Raclavská *et al.*, 2007). The biomass of cocksfoot contained 4.12% lignin in dry matter at the heading stage and 5.31% DM at the flowering stage. The same trend of the lignin content increasing from the heading to the flowering stage was estimated in the tall fescue biomass, but it did not exceed the allowable limit, and therefore it should not exert any appreciable influence on microbiological decomposition.

Conclusions

The biomass of cocksfoot and tall fescue at the heading stage is better suited for biogas production, since it contains 4% lignin and 20–23% water-soluble carbohydrates in dry matter and a more adequate carbon-to-nitrogen ratio – 39 for cocksfoot biomass and 22 for tall fescue biomass; at the flowering stage the biomass contains 22% more lignin, 30% less water-soluble carbohydrates, and a less adequate carbon-to-nitrogen ratio – 48 for cocksfoot biomass and 71 for tall fescue biomass.

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Grass utilisation for thermal energy purposes

Andert D.[1], Gerndtová I.[1] and Frydrych J.[2]

[1]*Research Institute of Agricultural Engineering, Prague, Czech Republic*
[2]*Oseva PRO Ltd., Grassland Research Station, Rožnov-Zubří, Czech Republic*
E-mail: andert@vuzt.cz

Abstract

In consequence of the increasing of the total level and productivity of agricultural production, the land area which is not utilised for food production is enlarged. These areas can be used for the growing of energy crops, among which also belong various kinds of grasses. In cases when the land is set aside by grassing or it is not utilised as a result of the diminishing numbers of beef cattle, the potential of perennial grassland to provide a quantity of grass which can be used for energy purposes is constantly increasing. Wet grass matter is suitable for biogas processing by means of anaerobic fermentation. Overripe and dry mass can be used as a fuel. In the tests a big boiler with a capacity of 1.8 MW and a small one with a capacity of 25 kW were used.

Keywords: biomass, biomass burning, renewable energy, grasses

Introduction

The search for alternative sources of energy is becoming a worldwide matter. In connection with the increasing total level and productivity of agriculture the land area which is not utilised for food production is growing. In addition to forage production, grasslands also have, in comparison with other crops, an irreplaceable non-production function.
There are two possibilities for utilising grass biomass for energy. In the case of dry mass it is burning and for wet grass matter it is the suitable processing of these organic materials by anaerobic fermentation with the subsequent utilisation of the biogas for energy.
The use of various forms of fuels in energy facilities can be divided according to their thermal outputs. In the case of installations up to 50 kW it is most common that in automatic heating devices fuel is used in the form of pellets and in heating devices with hand firing in the form of briquettes. However, this concerns above all those fuels based on wood and wood bark, whereas other mixed phytofuels are used to a very small extent. Big installations seek to use fuels with minimal requirements for further treatment; this means especially sorted straw and wood chips. Sorrel chips or sorted hay are utilised, for example, to a minimum extent. These fuels are often used in mixtures.

Material and methods

The combustion tests were carried out with the use of a local heating device with a capacity of 25 kW and a central heating device with a capacity of 800 kW. The tests using a big boiler K2 with a capacity of 1,800 kW were realised in the municipal heating plant in Bouzov. This boiler is designed for the combined combustion of various kinds of pure biomass. For the testing of a small boiler the VERNER V 25 type was selected. This boiler is intended for the combustion of lump wood. The test was carried out in Červený

Kostelec using briquettes with a diameter of 60 mm. These briquettes were manufactured on a hydraulic press.

Results and discussion

The quantity of CO emissions during the burning of wood chips moved around 50 mg m^{-3} N at 110 g kg^{-1} O_2 in waste gases. This value is very favourable and shows a well-adjusted burning regime.

Figure 1. Measured Verner 1,800 kW boiler

The solid emissions which originated during the combustion of wood were 142 mg m^{-3} N at 110 g kg^{-1} O_2 in waste gases. However, this value is influenced by the type of separator used and does not provide much information about the burning process. In terms of burning, the ideal fuel for boilers of this type is dry wood matter. The NO_x emissions were 168 mg m^{-3} N at 110 g kg^{-1} O_2 in waste gases. This value is favourably low and represents an indicator of a well-adjusted burning process with a low excess of air.
In order to transport deer's foot (*Agrostis*) into the boiler the second part of a conveying device intended for stalks and fibrous materials was used. In the course of this test the influence of a lower fuel volume density during conveying and also in the burning process in the boiler combustion chamber was also noticed. This chamber was filled with fluffy fuel (in various stage of burnout) more than during the burning of wood chips. The combustion chamber, manufactured from ceramic materials, was considerably colder and in the end this fact influenced the generation of CO emissions and, subsequently, the emissions of solid particles. The quantity of CO emissions during the burning of the deer's foot moved about 596 mg m^{-3} N at 110 g kg^{-1} O_2 in waste gases. This value is higher than during the burning of wood chips. The process of burning was under way at a lower boiler output with a considerably higher excess of air, which subsequently influenced the final quantity of emissions converted into reference status. The quantity of NO_x emissions was 308 mg m^{-3} N at 110 g kg^{-1} O_2 in waste gases. The effect of the different times of harvesting of the deer's foot was not recorded.

Small boiler measurement

The VERNER U 25 boiler operates on the principle of two-stage combustion, in which the fuel is gasified and the gases that are produced are subsequently burned. It is a firebox boiler with a smoke-tube exhaust heat exchanger. The bore of the pipes is 50 mm.

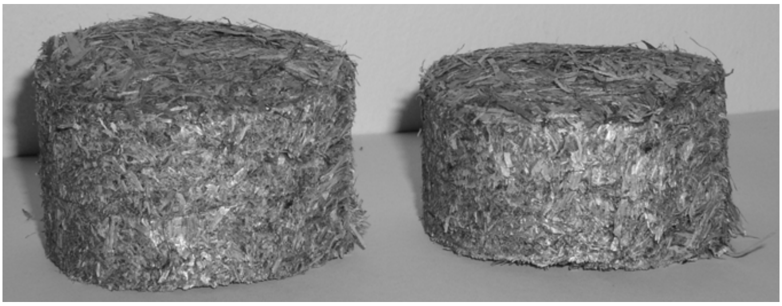

Figure 2. Briquettes produced from deer's foot (*Agrostis gigantea*) (sieve 10 mm)

Figure 3. Briquettes produced from deer's foot (*Agrostis gigantea*) (sieve 20 mm)

The dehumidification and gasification of the fuel proceed in an upper filling chamber under an aerobic atmosphere. The gas produced passes through a ceramic nozzle, where it is blended with secondary combustion air, in the lower chamber. In this chamber, which is equipped on its side walls with a water covering, the gas burns out on the balanced surface. From this space the combustion gases proceed through a tube heat exchanger into the flue gas installation.

Conclusions

The combustion tests carried out proved that it was possible to burn the grasses in selected combustion installations within the emission limits. It was proved that deer's foot and fescue are suitable fuels. For combustion purposes it is appropiate to harvest as late as possible after the technical ripeness of seeds and not before it. The size of the openings in the deer's foot scraps before pressing into briquettes has no influence on emissions, but only on the quality of the briquettes. Oat grass is a less suitable fuel. During further research grass mixtures, brome grass, and phalaris will be tested. In the case of grass combustion there is also a legislation problem, because a boiler can burn only the kind of fuel for which it was tested and approved. However, at the present time, the big boilers are intended only for burning wood and straw and small boilers only for burning wood. The only exception is the automatic boiler A25, designed for the burning of pellets, which is also approved for small cereal pellets.

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An analysis of the floristic composition of two mountain golf courses

Macolino S., Da Ronch F., Susan F. and Ziliotto U.

University of Padova, Department of Environmental Agronomy and Crop Productions, Legnaro (PD) Italy
E-mail: stefano.macolino@unipd.it

Abstract

The floristic composition of roughs and fairways of two mountain golf courses is here described in order to evaluate the role of golf courses on enhancing biodiversity. The golf courses studied were located at 1,000 and 1,250 m a.s.l. in the Alpine area of Veneto region. Fairways and roughs were established on the original sward. During the growing season floristic surveys were performed on roughs and fairways of each site using the Raunkiaer method. The total number of species was higher in Sappada than in Asiago golf course. In both sites the number of species did not differ between fairways and roughs; however, a different plant composition was observed in the two playing areas. Fairways are dominated by short size species such as *Plantago major* and *Trifolium repens*, while the vegetation of roughs is composed for a large part by tall size species. The great difference in the floristic composition between fairways and roughs and the amount of species recorded indicate that seasonal golf courses could contribute to maintain plant diversity especially in mountain areas where traditional farming system has declined.

Keywords**:** mountain golf course, floristic composition, plant species biodiversity, coenotic biodiversity

Introduction

During the second half of 20th century grassland agriculture of mountain areas in Europe dramatically decreased and substantial changes occurred on forage-farm system. Pastures and permanent meadows of Alpine areas were rapidly abandoned and invaded by the surrounding woody species; only in some cases, they were converted to new more productive vegetation types such as *Lolietum multiflori* Dietl et Lehmann, 1975. However, at the same time, golf courses have spread in the Mediterranean Countries of Europe and especially in the touristic areas such as Italian Alpine region. The golf course hole consists of four different areas: ‘green’, ‘tee’, ‘fairway’ and ‘rough’. Golf quality depends primarily on conditions of its green, since high quality green must provide an excellent playable surface. High sport performances are also required to tee, while the level of fairway maintenance is always less than that of green and tee. Rough is a semi-natural area that receives a minimum maintenance. Fairways and roughs represent the larger part of golf course (Emmons, 2000). In marginal areas golf course could play also an important role on preserve biodiversity. Cultural practices strongly influence plant community. Fairways differ from roughs overall for the mowing frequency. If fairways and roughs were established on existing swards, we assume that rough vegetation could be similar to that of local meadows, while fairway vegetation could be more close to that of pastures. To support this theory, the results of floristic surveys made on the roughs and fairways of two mountain golf courses of Italian side of the Alps are here reported.

Materials and methods

Floristic surveys were made during summer 2008 on two mountain golf courses of Italian Alpine region. The two sites were: ‘Sappada golf club’ and ‘Asiago golf club’. The first golf course is located in the Belluno dolomites at 1,250 m a.s.l., while the second in the Prealps of Vicenza province at 1,000 m a.s.l. The golf course of Sappada was constructed five years ago with 5 holes, at present consists of 9 holes, roughs and fairways were established on the original sward (permanent meadows). During the growing season fairways are mowed once a week, while roughs received only two or three cuts. The Asiago golf club was constructed ten years ago; some fairways were established on original permanent meadows, while others on a wood area after deforestation of Norway spruce (*Picea abies* (L.) H. Karst.) trees. In the present study only the fairways and roughs established on the existing meadow sward were considered. During the second half of August 2008, a floristic survey was made on three contiguous roughs and fairways

Table 1. Results of floristic surveys performed on the two golf courses studied using the Raunkiaer method (values indicate the frequency of the species over 10 sample areas)

	Asiago						Sappada					
	f_1	f_2	f_3	r_1	r_2	r_3	f_1	f_2	f_3	r_1	r_2	r_3
Differential species of *Polygono-Trisetion* alliance												
Trisetum flavescens (L.) Beauv.							5	2	3	8	7	4
Poa alpina L.							8	9	10	6	5	4
Ranunculus montanus Willd. (gr. *montanus*)							4	9	2		3	2
Crocus albiflorus Kit.											1	
Phleum alpinum L.							2					
Differential species of *Cynosurion* Tx. 47 alliance												
Lolium perenne L.	9	8	8	9	8	5						
Plantago major L.	7	6	1				1	2	2	2		
Poa annua L. (*Poa* aggr.)	8	1	1	7	6	9			2			
Characteristic species of *Arrhenatheretalia* Pawl. 28 order												
Leontodon hispidus L.							3	5	4	2	6	4
Prunella vulgaris L.							1	2	3			1
Leucanthemum vulgare Lam. (gr. *vulgare*)							2		6			
Lotus corniculatus L. (gr. *corniculatus*)										3		
Tragopogon pratensis L.										1		
Bromus hordeaceus L.												3
Achillea millefolium L. (gr. *millefolium*)				2	3				2			3
Carum carvi L.	2					1	8	9	7	8	9	7
Alchemilla vulgaris L. *sensu* Sch. et K.	2	2	4	7		2	6	9	7	2	7	2
Trifolium repens L.	8	8	5	2	1	2	9	10	9	8	8	1

Table 1 to be continued

Differential species of *Arrhenatheretalia* Pawl. 28 order												
Festuca arundinacea Schreber							4	7	7		5	2
Avenula pubescens (Hudson) Dumort.							1	1	2	1	1	
Deschampsia caespitosa (L.) Beauv.								1	2		1	2
Lathyrus pratensis L.										4	4	1
Plantago media L.								2	2			
Taraxacum officinale Weber	8	5	5	9	8	1	7	9	5	3	9	10
Heracleum sphondylium L.								1		1		
Dactylis glomerata L.					1		2	2		8	8	9
Anthriscus sylvestris (L.) Hoffm.										1	5	
Veronica chamaedrys L.	3	1	3			3						
Colchicum autumnale L.					1							
Characteristic species of *Molinio-Arrhenatheretea* Tx. 37 class												
Poa pratensis L.							5	7	6	4	5	3
Trifolium pratense L.							4	5	4	8	5	7
Festuca gr. *rubra*							2	1	1			2
Rumex acetosa L.										4	3	2
Anthoxanthum odoratum L. (*Anthoxanthum* aggr.)					4		5		1			1
Ranunculus acris L.	1	4	2	3	4					4		
Poa trivialis L.						6						
Companion species												
Brachypodium pinnatum (L.) Beauv.										1	1	1
Cerastium spp.							1	1		1	1	
Cirsium arvense (L.) Scop.							1			1		1
Daucus carota L.									1	2	1	
Oxalis acetosella L.									1	6	1	
Pimpinella saxifraga L.							1	7	3	7	6	5
Veronica hederifolia L.									1	7	6	6
Veronica officinalis L.	3		5			2						

Other companion species

Asiago: *Cirsium eriophorum* (L.) Scop. 3r = 1; *Fragaria vesca* L. 3r = 1; *Galium mollugo* L. 3r:5; *Urtica dioica* L. 3r = 1. **Sappada**: *Campanula rotundifolia* L. (aggr.) 2r = 1, 1r = 1; *Carex caryophyllea* La Tourr. 1f = 1; *Carex montana* L. 2f = 2, 1f = 2; *Cerastium fontanum* Baumg. 1f = 7; *Festuca* gr. *ovina* 1f = 1, 1r = 2; *Geranium rotundifolium* L. 1r = 1; *Vicia* sp. 2r = 4, 1r = 5

$f_{1, 2, 3}$ = Fairway 1st hole, 2nd hole, 3rd hole; $r_{1, 2, 3}$ = Rough 1st hole, 2nd hole, 3rd hole

in both the abovementioned golf courses based on Raunkiaer methods (Pignatti, 1976). The presence of the different species on 10 sample areas of 625 cm^2 (25 cm × 25 cm) scattered over the vegetation in 3 roughs and 3 fairways of each course was recorded.

Results and discussion

Results showed a clear difference between the botanical composition of the two golf courses studied. While the vegetation of Sappada golf course was composed by 25.5 species (average of three roughs and three fairways) in the Asiago golf club only 9.3 species were recorded, on average. The cluster analysis based on floristic surveys of the 12 areas also highlighted two separate groups corresponding to the two locations of study (data not shown).

Considering the phytosociological analysis (Table 1) groups of Asiago could be attributed to the alliance *Cynosurion* Tx. 47, while those of Sappada showed similarity with the vegetation of alliance *Polygono-Trisetion.* The cluster analysis results have also separated, at 30% of the total variability, two groups represented by the roughs and fairways surveys. In the case of Asiago location this difference mostly depended on the presence in the fairways of species adapted to high mowing frequency typical of turfgrass management such as *Plantago major* and *Trifolium repens*; rough vegetation, on the contrary, was dominated by tall fast growing species characterized by a less tolerance to frequent defoliations: *Achillea millefolium*, *Anthriscus sylvestris*, *Galium mollugo*, *Dactylis glomerata*, and *Achillea millefolium.* Similarly, the most abundant species in Sappada fairways are short size species such as *Poa alpina*, *Prunella vulgaris*, *Plantago major*, *P. media*, *Leucanthemum vulgare*, *Festuca rubra* and *Carex montana,* while roughs are composed exclusively by medium-tall size species i.e. *Trisetum flavescens*, *Dactylis glomerata*, *Anthriscus sylvestris*, *Rumex acetosa*, *Vicia* spp., *Lathyrus pratensis*, and *Lotus corniculatus*. Contrary to the species composition, the total number of species appeared to be not affected by mowing management. In both golf courses the species number was almost the same in fairway and rough (Asiago: 9.0 (fairway) versus 8.3 (rough), Sappada: 22.6 versus 24.6).

Conclusions

This study suggests that, apart from local environmental conditions, the golf courses with self-established vegetation can play an effective role on conserving biodiversity either at coenotic or species level.

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The effect of returning turfgrass clippings on turfgrass sward yield

Kauer K., Laidna T., Keres I., Köster T., Noormets M., Parol A., Raave H., Selge A. and Viiralt R.

Estonian University of Life Sciences, Institute of Agricultural and Environmental Sciences, Tartu, Estonia
E-mail: henn.raave@emu.ee

Abstract

The aim of the study was to analyse the effect of returned clippings on the yield of a turfgrass sward. The study was carried out on a sward established with a 50/50 seed mixture of *Festuca rubra* ssp. *rubra* and *Poa pratensis*. Seven fertilizer treatments (kg ha^{-1}) were used with N varying between N_0 and N_{400}, P between P_0 and P_{45} and K between K_0 and $K_{240.}$ The sward was cut fifteen to twenty times during the growing season at a height of 5 cm. The clippings were either removed or returned to the plots. The effect of clippings on the sward yield was variable and fairly weak. On only one of the seven fertilization treatments, $N_{240}P_{34}K_{144,}$ did returned clippings increase the yield of the sward significantly ($P > 0.05$). A positive effect of returned clippings appears only in those years when moisture conditions were sufficient for plant growth.

Keywords: turfgrass, clippings, decomposition, fertilization, yield

Introduction

Returning clippings increases sward yield and reduces N fertilization (Starr and DeRoo, 1981; Busey and Parker, 1992; Kopp and Guillard, 2002). Yield increases, as an effect of returned clippings, vary to a great extent between 15 and 221% (Starr and DeRoo, 1981; Kopp and Guillard, 2002). The reasons for such high variations occurring are not wholly clear; they could result from the duration of trial period (Qian *et al.,* 2003), soil moisture holding capacity (Kopp and Guillard, 2002) and soil organic matter content (Kopp and Guillard, 2002; Qian *et al.,* 2003). The aim of this study was to investigate how much the clippings effect on the yield depended on fertilization, the quantity of returned clippings and the weather conditions.

Methods

The experiment was carried out at the Estonian University of Life Sciences in the Eerika Experimental Station (58°23'32"N latitude, 26°41'31"E longitude) during 2004–2008. The experiment was arranged as a 2 × 7 factorial and set out in a randomized complete block design with four replicates. The soil of the experimental field was Stagnic Luvisol. The site had been seeded in 2003 with a turfgrass mixture (*Festuca rubra rubra* 50% and *Poa pratensis* 50%). Fertilizer treatments for the turfgrass sward were $N_0P_0K_0$ (hereafter N_0), $N_0P_{22}K_{96}$ (PK), $N_{80}P_{11}K_{48}$ (N_{80}), $N_{160}P_{22}K_{96}$ (N_{160}), $N_{240}P_{34}K_{144}$ (N_{240}), $N_{320}P_{45}K_{192}$ (N_{320}) and $N_{400}P_{56}K_{240}$ (N_{400}). The N and K fertilizer was applied to the plots in 2 to 4 splits depending on the ratio. The swards were cut 15 to 20 times at a height of 5 cm during the growing season. For the cutting, a lawn mower with a bag attachment was used. After every cutting the material was removed from the bag and weighed. After the weighing procedure, the clippings of the turfgrass were either returned (hereafter CRT) to the plots or removed (hereafter CRM). Measured rainfalls during the growing season (April to October) by year were 530 mm in 2004, 402 mm in 2005, 296 mm in 2006, 426 mm in 2007 and 614 mm in 2008. The statistical package Statistica 7 (build 7.0.61.0 from StatSoft, Inc.) was used for all the statistical analyzes. Factorial ANOVA was applied to test the effect of the treatments and the growing year on the turfgrass sward yield.

Results and discussion

The influence of CRT on the sward yield was weak (Figure 1). Only one of the seven fertilization treatments (N_{240}) in combination with CRT caused a significant yield increase ($P < 0.05$). The other fertilization treatments (except variant N_0) in combination with CRT caused slight but insignificant increases in yield and the difference in the yields of the CRT and CRM plots were insignificant ($P > 0.05$). The effect of clippings on the yield depended on the quantity of CRT, the rate of applied N and the weather conditions in the growing season. The amount of CRT (returned clippings) varied from 141 to 596 g DM m^{-2} $year^{-1}$ and was dependent on the rate of applied N fertilization. The yield increase was concurrent with an increase in applied N (Table 1). A significant difference ($P < 0.05$) in yields appeared only with a background of N_{240} where amount of CRT was 550 g DM m^{-2} $year^{-1}$. In treatments N_0–N_{160} where amount of CRT varied from 152 to 344 g DM m^{-2} $year^{-1}$ there was no significant effect on the sward yield ($P < 0.05$). CRT did not significantly influence ($P < 0.05$) the yield in fertilizer treatments N_{320} and N_{400} where the largest amounts of clippings, 537 and 583 g DM m^{-2} $year^{-1}$ respectively, were returned to the plot.

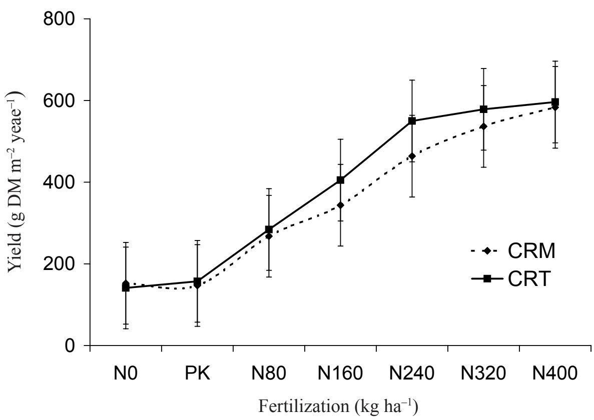

Figure 1. Clippings treatment influence on turgrass sward yield depending on fertilization (mean ± SE, $P < 0.05$)

The reason for the low level of influence of CRT on sward yield could be the high N fertilizer rate which went beyond meeting the plants' basic requirements for N. We have noted the effectiveness of N will start to decrease from the rate of 160 kg ha^{-1} in the instance of *Festuca rubra* and 400 kg ha^{-1} in the instance of *Poa pratensis.* The influence of CRT on sward yield varied between the years of the experiment and depended greatly on the amount of precipitation. In 2006 when the growing season was dry (rainfall of 296 mm), the yields of the CRT and CRM treatments did not differ; the same result occurred in 2008 when precipitation was distributed unevenly throughout the growing season.

Table 1. Dry matter yield (g m^{-2} yr^{-1}) of turfgrass swards with clippings removed (CRM) and with clippings returned (CRT)

Fertilization rate	2004		2005		2006		2007		2008	
	CRM	CRT	CRM	CRT	CRM	CRT	CRM	CRT	CRM	CRT
N_0	224	174	134	129	129	128	114	99	161	176
PK	204	189	122	127	149	161	101	113	159	196
N_{80}	302	330	236	270	264	260	232	251	305	309
N_{160}	411	417	292	442	330	351	290	354	395	461
N_{240}	555	602	478	610	378	413	375	516	533	608
N_{320}	635	645	550	701	427	433	437	509	634	604
N_{400}	692	669	603	733	447	413	515	548	660	618

According to our results the influence of clippings on the sward yield was not as obvious as several earlier studies have shown (Starr and DeRoo, 1981; Kopp and Guillard, 2002). Even though in some of the years of the experiment, dependent on the fertilization treatments, the yield of the plots with CRT treatment surpassed the yield of CRM treatment by as much as 51%, the average yield increase during the period 2004–2008, did not exceed 18.5% for any fertilization treatment. Kopp and Guillard (2002) have concluded differences in the soil moisture holding capacities at experimental sites could explain the variation in the influence of clippings on yields. Our investigation showed the influence of clippings on the yield depended on the moisture conditions in the growing season. In dry years the clippings effect was much lower than in years when moisture conditions were sufficient for grasses to grow. The reason for the diminishing effect of CRT in dry weather conditions could be the smaller quantity of the returned clippings and the lesser ability for nutrient uptake by the grasses. A special trial conducted to investigate the decomposition process demonstrated the release of N did not differ significantly in dry or moist growing seasons. The release of N from clippings in a dry growing season was only slightly slower than in a moist season (Kauer *et al*., unpublished data). The research of Kopp and Guillard (2002) showed that CRT with a background fertilizer treatment of N_0 kg ha^{-1} produced a sward yield comparable to CRM with a background of N 392 kg ha^{-1}. The results of our experiment are almost the opposite. In four out of five years the sward yield of N_0 (unfertilized) in combination with CRM was slightly higher ($P < 0.05$) than N_0 with CRT treatment. The measurements made in 2006 and 2007 showed that the quantity of N returned to the plot with CRT in treatment N_0 was from 33 to 60 kg ha^{-1}. As there was no particular effect of nitrogen recorded, we can suppose that the majority of released nitrogen could be lost by either, or both, volatilizing and immobilizing by decomposers. The results of the clippings decomposition study from the N_0 treatment indicated the N content in clippings was not sufficient for decomposers and after 2 weeks N immobilization occurred. N immobilization was inherent only in clippings from plots which were either unfertilized or fertilized with low N rates (< 160 kg ha^{-1} N) (Kauer *et al*., unpublished data).

Conclusions

The effect of clippings on the turfgrass sward yield appeared only when larger quantities of clippings were returned. This indicated that either losses or immobilization of nitrogen occurred during the decomposition process. The difference in the effect of clippings on yield was caused mainly by variation in moisture conditions in the experiment years. The clippings influence was significant only in those years when moisture conditions were favourable for plant growth.

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Influence of nitrogen fertilisation rates on *Festulolium* and *Lolium* × *boucheanum* forage yield and persistency

Gutmane I. and Adamovics A.

Latvian University of Agriculture, Jelgava, Latvia
E-mail: aleksandrs.adamovics@llu.lv

Abstract

The objective of this research was to study the influence of the fertilisation rate on the dry matter yield structure and sward persistency of the *Festulolium* and *Lolium* × *boucheanum* varieties under the agro-ecological conditions of Latvia. Field trials were established on sod-podzolic soil fertilised with N $120_{(40+40+40)}$, $N180_{(60+60+60)}$, P 78, and K 90 kg ha^{-1}. The forages were harvested three times during the growing season. *Festulolium* hybrids are among the most persistent and productive grasses of the grasses used in many European countries, especially in adverse environments. The results of the experiments in the years 2003–2007 highlight the significant dependence of the DM yield on the variety used and the increase in the N fertiliser dose. On average, an increase in the N fertiliser dose from 120 to 180 kg ha^{-1} contributed to an increase in the DM yield of 1.6 t ha^{-1} or 17%. In the first year of yielding increased nitrogen rates a positive effect was better expressed in the DM yield of loloid *Festulolium* cultivars, and was less expressed in festucoid *Festulolium* cultivars. In the second and third years of yielding no difference in the positive effect of increased nitrogen rates between loloid and festucoid *Festulolium* cultivars was observed.

Keywords: *Festulolium, Lolium* × *boucheanum*, nitrogen fertilisation, productivity

Introduction

Nitrogen fertilisation is a management factor that greatly influences the perennial grass yield. The *Lolium* species requires high nitrogen fertilisation when it is grown for a high dry matter yield. The requirement of reducing N losses to the environment has changed fertilisation practices. Under more sustainable agricultural practices, the N fertiliser rate has to be reduced to an ecological optimum of the order of 150–200 kg ha^{-1} per year (Lantinga *et al.,* 2002).
The fertilisation level has an effect on the persistence and affects the progress of the yield during the grass phase. Tolerance to adverse weather conditions and winter resistance may be enhanced markedly when plants are provided with abundant N (Aavola, 2005). On the other hand, lower N rates can have a positive effect on persistence (Soegaard *et al.,* 2007). The introduction of biotic and abiotic stress tolerance from *Festuca* spp. into *Lolium* spp. offers unique opportunities for the production of versatile hybrid varieties with new combinations of useful characteristics suited to modern grassland farming (Humphreys *et al*., 2006). *Festulolium* hybrids are promising species for use as fodder grasses. Because of its competitive productivity *Festulolium* may be ranked equally with the main forage grasses, timothy and meadow fescue, grown in the climatic zone of Latvia (Gutmane and Adamovich, 2006).

Materials and methods

Field trials were conducted in Latvia on sod-podzolic soils. The pH was 7.1 and the phosphorus and potassium levels were 253 and 198 mg kg^{-1}, respectively. The organic matter content was 31 g kg^{-1}. The swards were composed of perennial ryegrass Spidola (control), *Festulolium* Perun (*L. multiflorum* × *F. pratensis*), Punia (*L. multiflorum* × *F. pratensis*), Saikava (*L. perenne* × *F. pratensis*), Lofa (*L. multiflorum* × *F. arundinacea*), Felina (*L. multiflorum* × *F. arundinacea*), Hykor (*L. multiflorum* × *F. arundinacea*), and hybrid ryegrass Tapirus (*L. multiflorum* × *L. perenne*). The trials were sown in May 2002, 2003, and 2004 without a cover crop; the seeding rate was 1,000 germinating seeds per m^{-2}. The plots were fertilised as follows: P 78 and K 90 kg ha^{-1} and two N fertiliser treatments, N $120_{(40+40+40)}$ and N $180_{(60+60+60)}$. The dry matter yield was determined for three years of sward use. The experimental data were subjected to ANOVA analysis.

Results and discussion

Festulolium hybrids and, especially, perennial ryegrass are often insufficiently resistant to over-wintering conditions. The meteorological conditions for the formation of a grass yield were most favourable in the years 2004 and 2007. These years had summers that were rich in precipitation. In less favourable years (2003, 2005, 2006) for the development of grass plants, with a hot and dry summer, the varieties showed differences in the structure of their yield formation.

The variance analysis data showed that in the three years of utilisation the dry matter yield for *Festulolium* and ryegrass swards was reliably ($P < 0.05$) dependent on the variety used, as well as on the nitrogen fertilisation rate. An increase in the N fertiliser dose from 120 to 180 kg ha^{-1} contributed to a significant increase in the DM yield for all the varieties investigated. On average, an increase in the N fertiliser dose to 180 kg ha^{-1} contributed to an increase in the DM yield of 1.6 t ha^{-1} or 17%. The dry matter yield was found to be heavily dependent on the climatic conditions in the particular year of yielding (Table 1).

The analysis of the fertilisation factor influence showed differences between years of sward use. The influence of the nitrogen rate on the DM yield was higher in the first year and lowest in the third year of sward use for all the cultivars investigated. The positive effect of increased nitrogen rates was better expressed in loloid *Festulolium* cultivars in the first year of yielding. The positive influence of increased nitrogen rates on the DM yield of festucoid *Festulolium* cultivars in the first year of yielding was less expressed. In the second and third years of yielding no difference in the positive effect of increased nitrogen rates between loloid and festucoid *Festulolium* cultivars was observed.

The analysis of the influence of the variety factor on the DM yield showed the opposite trend. The influence of the variety used was lower in the first year of sward use. An increase in the influence of the variety used on the dry matter yield was established in the third year of sward use.

The highest average DM yield in all the years of sward use was provided by the Hykor and Felina cultivars. The same cultivars had the highest plant height before harvesting. These findings are in correspondence with the morphological character of the plants; Hykor and Felina represent the festucoid type of *Festulolium*. During the three years of herbage use the lowest yield was provided by the perennial ryegrass Spidola. This can be explained by the rather poor over-wintering performance of the perennial ryegrass and the plant height. The differences between varieties in terms of DM yield were highly

Table 1. Average DM yield for three years of sward use (t ha^{-1})

Year of sward use	Nitrogen levels – F_A ($kg\ ha^{-1}$)	Varieties – F_B							
		Spidola	Lofa	Felina	Saikava	Hykor	Perun	Tapirus	Punia
1st	N 120	8.10	11.70	15.96	9.45	13.67	13.18	11.12	13.34
	N 180	10.22	13.64	16.85	12.38	15.13	15.66	13.52	15.81
	$LSD_{0.05}$ for DM yield: F_A= 0.28; F_B= 0.56; F_{AB}= 0.79								
2nd	N 120	5.85	7.61	12.64	6.11	10.95	8.27	7.20	8.36
	N 180	6.40	8.89	14.88	7.45	12.93	10.27	8.64	9.91
	$LSD_{0.05}$ for DM yield: F_A= 0.21; F_B= 0.42; F_{AB}= 0.60								
3rd	N 120	4.83	6.89	8.49	6.09	10.14	7.67	6.27	6.86
	N 180	5.84	7.72	10.02	7.44	11.48	8.76	7.40	7.86
	$LSD_{0.05}$ for DM yield: F_A= 0.23; F_B= 0.46; F_{AB}= 0.65								

significant and maintained a similar tendency during the three years. The average DM yields of *Festulolium* cultivars were 3.81 t ha^{-1} higher compared to perennial ryegrass, but those of hybrid ryegrass 2.15 t ha^{-1} higher.

The longevity of *Festulolium* swards was affected by different reasons, such as the suitability of each variety for specific conditions, different stress conditions, and management. Under cutting conditions the yield is often reported to decrease over successive years, with the highest yield in the first harvest year. Our results show a substantial decrease in the DM yield even between the first and second years of yielding. The average DM yield distribution during the years of yielding showed significant differences. The maximum yield was obtained in the first year of sward use.

Conclusion

The productivity of grass biomass was dependent on the cultivar used and the nitrogen fertilisation rates. The dry matter yield was found to be heavily dependent on the climatic conditions in the particular year of yielding and particular period of regrowth.

Significant differences in the DM yields of *Festulolium* and *Lolium* × *boucheanum* were found between the first, second, and third years, with the highest yield in the first harvest year.

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Biogas production from energy grasses

Adamovics A., Dubrovskis V. and Plume I.

Latvia University of Agriculture, Jelgava, Latvia
E-mail: aleksandrs.adamovics@llu.lv

Abstract

Fodder galega (*Galega orientalis* Lam.) and red clover (*Trifolium pratense*) are fodder legumes which have a high productivity and capacity to fix atmospheric nitrogen. Thus they reduce the need for N-fertilisers. Reed canary grass (*Phalaris arundinacea*) can be harvested during long periods without reseeding and without application of pesticides. Investigated dry matter yields were 9.6–11.2 Mg ha^{-1}, 8–13 Mg ha^{-1} and 7–11 Mg ha^{-1} for galega, red clover and reed canary grass respectively. Specific methane yields obtained per 1 kg of volatilised organic solids (VOS) were 218.6 l kg_{VOS}^{-1} from cow's manure (control), 312.5 l kg_{VOS}^{-1} from galega, 83.2 l kg_{VOS}^{-1} from galega haylage, 234.1 l kg_{VOS}^{-1} from clover and 133.9 l kg_{VOS}^{-1} from reed canary grass. Specific volumes of methane output from galega or clover substrates were higher compared to that obtained from cow manure (control) while lower methane output were obtained from anaerobic digestion of canary grass or galega haylage. Estimated volumes of methane released from galega haylage, in dependence on the high (19.4%) and low (11.1%) organic loads, were 46.8 and 119.6 l kg_{VOS}^{-1}, respectively.

Keywords: *Galega*, galega haylage, clover, reed canary grass, energy crops, biogas, methane

Introduction

Various plants can be raised as a source for the biogas production in Latvia (Adamovics *et al.*, 2007). One of most promising is galega (*Galega orientalis* Lam.) recently introduced in Latvia, due to its persistency and high yielding ability. This perennial legume survives in pure stands for 25 and more years and provides annual DM yields from 9.5 to 11.2 Mg ha^{-1} (Adamovics *et al.*, 2006). Successful treatment of galega seeds with nodule bacteria results in the fixation of atmospheric nitrogen from 143 to 453 kg ha^{-1}, and it can thus decrease the need for commercial nitrogen fertilisers. The usage of the symbiotic bacteria potential for fodder galega and other legumes, e.g. galega or clover, contributes to the production of ecologically safe forage and cheap source for biogas production. Perennial herbaceous crops, e.g. galega, can be easily stored as haylage, thus providing its usage for fodder or for round the year biogas production. Usage of perennial plants, especially legumes, for biogas production can be an important alternative for the farmers, due to the unstable animal breeding market in Latvia, where the number of cows has decreased during recent decades. Perennial legumes usage for biogas production can be the right solution in such situations. Energy crops typically have high total solids content and their digestion requires long hydraulic retention time and large volumes of digesters.

The aim of this study was to estimate the productivity of the fodder galega and galega-grass mixtures and to investigate the biogas output from galega, galega haylage, red clover and red canary grass in an anaerobic fermentation process.

Materials and methods

Field experiments with fodder galega were carried out at the Latvia University of Agriculture during a 25 year period (1981–2005). Thirty five mixed (13 binary and 22 multi-species) swards were developed on stagnic – luvisol (pH_{KCl} was 6.7, mobile P 52 and K 128 mg kg^{-1} of soil). Pure swards, binary- and multi-species seed mixtures were composed of fodder galega cv. Gale and 13 grass species. The total seeding rate was 1,000 germinating seeds per 1 m^2. In all experiment series the mixture contained 40% fodder galega and 60% grass seeds: 7 binary mixtures 40:60, 14 three-component mixtures 40:30:30, 5 four-component mixture 40:20:20:20, 1 five-component mixtures 40:15:15:15:15 and 2 six-component mixtures 40:12:12:12:12:12.

Biogas yield was investigated with laboratory equipment B4 comprising 10 digesters of 5 l volume operated in a batchwise mode at temperatures 37 ± 1.0°C or 54 ± 1.0°C. The substrates used for anaerobic fermentation in digesters D1–D4 were galega mixtures with inoculum (fresh cow manure) in different proportions (Table 1). Galega haylage, red clover and red canary grass mixtures with water and with inoculum (fermented cow manure) were used for anaerobic fermentation in digesters D5–D10. Biomass had previously been chopped and mixed with water. Substrates were analysed using approved methods for organic matter, volatile solids and moisture content investigation before filling in and after extracting out the digesters. Accuracy of measurements was ± 0.02 for pH value, ± 0.0025 l for gas volume and ± 0.1°C for temperature. Anaerobic fermentation in the digesters was provided for a 2–3 month period to ensure that all extractable biogas was obtained.

Results and discussion

Average yields of dry matter (DM) were 8.97 Mg ha^{-1} obtained at early flowering on stagnic luvisol in a two-cutting management during 25 years of pure galega growing without reseeding. Average yields of galega had increased continuously during a 25-year period. This evidence can be explained also by the global rising of average temperature and/or content of carbon dioxide in atmosphere. Fodder galega significantly surpasses other forage legumes in respect to productive longevity, and fluctuations in DM yield were insignificant within the harvesting years.

Table 1. Average substrates and biogas parameters obtained in anaerobic fermentation process

Parameter	Unit	D1	D2–D4	D5	D6	D7–D8	D9–D10
Substrate composition	%	100 cm	50 cm 50 g + w	55 in 45 gh	32 in 68 gh + w	15 in 85 c + w	14 in 22.6 rcg 63.4 w
Total substrate weight	kg	4.12	3.504	1.142	2.144	3.371	3.140
Total solids	%	14.7	9.3	20.9	11.9	7	10
Organic solids	%	12.8	7.0	19.4	11.1	6.6	9.3
Biogas yield	l kg_{VOS}^{-1}	411	532.9	116	244	429	274.6
Average methane content	%	53.2	58.4	40.1	49	54.6	48.8
Methane yield	l kg_{VOS}^{-1}	218.6	312.5	46.8	119.6	234.1	133.9
Conversion rate	%	62.5	65.6	23	48.2	64.2	56.2

VOS – volatile organic solids, cm – cow manure, w – water, g + w – galega plus water, gh – galega haylage, in – inoculum (fermented cow manure), gh + w – galega haylage plus water, c + w – red clower plus water, rcg – reed canary grass

Inclusion of a grass species in galega resulted in an increase of dry matter yield by 28% to 36% in the first production year already. Split application of the 90 kg N fertiliser decreased the dry matter yield by 1.04 Mg ha^{-1} at two cutting management, compared to unfertilised plots. Average DM yields from three species galega-grass swards with no N fertiliser were 9.80 Mg ha^{-1} or 6.56 Mg ha^{-1} in the two-cutting or four-cutting management respectively. Grasses competitive with galega reduced the productive longevity of swards compared to pure galega.

Fermentation process was weak in all digesters D1–D10 working in a batch mode during the first 2–3 day period after the start. Results of anaerobic fermentation of the biomass are shown in Table 1. Increase of organic matter load in a mixture from 11.1% (in D6) to 19.4% (in D5) results in lowering of methane content, methane yield and conversion rate for the galega haylage substrates. Very low methane yield obtained in the digester with galega haylage can be explained by the simultaneous impact of both a high organic matter content and low pH value in the digester D5. Methane concentrations in output gases from all energy grasses were within the range of 40.1%–58.4%, that is suitable for further biogas treatment and usage for energetic purposes. Investigated average specific volumes of methane per 1 kg of volatised organic matter (VOC) was 218.6 l kg_{VOS}^{-1} for cow manure (control) 312.5 l kg_{VOS}^{-1} for galega, 83.2 l kg_{VOS}^{-1} for galega haylage, 234.1 l kg_{VOS}^{-1} for clover and 133.9 l kg_{VOS}^{-1} for reed canary grass.

Average results shows that specific volume of methane output from galega or clover substrates were higher compared to that obtained from cow manure (control), while lower methane outputs were obtained from anaerobic digestion of canary grass or galega haylage. Fur further increase of methane output from the biomass there is a need to optimise the organic loads and pH values within substrates.

Conclusions

The annual fodder galega yield has varied from 9.56 to 11.2 Mg ha^{-1} and the average productivity has been increasing steadily during the 25-year period without reseeding or cultivation. Inclusion of a grass species in galega swards resulted in a yield increase of 28% to 36% in the first production year already. Galega haylage and red canary grass have a higher dry mass content, the fermentation therefore progressed slowly and biogas had low methane content. Methane concentration in gases obtained from all energy grasses was suitable for further biogas treatment and usage for energetic purposes.

Investigated average specific volumes of methane per 1 kg of volatised organic matter (VOC) were 218.6 l kg_{VOS}^{-1} from cow manure (control) 312.5 l kg_{VOS}^{-1} from galega, 83.2 l kg_{VOS}^{-1} from galega haylage, 234.1 l kg_{VOS}^{-1} from clover and 133.9 l kg_{VOS}^{-1} from reed canary grass.

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Utilization of grass for anaerobic fermentation

Andert D.[1], Frydrych J.[2], Gerndtová I.[1] and Hanzlíková I.[1]

[1]*Research Institute of Agricultural Engineering, Prague, Czech Republic*
[2]*Oseva PRO Ltd., Grassland Research Station, Rožnov-Zubří, Czech Republic*
E-mail: andert@vuzt.cz

Abstract

Increasing the level and productivity of agricultural production also increases the land area not utilized for food production. This area can be used for growing energy crops, including grasses. When land is introduced into the set-aside condition by grassing or the potential of perennial grasses is not realized as a result of a reduced cattle herd, the amount of grass which can be utilized for energy purposes also increases. The experiments were carried out on the principle of single-stage anaerobic digestion within the mezophyle range. During the experiments the cumulative production of biogas and its composition were measured. Disintegration of the processed grass through pressing and cutting was performed. Such an adaptation of the material resulted in increased biogas production. Additionally, the optimum share of grass dry matter from 350 to 500 g kg^{-1} in the total D.M. of the mixture shows increased cumulative biogas production. The experimental results prove the suitability of grass phytomass as material for biogas production.

Keywords: grass, anaerobic digestion, biogas

Introduction

Searching for new energy resources has become a worldwide phenomenon. In connection with the increasing level and productivity of agriculture, the amount of set-aside land not used for food production has grown as well. Besides forage production, grassland also has exceptional significance as regards its non-production function. Among the important functions belong: water management – rainfall retention; anti-erosion – i.e. protection against water and wind erosion; protection in relationship to the hydrosphere – the root system reduces underground water pollution; aesthetic – grassland maintains the appearance of the landscape; economic and social functions – generating of jobs for the population in marginal areas. In the case of arable land introduced into a set-aside regime, these areas need to be cultivated by cutting. Increased economic pressure or the profitability of agricultural production is another reason for the reduction of the cultivated area, particularly in marginal regions. It may be assumed that, similarly as in Germany or Austria, the social pressure on land owners will increase – mainly in tourist regions – to provide regular maintenance for all grassland (Andert, 2006).
There exist two possible ways to use grass biomass for energy: the combustion of dry material and the suitable processing of wet material by anaerobic fermentation, with subsequent exploitation of biogas energy.

Material and methodology

For these experiments agrostis gigantean (Rožnovský), fescue Kora, reed canary grass Palaton, reed canary grass Lera, reed canary grass Chrifton, a grassland mixture for

wetter conditions, a grassland mixture for dry conditions, brome grass Tacit, and arrhenatherum elatius Roňovský were employed. The experiment was realized with variants without N fertilization and with an N dose of 50 kg ha^{-1} y^{-1}.
A laboratory workplace was built for biogas production grown from a special substratum. A set of fermentors is placed in a heated water bath. Each fermentor has its own gas container for reading the quantity of biogas produced. These small devices serve for the determination of biogas production and the specification of other properties of the phytomass mixture of energy plants, slurry, fugate, and neutralization agents, with the aim of reducing the acidity of the organic substratum mixture processed under anaerobic conditions. To analyze the biogas that was generated, an AIR LF analyzer was used. This device was further employed for measuring the CO_2, CH_4, and S_2 contents. Also available were a pair of larger reactors with comparative metanogenesis measurements. Those mixtures tested with good results in the small fermentors are then verified in the larger laboratory fermentors.

Results and discussion

Procedure for biogas yield determination

The production of biogas from individual types of substrate and its chemical composition were investigated. The two reactors made it possible to optimize the fermentation blend composition, have better control over the process course, and monitor the operational temperature effect. For the inoculation of the metanogenesis process we used a blend of fermented fugat from the biogas plant RAB Třeboň and fresh pig slurry, also

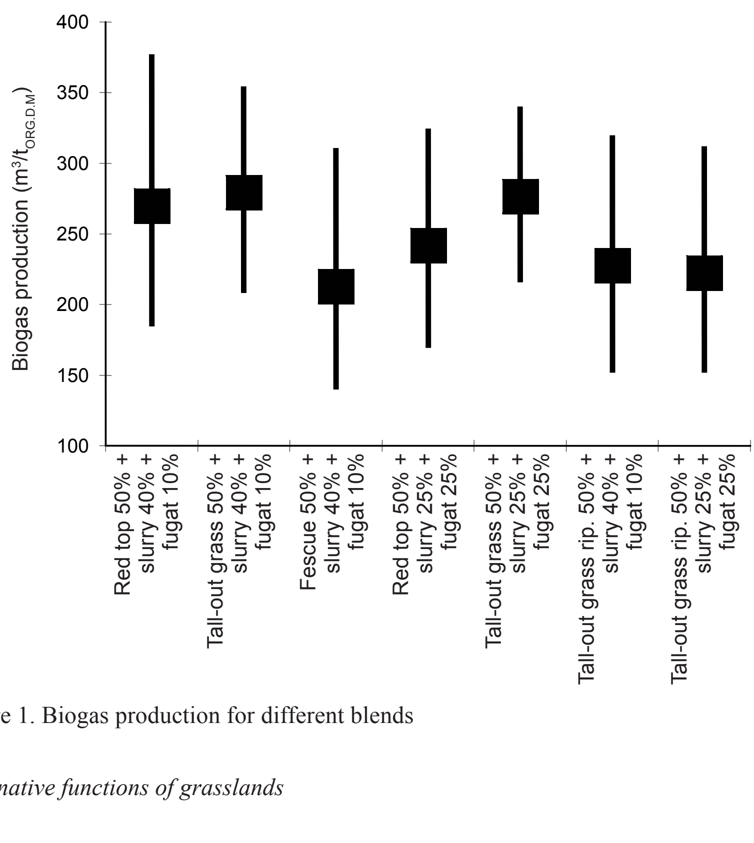

Figure 1. Biogas production for different blends

from Třeboň. For all the experiments identical conditions were set up. The fermentors operated at a temperature of 42°C, i.e. within the thermophilic field. The dry matter weight percentage of the initial blend of mixed substratum was between 40 and 80 g kg^{-1}. The resultant biogas production (in litres) was always related to a mass of 1 kg of sample organic dry matter.

Conclusions

The particular grassland mixtures and grass species included in the project displayed different levels of dry matter content in the green material, which mainly increased with the vegetation ageing and delays in the timing of the first harvest. The highest dry matter content was found for the plants harvested in September (for brome grass in its fertilized variant the dry matter content in green material was 632 g kg^{-1}). Particular grassland mixtures and grass species also react differently from the point of view of their dry matter yield and optimum harvest time for biomass and its utilization for energy purposes during the harvest year with the aim of reaching the maximum dry matter yield. A reduction in the dry matter yield of grassland harvested in later summer and autumn in the first cut is caused by the leaf fall and plant lodging (e.g. grassland mixtures or arrhenatherum elatius). Following the first results, the harvesting of the grassland mixture in wetter and dry conditions in June and July can be recommended, with possible multi-cut utilization. Especially for these mixtures, the high yield potential of green material in an early cut can be utilized.

The first measurements prove it is possible to use a high share of agrostis gigantean in the batch. The dry wetter share in the mixture was about 500 g kg^{-1}. Biogas production from the mixture with agrostis gigantean is fully comparable with biogas produced merely from slurry. Average yields of 265 m^3 $t_{odm}{}^{-1}$ in the mixture are normally reached and the maximum yield achieved was 378 m^3 $t_{odm}{}^{-1}$. This was with agrostis gigantean 1 month before its technical ripeness. Very good results were also achieved for arrhenatherum elatius, where the span between the maximum and minimum production achieved was the least. Very good results were also achieved with the mixture from a wetter site. Fescue seems to be a less suitable plant for biogas production. With the extended reaction time stagnation of biogas generation occurs and the methane content drops after 33 days. This was proved by the substratum exhausted in the fermentor. All the tests prove the suitability of the utilization of young plants two months or at least one month before their technical ripeness. Harvesting one month after ripeness shows significantly worse results. Other trials will be focused on the structure effect of the grass species.

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Breeding of cocksfoot genotypes for orchard land planting

Babic S.[1], Sokolovic D.[1], Radovic J.[1], Andjelkovic S.[1], Jevtic G.[1] and Simic A.[2]

[1]*Institute for Forage Crops, Krusevac, Serbia*
[2]*Faculty of Agriculture, Zemun-Belgrade, Serbia*
E-mail: snezana.babic@ikbks.com

Abstract

Cocksfoot (*Dactylis glomerata* L.) is one of the most important cool season forage grasses. It shows a high yield of quality forage as a component of different grass legume mixtures with more then five years of utilisation. An important characteristic is its tolerance to shade, which enables this species to be incorporated in mixtures for the planting of the land in orchards. At the same time it can be used for forage production by hay-making or grazing among fruit plants. This alternative usage of cocksfoot demands adapted cultivars with a prostrate habitus, products of specific breeding programmes. In this research 12 cocksfoot genotypes, chosen for having an adequate habitus, was evaluated in order to select promising genotypes for further specific cultivar breeding. Phenological and morphological traits and dry matter yield, respectively, were investigated during a two-year period. All the data were processed with ANOVA and an LSD test. The five most promising populations, with a lodged habitus and a high yield, were chosen for further breeding.

Keywords: cocksfoot, breeding, populations, prostrate habitus, forage yield

Introduction

Cocksfoot is one of the most important forage perennial grasses in Europe and Serbia. It has great adaptability, showing a high yield of quality forage over 10 Mg ha^{-1} (Casler *et al.*, 2000; Sokolović *et al.*, 2004). If it is cut frequently, the quality of cocksfoot dry matter (DM) can be comparable with the quality of perennial ryegrass (Turner *et al.*, 2005). It has shown a very high and stable yield in mixtures with legumes and other grasses (Balan *et al.*, 2006; Kyriazopoulos *et al.*, 2008). Additionally, cocksfoot is a forage species which has a good tolerance to shade (Rodriguez-Barreira *et al.*, 2008), where the effect of summer drought and heat is less then in open grassland (Mosquera-Losada *et al.*, 2005). It represents an excellent species for sown grasslands in orchards for forage production, weed reduction, and avoiding herbicides. In Serbia *Dactylis glomerata* L. is a characteristic species of grasslands from the alliance *Arrhenatherion elatioris* with a different presence and covering. In natural habitats it occurs on various meadows in moderately moist soils, from lowland to mountain habitats over 1,000 m a.s.l. (Sokolović *et al.*, 2003) especially in shady places such as sparse woods, wood edges and abundant orchards. The primary goal in cocksfoot forage breeding is obtaining cultivars with a high yield and quality for livestock feed (Casler *et al.*, 2000). But if the cultivar is unique for orchard land planting, it has to be productive and to have a prostrate short habitus at the same time. Breeding that material should incorporate two-way approach in research. Besides direct selection for dry matter yield and quality, the breeder's attention must be focused on some specific morphological traits of the habitus. The genetic variability of all the agronomical traits important for breeding represents a basic prerequisite for successful selection (Christie and Krakar, 1980). The primary goal of this work was to investigate populations of cocksfoot chosen during previous research according to their prostrate habitus.

Material and methods

This research included 10 chosen populations originating from Serbian autochthonous populations and 2 populations from the Czech Republic. The trial was established on an experimental field of the Institute for Forage Crops in the spring of 2005 as spaced plants with 30 plants per population in three replications. The morphological traits (plant height, leaf length, leaf width, number of leaves per tiller, number of vegetative, generative and total tillers per plant, and leaf-stem ratio), time of tillering, and dry matter yield (DMY) were investigated over a 2-year period (2006–2007) and presented as average values. In both years the DMY was analysed in two cuts and presented as an annual yield. The height was measured with pulled plants at the first cut. The leaf-stem ratio was determined on a dry matter basis and presented as a percentage. The time of tillering is presented as the number of days from April 1st. Plant habitus was scored between 1 for erectum (100% of upright plants) and 9 for prostratum (100% of lodged plants). All data were analysed by ANOVA and the significance of the differences was determined with the LSD test. Broad sense heritability (h_b^2) was calculated for all traits according to the formula

$$h_b^2 = \frac{\delta_g^2}{\delta_f^2} \times 100$$

where: δ_g^2– genetic variance; δ_f^2 – phenotypic variance

Results and discussion

Dactylis glomerata is a forage grass species which tolerates shade and can provide a yield in that environment. The breeding model of cultivars for orchards determines that desirable genotypes should have prostrate, short, and well-yielding plants. The populations included in the nursery, chosen in a previous breeding cycle as prostrate, had an average score of over 7 for this trait (Table 2). As was expected, in this trial the populations had a large proportion of short and lodged plants. Additionally, some genotypes which will be chosen from those populations must have good DMY and leafiness, as a prerequisite for good herbage quality. There was significant variability between the populations for all morphological traits (Table 1) and DMY (Table 2). The time of tillering is ranked in ten days in the middle of May (Table 1). Three of them (14V, 19V, and 12V) were earlier (first ten days of May), while the rest of the populations showed medium maturity. The plant height was under the common height for cocksfoot reported earlier (Sokolović *et al*., 2004). For some populations (23V and 36S) the average height was significantly lower, which was a desirable level in this breeding model. The populations 35S, 7V, and 14V had the highest average leaf sheath size (length and width), as well as the largest number of leaves per plant. These morphological traits affect the forage quality by increasing the quality of dry matter and improving the crude protein content. A similar effect on dry matter quality is also expected for a good leaf-stem ratio.

Table 1. Average trait values of chosen cocksfoot populations

Traits Populations	Time of tillering	Plant height (cm)	Leaf length (cm)	Leaf width (mm)	No. of leaf per tiller	No. of vegetative tillers	No. of generative tillers	Total No. tiller per plant	Leaf-stem ratio
35S	48.9	58.5	30.5	10.5	3.1	17.9	27.7	45.6	34.6:65.4
36S	48.9	49.5	25.7	8.7	2.9	22.9	19.5	42.4	41.1:58.9
1V	44.5	58.8	21.2	8.2	3.2	9.5	28.7	38.2	23.0:77.0
2V	43.7	66.3	27.0	9.4	3.1	8.2	37.7	45.9	33.3:66.7
7V	48.3	73.9	27.5	10.6	3.1	10.6	66.6	77.2	30.0:70.0
8V	48.7	66.0	26.2	10.4	3.1	12.9	50.9	63.9	43.4:56.6
12V	40.3	77.8	25.6	9.7	3.1	19.5	37.5	57.0	24.3:75.7
13V	41.5	73.4	24.2	9.5	2.8	6.2	54.9	61.1	30.3:70.0
14V	38.7	83.3	28.3	10.8	3.2	32.2	23.1	55.3	39.9:60.1
19V	39.7	77.8	24.1	10.3	3.6	21.9	30.1	51.9	29.2:70.8
21V	48.4	67.1	27.3	8.8	2.9	5.0	14.4	19.5	36.1:63.9
23V	47.0	44.7	22.2	8.9	2.4	7.3	25.7	33.0	36.2:63.8
Average	44.9	66.48	25.84	9.68	3.08	14.52	34.74	49.26	33.4:66.6
LSD_{005}	2.34	8.2	3.40	1.12	0.34	11.94	20.59	22.44	
LSD_{001}	3.10	11.5	4.49	1.48	0.45	15.77	27.21	29.66	
h_b^2	93.0	79.5	72.9	78.7	72.15	75.33	79.31	77.72	

Table 2. Dry matter yield (g plant^{-1}) of chosen cocksfoot populations

Populations	Annual yield in first year	Annual yield in second year	Average annual DMY	Plant habitus
35S	57.76	148.49	103.13	8.5
36S	61.18	68.93	65.06	8.4
1V	27.99	105.95	66.97	7.2
2V	26.92	181.16	104.04	8.2
7V	50.04	319.53	184.78	7.5
8V	41.20	225.22	133.21	7.2
12V	74.71	213.79	144.25	7.5
13V	25.66	309.25	167.45	7.4
14V	56.22	167.22	111.72	7.3
19V	36.91	197.81	117.36	8.5
21V	26.67	71.89	49.28	7.1
23V	10.41	72.67	41.54	8.6
Average	41.30	173.49	107.40	7.78
LSD_{005}; LSD_{001}	9.2; 12.1	26.1; 34.5	26.2; 34.7	
h_b^2	76.89	70.47	74.15	

The best ratio, with a proportion of leaves of about 40%, was estimated for the populations 36S, 8V, and 14V. Variation in the tiller number between populations was noticeable with average of almost 50 tillers per plant. Broad sense heritability was high for all the analysed traits (over 70), which indicates that an improvement of all traits could be possible and predictable in these populations. The average DMY of the populations ranged from 41.54 to over 184 g per plant (Table 2). In the second year, the populations 7V and 13V had the highest average DMY, over 300 g per plant.

Conclusions

A high level of variability of important traits was detected among the populations. All the populations chosen as sources for further orchard cultivar breeding showed a prostrate habitus on average. The best-yielding populations, with desirable morphological traits, but different maturity, were 7V, 8V, 12V, 13V, and 35S. Plants from those populations will be included in the breeding of special-purpose cultivars for orchard grass planting.

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Tetraploid red clover – in a pure stand or mixed with timothy?

Bender A., Tamm S. and Aavola R.

Jõgeva Plant Breeding Institute, Jõgeva, Estonia
E-mail: Ants.Bender@jpbi.ee

Abstract

A field trial was performed at Jõgeva PBI to study the possibilities of cultivation of tetraploid red clover (*Trifolium pratense* L.) Varte in a pure stand or mixed with timothy (*Phleum pratense* L.) Jõgeva 54. The purpose of the study was to specify the impact of timothy admixture on the forage yield and quality, and its potential to influence these by defoliation. The results show that the cultivar Varte sown in a pure stand without nitrogen fertiliser ensures dry matter (DM) yield of 23–24 Mg ha^{-1} as a total of two crop years. Adding timothy to the mixture makes it possible to enhance the total yields of DM, digestible DM (DDM) and crude protein (CP), but spoils the herbage quality: contents of CP and DDM decline and the neutral detergent fiber increases. Varte, predominating in the ley, enables to prolong the sward persistency from two to three harvest years and reduce the need for mineral nitrogen. Nitrogen application becomes beneficial by the 3rd harvest year of ley, when the proportion of red clover has dropped below 70%.

Keywords: tetraploid red clover, timothy, ley, defoliation, yield, herbage quality

Introduction

Diploid red clover with timothy admixture has been cultivated in field crop rotations in Estonia for a long time. The stands are harvested for two years: in the first the forage from a ley rich in clover (> 75% in the herbage) is harvested relying on its atmospheric nitrogen fixation. In the 2nd year, mineral fertiliser (N 70–105 kg ha^{-1}) application ensures that the herbage is rich in timothy (share 70–75%). By adding grass to the clover a better stand persistence, balance between the nutrients, higher yield in the 2nd crop year and fewer weed problems are achieved. By now the situation has changed: (1) tetraploid red clover varieties with improved productivity and longevity are used (Bender, 2000), (2) the price of nitrogen fertilisers has increased, (3) milk production of dairy cows has risen (7,390 kg in 2008, http://www.jkkeskus.ee) and that imposes higher quality standards on forage, (4) silage maize cultivation supplies the feed rations with carbohydrates.
The purpose of the current study was to compare the productivity and herbage quality of pure stand of tetraploid red clover with clover-grass mixtures and to evaluate the possibilities of influencing these through defoliation regimes.

Methods and materials

A field trial sown in July 2003 to a ploughed fallow included an Estonian early tetraploid red clover Varte (16 kg ha^{-1}), timothy Jõgeva 54 (12 kg ha^{-1}) and clover + timothy (12 +

6 kg ha^{-1}). The experimental area was located on calcaric cambisol. Prior to sowing, P 20 kg ha^{-1} and K 66 kg ha^{-1} were applied. Before sowing, and in the spring of the crop years, N 80 kg ha^{-1} for the pure sowings and N 60 kg ha^{-1} for the timothy regrowths were applied. The same rates were used for the clover-grass mixture in the 3rd crop year.
Six different times (at weekly intervals) of the first defoliation were used to measure its effect on the herbage yield and quality. Regrowths were harvested 42 days after the preceding cut, although the real regrowth made it possible to abide by the plan only in 2004 and 2005. Drought in the summer of 2006 stopped the regrowth for weeks and its forming period was much longer than anticipated.
The contents of crude protein (CP), acid detergent fiber (ADF) and neutral detergent fiber (NDF) in the herbage were determined in an accredited laboratory. Digestibility of dry matter (DDM) was calculated.

Results and discussion

The yields of timothy when sown in pure stands remained below those of red clover and the clover-grass mixture (Table 1). In most treatments the yield differences were statistically significant. The greatest difference was observed in the CP yields.
The comparison between the DM yield (DMY) of pure red clover and the clover-grass stands showed that in the first crop year timothy increased the forage yield in most defoliation regimes by less than 5%. In the 2nd crop year of ley, timothy considerably increased the DMY. Depending on the time of first harvest and successive defoliations the DMY of clover-grass stands was by 12.8–23.7% higher than that of pure red clover. The highest DMY surplus which was due to timothy (53.0–85.8%) was received in the 3rd crop year from the clover-grass stand. In the case of two harvest years, the admixture of timothy in tetraploid red clover produced a DMY surplus of 8.1–16.8%. When the duration was extended to 3 harvest years timothy contributed by 16.1–27.0% to the total DMY depending on the treatment.
Admixture of timothy in red clover increased the DM content of forage. The more timothy was present the stronger was the effect. In the first harvest year the DM content of clover-grass herbage cut at various first times was by 0.5–2.4%, in the 2nd year by 1.8–4.4% and in the 3rd by 1.7–12.0% higher than in the pure stand of clover.
Admixture of timothy in clover lowered the forage quality (Table 2). The adverse effect was more pronounced in the first cut because the regrowth of timothy is poorer compared with early red clover. The species composition of the swards had undergone a change by the 3rd harvest year. Then the quality of the mixture in the first cut was worse than that of red clover: CP content by 19–81 g kg^{-1} and DDM by 6–65 g kg^{-1}. Regardless of the lower digestibility and CP content of clover-grass it produced significantly higher yields of DDM and CP than pure red clover.
The total forage yield of clover-grass swards in the first three treatments could be classified as good or satisfactory (http://agsource.crinet.com/page486/ForageQualityStandards; Tamm, 2005). In these treatments the reason behind the quality deterioration was not due to a reduced CP content but to an excessive NDF content. In the sixth treatment in the 2nd harvest year and from the fourth treatment in the 3rd year a part of the DM did not meet the quality standards set for satisfactory forage. This was caused by the drop of CP content below 120 g kg^{-1} in the first cut. Timothy generally did not produce good quality forage at the exploited defoliation intervals and fertilisation background – mainly due to a low CP content.

Table 1. Total yields of the swards harvested during two and three years (2004–2006)

Treatment	Clover		Clover-grass		Timothy		LSD 0.05	
	2004–2005	2004–2006	2004–2005	2004–2006	2004–2005	2004–2006	2004–2005	2004–2006
Dry matter (Mg ha^{-1})								
1	22.0	26.1	25.0	31.6	20.2	25.4	1.21	1.42
2	23.5	27.5	25.4	32.2	21.7	25.9	1.28	1.51
3	23.3	26.9	25.5	31.2	21.4	26.5	0.64	0.52
4	24.6	30.2	27.2	37.1	19.9	25.9	1.81	3.00
5	25.2	30.6	28.8	36.6	22.8	29.3	2.41	3.10
6	27.3	32.0	31.9	40.7	24.7	32.0	1.72	1.60
LSD 0.05	0.7	1.2	1.2	1.9	0.9	1.3		
Digestible dry matter (Mg ha^{-1})								
1	14.9	17.7	16.6	21.1	13.4	16.8	0.83	0.97
2	15.9	18.5	16.9	21.5	14.2	17.0	0.85	0.98
3	15.9	18.3	17.2	20.8	13.9	17.2	0.42	0.33
4	16.4	19.9	17.7	23.8	12.4	16.1	1.19	1.71
5	16.6	19.9	18.5	23.3	14.2	18.2	1.56	1.99
6	17.3	20.4	20.1	25.3	15.1	19.7	0.97	0.92
LSD 0.05	0.5	0.8	0.8	1.2	0.6	0.9		
Crude protein (kg ha^{-1})								
1	4,783	5,577	4,934	6,044	2,766	3,445	225	239
2	5,034	5,874	5,355	6,510	2,732	3,278	258	296
3	5,005	5,701	5,212	6,091	2,115	2,676	145	162
4	5,016	5,857	5,090	6,366	1,819	2,336	329	437
5	5,082	5,820	4,925	5,792	1,963	2,423	411	476
6	4,856	5,578	4,928	5,771	1,747	2,251	180	142
LSD 0.05	141	214	213	297	172	237		

Table 2. Impact of timothy admixture in red clover on the crude protein (CP) and digestible dry matter (DDM) content in the forage at first cut, in g kg^{-1}

Treatment	Harvest year					
	I		II		III	
	CP	DDM	CP	DDM	CP	DDM
1	–21	–7	–68	–37	–34	–6
2	–4	–5	–37	–38	–62	–52
3	–12	–15	–53	–55	–51	–36
4	–6	–11	–60	–54	–19	–15
5	–12	–4	–62	–44	–38	–32
6	–45	–28	–31	–4	–81	–65

Conclusions

Biennial ley can be seeded with tetraploid red clover Varte. Good quality forage can be produced for two years (DM yield sum 23–24 t ha^{-1}) without nitrogen if the first cut is taken before mid-June and the regrowths are harvested six weeks after the preceding cut. Admixture of timothy in tetraploid clover prolongs the duration of the clover-grass sward with nitrogen background by one year, and ensures higher total yields of DM, DDM and CP. The favourable effect is greater in the 2^{nd}, but particularly in the 3^{rd} harvest year. Timothy as a companion species affects the forage quality: it increases the DM and NDF content while reducing the CP content and DDM. The first year's sward of clover-grass should be defoliated for the first time a week before the pure sown clover. The most appropriate time for harvesting the 2^{nd} and 3^{rd} year's stands of clover-grass arrives in early June. Six weeks of regrowth is likely to ensure good quality forage from red clover and from a ley rich in clover. The subsequent quality can be controlled through changing the frequencies in the years with sufficient precipitation.

In delayed first defoliation of old clover-grass swards the forage quality deteriorates through decreased CP content, and in the delayed cutting of aftermaths through poor DDM.

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Effects of fertilisation level on the productivity of three permanent ryegrass meadows in the upper Veneto plain (N-E Italy)

Bonifazzi B., Da Ronch F. and Ziliotto U.

Dipartimento di Agronomia ambientale e Produzioni vegetali dell'Università degli Studi di Padova – AGRIPOLIS, Legnaro (PD), Italy
E-mail: barbara.bonifazzi@unipd.it

Abstract

The results of three plot trials conduced in three permanent ryegrass meadows in the upper Veneto plain, in order to evaluate the effects of three different fertilisation levels on quantitative production, are described. The lower fertilisation level was equal to the uptake rates in the previous year. These meadows are characterised by soil particularly rich in organic substances, N and, in some cases, also P and K. In the period 2005–2006 all the trials produced a high amount of forage (from 14.7 to 18.7 t ha^{-1} year^{-1} of DM) but they did not show any significant differences between different fertilisation levels. The corresponding yearly uptakes of N were equal to or slightly higher than the distribution on the lower fertilisation × level and, in any case, lower than 340 kg ha^{-1} year^{-1}.

Keywords: fertilisation level, *Lolium multiflorum*, N uptake, permanent meadows, ryegrass

Introduction

In the upper Veneto plain, between the Brenta and Bacchiglione rivers, the breeding of milk cattle is still widespread. The farms are mainly based on dairy cows feeding on the products of permanent ryegrass meadows, partly on perennial green fodder (from arable land) with high productivity (such as silage corn) and partly on food with a high nutritive value of an extra-farm origin. Depending on the zootechnical management, the permanent ryegrass meadows, like all other cultures in the area under consideration, are intensively fertilised and then they have high production, but not always with high quality value. In this case the botanical composition suffers a simplification or even becomes banal (Rodaro *et al*., 1998, 2000).

According to the Council Directive 91/676/CEE concerning the protection of water against pollution caused by nitrates from agricultural sources, it is actually not allowed to supply more than 340 kg ha^{-1} year^{-1} of nitrogen from organic manure. In order to clear the effects of the annual application of that law on the productivity of the permanent ryegrass meadows in the plain, three tests were carried out on three meadows in the upper Veneto plain with three different fertilisation levels, of which the lower one was calculated to be equal to the uptake. The results and the comments about the effects of these levels on the quantity produced by the meadows in the first two years testing are presented.

Materials and methods

In February 2005 three different permanent meadows in the upper Veneto plain were selected as typical examples of the grasslands in this area (Rodaro *et al.*, 1998, 2000). They differ in the types of soil: the first, located in Carmignano di Brenta (Test 1), presents a silt clay loam soil with good permeability, the second, located in Gazzo Padovano (Test 2), presents clay loam soil, and the last, located in Bressanvido (Test 3), presents clay loam soil, but less permeable and thus more exposed to water stagnation even after watering. Three soil samples, from depths of 0–5 cm, 5–10 cm, and 10–20 cm, were taken at the beginning of the experiment from every ryegrass meadow in order to perform soil chemical analysis.

All the tests were set up using the experimental design of a randomised block with four replications. In each trial 9 thesis obtained from the factorial combination of 3 cut frequencies and 3 fertilisation levels (organic and mineral) were compared. The plot size of the 36 thesis was 4.00 m × 6.00 m = 24 m^2, in which the central 3.00 m × 6.00 m = 18 m^2 was used for the experimental sampling. The fertilisation levels were: (1) equal to uptake N rate; (2) equal to 1.5 uptake N rate, and (3) equal to 2 uptake N rate. The annual rate of N, P, and K fertilisation was determined by the amount of forage products on average by tests in the past year. It was also considered that 10 t of DM of forage remove 160 kg of N, 45 kg of P_2O_5, and 180 kg of K_2O. For 2005 there were no meadow production data so for all three tests the hypothetical value of 15 t ha^{-1} was considered. For the year 2006 Test 2 and Test 3 produced 15 t ha^{-1}, as predicted, and Test 1 produced 18.7 t ha^{-1} of DM. The amount of individual mineral elements (P, K, N), was calculated on the basis of this production and was brought about by organic manuring in autumn ending (50%), and with mineral manuring in spring (the remaining 50%).

The mineral manuring was distributed in the following way: the P and K rates were distributed at one time in the winter with ⅓ of the N rate; the remaining rate of N was divided into three parts and distributed before the first three cuts.

The first cut in all the plots took place at the same time as *Lolium multiflorum* was sprouting. The other cuts were made according to three different cut frequencies, one every 30 days, one every 38 days, and the last one every 50 days. For every cut the single plot was mown and the forage obtained was weighed. A sample of 1 kg was taken to estimate the DM content.

The next step was the application of variance analysis (ANOVA) regarding the production of the plots. Below, for the sake of brevity, only the annual DM production between the years 2005 and 2006 is provided and commented on; besides this, only the effects of different fertilisation levels are reported, since, in each case, the results between the cut frequency and fertilisation interaction were not significant.

Results and discussion

At the beginning of the experiment the soil of all three meadows was characterised by a marked decrease in the amount of organic matter and N content from the topsoil to the subsoil (Table 1).

The content of available P was fairly good only in the first two soil layers of Test 1, and in the first layer of Test 3. Similarly, the available K content was rather high in the first two layers of Test 1, as well as in the first layer of Test 2 and in the second layer of Test 3. On the basis of C/N ratio values, only the top layers of Test 2 were able to improve the amount of humus.

The total DM yield of the three meadows was rather high in both 2005 and 2006, and it was not affected by fertilisation (Table 2).

Table 1. Chemical properties at the beginning of the experiment in different soil layers (mean of three values)

	pH	Chemical properties				
		organic matter (g/100 g)	N tot. (g/100 g)	P (ppm)	K (ppm)	C/N
Test 1: Carmignano di Brenta						
0–5	7.05	11.38	0.62	16.93	577.93	10.7
5–10	7.11	8.12	0.49	9.50	259.13	9.7
10–20	7.61	3.73	0.22	3.45	83.63	10.0
Test 2: Gazzo Padovano						
0–5	6.61	5.52	0.27	3.04	149.57	12.2
5–10	7.00	2.44	0.12	0.84	50.40	12.2
10–20	6.85	1.62	0.09	1.09	46.17	11.0
Test 3: Bressanvido						
0–5	6.69	10.83	0.55	9.52	299.60	11.4
5–10	6.83	7.06	0.38	4.68	154.53	10.6
10–20	7.13	3.73	0.22	0.80	116.17	9.6

Table 2. DM yield and N uptake for the fertilisation levels

	Test											
	1				2				3			
					F level							
	1.0	1.5	2.0	med.	1.0	1.5	2.0	med.	1.0	1.5	2.0	med.
Year yield (q ha^{-1} DM)												
2005	18.1	18.7	19.3	18.7	14.3	15.1	15.3	14.9	15.5	16.0	16.5	16.0
2006	18.1	17.8	18.3	18.1	15.5	16.1	16.3	16.0	14.6	14.8	14.7	14.7
Mean	18.1	18.3	18.8	18.4	14.9	15.6	15.8	15.5	15.1	15.4	15.6	15.4
Quantification of N uptake (kg ha^{-1})												
2005	290	299	309	299	229	242	245	239	248	256	264	256
2006	290	285	293	289	248	258	261	256	234	237	235	235
Mean	290	292	301	294	238	250	253	248	242	246	250	246

The DM yield of Test 1 was 18.7 t ha^{-1} (average of the nine treatments) and 18.1 in 2005 and 2006 respectively, with an N uptake of 299 and 289 kg ha^{-1}, while the total DM yield of Test 2 was 14.9 (2005) and 16.0 (2006), with an N uptake of 239 and 235 kg ha^{-1}, and that of Test 3 was 16.0 (2005) and 14.7 (2006); the N uptake in this case was 256 and 235 kg ha^{-1}. The results showed that the N uptake was equal to or a little higher than that provided by the lower fertilisation level of each test [240 kg ha^{-1} (Tests 2 and 3), 300 kg ha^{-1} (Test 1)].

Conclusions

The results showed that to defend the productivity of the permanent ryegrass meadows in the upper Veneto plain it is enough to carry out annual fertilisation equal to or a little higher than the removal rate. In this case the application of the Council Directive 91/676/CEE should not cause negative consequences for meadow cultures.
However, these results relate only to two years of experimentation and, in particular, these soils were rich in organic matter and nutrient content, so it will be necessary to determine if it is possible for the high production of these meadows to be conserved, over time, using fertilisation equal to the removal rates during a longer period of years without forgetting that these are irrigated crops, so they have a high level of runoff.

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Trifolium subterraneum L. (Subterranean clover) on arable land in regions with limited precipitation

Brant V., Neckář K., Hakl J., Holec J., Pivec J. and Venclová V.

Czech University of Life Sciences Prague, Department of Forage Crops and Grassland Management, Prague, Czech Republic
E-mail: brant@af.czu.cz

Abstract

Possibilities for successful growing of *Trifolium subterraneum* L. in regions with insufficient precipitation were tested on arable land in Central Bohemia during 2005–2007. The development of pure stands of *T. subterraneum* (spring sowing, 30 kg ha^{-1}) and aboveground biomass production were tested in small-plot trials. At the same time, *T. subterraneum* was evaluated as a summer catch crop and was sown after winter wheat harvest at the end of August (30 kg ha^{-1}). Average (2005–2007) dry matter production of pure stands of *T. subterraneum* assessed at the end of August was 7.498 Mg ha^{-1}. When grown as a catch crop, average aboveground biomass production at the end of the vegetation period was 1.188 Mg ha^{-1}. The biomass production was related to the weather conditions during crop development, and in case of catch crop also to the development of volunteer forecrop.

Keywords: *Trifolium subterraneum,* catch crop, pure stands, biomass production

Introduction

Trifolium subterraneum L. (Subterranean clover) is an annual species which is able to overwinter. Its native area of occurrence is in the Mediterranean (Duke, 1981). Wild forms of this species are sometimes accidentally and temporarily introduced into the area of the Czech Republic (Kubát, 2002). There are three subspecies recognized inside the species: ssp. *subterraneum*, ssp. *yanninicum* and ssp. *brachycalycinum*. Flower stalks reflex after flowering and penetrate into the soil. Stems and flower stalks lying on the soil surface do not create adventitious roots (McGuire, 1985). According to Duke (1981) *T. subterraneum* can be grown in areas with annual mean temperature from 5.9 to 21.3°C. The greatest increase in biomass production of *T. subterraneum* was recorded in a temperature range of 15–25°C (Guerrero and Williams, 1975). In general, growing areas with an annual rainfall from 380 to 1,630 mm are suitable for *T. subterraneum*, but the species development is influenced mainly by the seasonality of precipitation (Murphy *et al*., 1976). In Europe, *T. subterraneum* growing on arable land is associated mainly with the support of non-production functions of agriculture, organic farming, and with the technologies of soil conservation tillage. Good vegetation cover of *T. subterraneum* when grown as an undersown cover in maize stands, which reached 30–40% cover in the second half of the vegetation, was described by Ammon and Scherrer (1994). According to Dieraurer and Stöpler-Zimmer (1994) *T. subterraneum* as an undersown cover can be used in stands of vegetables weak in competition. In these systems, the shorter height of *T. subterraneum* compared with the vegetables is an advantage. Freyer (2003) classified *T. subterraneum* as a cover crop which is sufficiently and regularly rooting in soil by hair roots. The aim of this study was to assess the growth characteristics of *T. subter-*

raneum stands on arable land in areas with limited precipitation under the conditions of the Czech Republic.

Materials and methods

The development of *T. subterraneum* stands grown as monocultures and as summer cover crops on arable land was tested at the Červený Újezd experimental station of the Czech University of Life Sciences Prague (CULS) during the years 2005–2007. An average yearly temperature on the stand is 7.9°C and the yearly precipitation is 525.8 mm (geographical coordinates: 50°04'34.45"N, 14°09'22.351"E – WGS 84). The soil was a clay loam. According to the latest climatic regionalization of the Czech Republic (Moravec and Votýpka, 2003) the locality falls into Class III, which is characterized by an average duration of the main vegetation period within the range of 160–177 days, average annual totals of precipitation below 580 mm, and the rainless period of more than 22 days. The sum of precipitations for the period from May to August was 380.8 mm in 2005, 274.0 mm in 2006, and 324.5 mm in 2007. The sum of precipitations from the sowing date of the stands grown as summer cover crops till the final date of the aboveground biomass evaluation was 36.2 mm in 2005, 36.4 mm in 2006 and 129.6 mm in the year 2007.

Monoculture stands were established on 29 April 2005, 10 May 2006, and 2 May 2007 with the row width 25 cm (sowing rate 30 kg ha^{-1}). The area of each experimental plot was 75 m^2 (3 m × 25 m). The aboveground biomass production of the stands was recorded from an area of 0.1 m^2 for five replicates on each experimental plot during 10^{th} and 15^{th} week after the sowing date (evaluation dates are presented in Table 1). During the aboveground biomass evaluation, the whole biomass that was above the soil surface was included. Weeds on the stands were managed mechanically during the vegetation period. The stands established as a summer cover crop after winter wheat harvest were sown on 24 May 2005, 30 August 2006, and 14 August 2007 (sowing rate 30 kg ha^{-1}, wide sowing). The area of each experimental plot was 30 m^2 (3 m × 10 m) in four replicates. The first evaluation of the aboveground biomass production was realized on 4 October 2005, 11 October 2006, and 3 October 2007, the second one on 20 October 2005, 1 November 2006, and 1 November 2007. The aboveground biomass production was evaluated on the area of 0.1 m^2 (two replicates in each plot). The production of the aboveground biomass of *T. subterraneum,* volunteer cereal forecrop, and weeds was recorded. In our trial breeding material from Deutsche Saatenveredlung Bückwitz (Germany) was used as seed of *T. subterraneum*. Statistical analysis was performed using STATGRAPHICS®Plus, version 4.0, ANOVA, Tukey method ($\alpha = 0.05$).

Results and discussion

Average (2005–2007) harvested dry matter production from aboveground biomass of pure stands of *T. subterraneum* was 3.012 Mg ha^{-1} in the 10^{th} week after sowing and 7.498 Mg ha^{-1} in 15^{th} week after sowing. There were no statistically significant differences in biomass production obtained in experimental years (Table 1). The stands of *T. subterraneum* showed 100% soil cover during the second term of aboveground biomass evaluation.

When assessing the dry matter yield of aboveground biomass of *T. subterraneum* grown as a summer cover crop, the highest values of biomass production were obtained in

Table 1. Date of sampling and dry matter production (Mg ha^{-1}) of the stands of *T. subterraneum* (spring seeded) in the years 2005–2007

Year	10th week after sowing		15th week after sowing	
	date of sampling	dry matter production (Mg ha^{-1})	date of sampling	dry matter production (Mg ha^{-1})
2005	07. 7. 2005	3.039a	10. 8. 2005	7.200a
2006	18. 7. 2006	3.001a	23. 8. 2006	6.982a
2007	11. 7. 2007	2.996a	09. 8. 2007	8.312a

ANOVA; $\alpha = 0.05$; different letters denote statistically different means within columns

2007. These values were statistically significantly higher compared to the aboveground biomass production obtained in 2005 and 2006 (Table 2). The increase in the aboveground biomass production in 2007 was probably caused by higher rainfall during the period between the date of sowing and the date of the last evaluation of aboveground biomass production. The rainfall during this period was 93 mm higher in 2007 than in previous years. The values of the aboveground biomass production of *T. subterraneum* grown as a summer catch crop were comparable to the production of *Trifolium incarnatum* stands. *Trifolium incarnatum* aboveground biomass production at the same location and with the same dates of sowing obtained during the last date of evaluation was 396.4 kg ha^{-1} in 2005, 592.6 kg ha^{-1} in 2006, and 2681.5 kg ha^{-1} in 2007 (Brant *et al*., 2009). Occurrence of weeds and volunteer cereal forecrop in *T. incarnatum* stands was also comparable. The stands of *T. subterraneum* grown as a summer cover crop can be

Table 2. Dry matter production (kg ha^{-1}) of *T. subterraneum* (catch crop), volunteers and weeds in the years 2005–2007

Date	Dry matter production (kg ha^{-1})			Date	Dry matter production (kg ha^{-1})		
	T. subterraneum	volunteer	weed		*T. subterraneum*	volunteer	weed
04. 10. 2005	432.5^{a}	507.5^{a}	170.8b	20. 10. 2005	563.3^{a}	504.9a	98.3^{a}
11. 10. 2006	297.6^{a}	417.1^{a}	9.6^{a}	01. 11. 2006	640.3^{a}	489.0a	12.9^{a}
03. 10. 2007	800.0^{b}	289.9^{a}	67.1^{ab}	01. 11. 2007	2360.8^{b}	522.5a	97.1^{a}

ANOVA; $\alpha = 0.05$; different letters document statistically different means columnwise

classified as stands with a lower competitive ability against the volunteer cereal forecrop based on the development of volunteers, which was greater than in the stands of *Sinapis alba* and *Phacelia tanacetifolia* (Brant *et al*., 2009).

Conclusion

Pure stands of *T. subterraneum* reached average dry aboveground biomass of 7.498 Mg ha^{-1} in August and showed a 100% soil cover. When grown as a summer cover crop, aboveground biomass production was comparable to stands of *T. incarnatum*. In future research it would be important to focus on the possibilities of *T. subterraneum* growing in conservation tillage systems in wide row crops and in the area of agro-environmental actions, especially in relation to the elimination of the risk of soil erosion.

Next, it would be necessary to evaluate the possibility of using *T. subterraneum* in mixtures with other legumes and grasses grown on arable land and to evaluate the production and growing parameters of these mixtures from the point of view of their growing period and competitive ability against the weeds.

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Grasslands of golf courses and their value for the landscape

Cagaš B.[1], Flodrová P.[2], Hejzlar J.[3] and Voigts M.[4]

[1]*OSEVA PRO Ltd., Grassland Research Station, Rožnov-Zubří, Czech Republic*
[2]*Austerlitz Golf Club, Slavkov u Brna, Czech Republic*
[3]*Valašský golfový klub Rožnov pod Radhoštěm, Czech Republic*
[4]*Kunětická Hora Golf Resort, Dříteč, Czech Republic*
E-mail: cagas@oseva.cz

Abstract

Investigations carried out on three golf courses in regions with different natural conditions (Kunětická Hora, Rožnov pod Radhoštěm, and Slavkov) revealed that the permanent grasslands in all the areas are of high aesthetic value to the landscape and serve as an environmental biotope with a great biodiversity of plant and animal species (Rožnov, Slavkov). In Kunětická Hora the grassland was established on a fly ash dump site and provided a basis for the secondary colonisation of the large park by native plant and animal species. The turf grass of golf courses also plays an important role in social and educational activities (employment, young people's education) in the sports and tourism industry and also in the advertising industry (making the locality and its surroundings appealing to visitors). Only the putting green, whose area is 10–15% of the entire park, is intensively treated with herbicides and cut. Green matter from the cuttings is dispersed over the place, and partly removed to special waste dumps. The ecological impact on the localities is relatively low, compared to (potential) intensive agricultural production which could be started in one of the localities under study.

Keywords: turf, golf course, fertilisers, pesticides, benefits, risks

Introduction

The turf grass of golf courses of a natural, semi-natural, or artificial origin has become an important phenomenon as a result of the unprecedented development of golf in the Czech Republic. Even the existence itself, but predominantly the increased acreage of these non-producing areas covered with grass, often composed of non-native plant material (greens) provoked a lively discussion about their importance. In many cases these areas replaced localities badly damaged by anthropogenic activity and unsuitable for other activities. In a number of cases they were established, for various reasons, on agricultural land which could have been used for crop production. The objective of this study, based on three golf courses, was to evaluate turf grass as an asset viewed from the aesthetic, environmental, landscape, social and educational aspects. On the other hand, it was also important to assess the environmental impact of turf grass, especially pollution by pesticides and mineral fertilisers.

Material and methods

The study of the environmental benefits of the turf grass of golf courses (a natural biotope, conservation of biodiversity of plant and animal species, landscape and aesthetic roles) and environmental impacts (pollution with mineral N and pesticides) was carried out on three golf courses situated in different localities in the Czech Republic. Their characteristics are given in Table 1. The assessment of the benefits and impacts was made in all three localities in the year 2008.

Table 1. Some characteristics of golf courses

Golf course	Area	Altitude (m)	Original use of the locality
Kunětická Hora	East Bohemia	250	fly ash dump site
Rožnov pod Radhoštěm	North Moravia	400	pasturage
Slavkov	South Moravia	300	park, arable land

Results and discussion

In assessing turf grass which is used for non-producing purposes or which is not used at all, it is important to discover whether it is capable of playing some roles which are not typical of productive grassland. Its benefit to humans and the landscape becomes apparent after comparison with the original turf grass (or other uses) of the locality. In all three localities the benefit of turf grass was confirmed; it can perform the function of a biotope, it is characterised by a great biodiversity of plants and animals, and it is suitably incorporated into the landscape and pleasing to the eye. Turf grass in the Kunětická Hora locality is a new phenomenon as it has replaced the original fly ash dump site, which was not in any case a prerequisite for biotope existence and functioning. The biodiversity of the original locality was also very low. At present, it is a developing locality with typical species composition where native self-seeded woody species (*Betula* spp., *Salix* spp., etc.) predominate. Compared with its original state, it has made a significant aesthetic contribution and has become an important landscape factor in the area. The turf grass in the Slavkov locality interconnects a historical palace garden and the intensively cultivated agricultural landscape in a natural and elegant way. The entire park, including the ponds and adjoining gardens, is an important biotope in the area, which focuses mainly on agricultural production. With regard to biodiversity, this golf course is a very rich locality, with more than 50 plant and more than 30 animal species. Similarly, the turf grass in the Rožnov locality interconnects a residential area with mostly recreational and sports facilities and forest-covered sub-mountainous areas of the Beskids (Table 2).

Table 2. Assessment of ecological and aesthetic impact of golf course turf grass on three different sites

Function/site	Kunětická Hora	Rožnov	Slavkov
Biotope	**	*	*
Biodiversity	**	*	**
Landscape	**	*	**
Aesthetic	*	*	*

Function: **very beneficial; *beneficial

High rates of mineral fertilisers and pesticides which are often applied to turf grass of golf courses may be one of the important environmental impacts on the landscape. On the golf courses studied, the rates of mineral N applied to the putting green did not exceed

32 g m^{-2}, while on the tees and fairways it was 29.5 g m^{-2}. These relatively high N rates are necessary to improve the competitive ability of grasses over broadleaved weeds and indirectly reduce the consumption of herbicides (Colhoun *et al*., 2005). The turf grass in the Kunětická Hora locality was fertilised only when needed with respect to minimum release as a result of the specific layout of the park. Throughout the year the turf grass on the greens was treated with 3–7 rates of fungicides (Amistar, Bravo, Heritage, Bumper, Previcur, Rovral, Quadris, Sportak Alpha) and the tees and fairways were treated once with herbicides (Aminex, Mustang, Dicopur, Lontrel, Starane) (Table 3). With regard to the potentially high probability of the incidence of fungal disease on the intensively treated turf, this is necessary (Smiley *et al*., 2005). These relatively highly treated parts constitute 1.5 ha at most on all sites, which is a maximum of 2% of the total turf grass area of the golf courses. In comparison with the area utilised for production purposes on the Slavkov site, this means a minimum environmental impact. Similarly, on the site at Rožnov pod Radhoštěm, the environmental impact caused by fertilisers and pesticides is lower compared with the area of the same size hypothetically utilised for animal grazing. The Kunětická Hora site cannot be judged from this viewpoint.

Table 3. Intensity of fertilising and pesticide treatment on turf grass on the three different sites

Part/site	N rate (kg ha^{-1}) and frequency of pesticide treatment					
	Kunětická Hora		Rožnov		Slavkov	
Green	*	3 (F)	320	4 (F)	310	7 (F)
Fairway	*	1 (H)	72	2 (H)	220	1 (H)
Tee	*	0	290	1 (H)	220	1 (H)
Others	*	0	0	0	0	0

*fertiliser application as and when needed; (F) – fungicides, (H) – herbicides

The turf grass of the three golf courses is a source of secondary activities, especially social and educational: a golf course creates new jobs (professional management and various support services) in regions which are facing unemployment problems. The positives are generating the interest of the young generations in sports and the countryside.

Conclusions

The benefit of the turf grass of golf courses on three sites with different conditions in the Czech Republic is a high biodiversity of plant and animal species, being a biotope and also being favourable to the formation of the landscape and its aesthetic qualities. These positives outweigh the environmental impact caused by the intensive application of fertiliser and pesticide to some part of the turf grass, which is only a small fraction of the entire park. The turf grass of the golf courses monitored plays a positive role in the social and educational areas.

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Impact of seasonal pasture on fatty acid composition of cows milk

Frelich J.[1], Šlachta M.[1], Špička J.[1], Samková E.[1] and Hanuš O.[2]

[1]*University of South Bohemia, Faculty of Agriculture, České Budějovice, Czech Republic*
[2]*Research Institute for Cattle Breeding, Ltd., Rapotín, Czech Republic*
E-mail: slachta@az.af.cz

Abstract

Bulk milk samples from a low-input mountain farm (at 575 m a.s.l.) in the Czech Republic were analyzed for fatty acid composition. Seasonal pasture from May to October (pasture period) and indoor grass-silage feeding from November to April (confinement period) of Holstein and Czech Spotted cows was practised. Five milk samples were collected in a pasture period and four samples in a period of confinement. The proportion of a major cis-9, trans-11 isomer of conjugated linoleic acid (CLA) was higher whereas the proportion of myristic (14:0) and palmitic acid (16:0) was lower in a pasture period than in a confinement period (1.01; 9.56; 26.12 vs. 0.56; 11.76; 35.43%, arithmetic means, respectively; $P < 0.05$). The proportion of total unsaturated acids was higher in a pasture period than in a confinement period (36.40 vs. 28.57% on average, respectively; $P < 0.01$). Positive changes in the fatty acid profile in terms of human health were thus confirmed in milk from grazing cows.

Keywords: milk fatty acids, cattle, Holstein, Czech Spotted, pasture, CLA

Introduction

Diet has a major influence on the composition of milk fat in ruminants. The addition of forage to the feed ration, especially fresh herbage, enhances the proportion of unsaturated: saturated fatty acids in milk fat (Jensen, 2002; Dewhurst *et al*., 2006). Consumption of saturated fat (mainly 12:0, 14:0 and 16:0 fatty acids) is associated with cardiovascular disease while unsaturated acids are regarded as beneficial for human health. Special attention is paid to a major cis-9, trans-11 isomer of conjugated linoleic acid (CLA), which has been proven to be a biologically active component with anticarcinogenic and other health-beneficial effects in animal models. In the Czech Republic, seasonal pasture combined with a fresh-cut forage supplementation used to be applied on low-input mountain farms. A limited amount of pasture resowing and mineral fertilization are generally practised there. Fatty acid profiles of milk of Czech Spotted and Holstein breeds have recently been reported mainly from indoor conserved-forage feeding systems (Pešek *et al*., 2006; Janů *et al*., 2007). The aim of this study was to examine the effect of pasture on the milk fat composition on a low-input mountain farm.

Material and methods

A dairy farm at 575 m above sea level in the south of the Czech Republic was selected for the examination. A production herd consisted of fifty-five Holstein and fifty-one Czech Spotted cows. The average milk yield was 6,673 and 5,529 kg per standard lactation (Holstein and Czech Spotted, respectively) in 2007. Calving took place continuously throughout the year. A pasture sward grazed *ad libitum* and a fresh cut herbage offered during milking (approximately 20 kg fresh weight day^{-1} cow^{-1}) supplied most of the feed ration from May to October (pasture period). The cows remained at pasture all day and returned to stalls just for milking two times a day. In a confinement period (November–April), the feed ration consisted mainly of grass silage prepared from pasture vegetation cut in late May or June, which was ensiled and fed to cows later in the year at 20–25 kg fresh weight day^{-1} cow^{-1}. Grain supplements (5–8 kg day^{-1} cow^{-1}) and mineral supplements were fed to cows throughout the year.

The vegetation of the pasture corresponded to the *Lolio-Cynosuretum* association (Frelich *et al*., 2006). In 2007 the species abundance was measured in five 16-m^2 pasture stands in May, July and in September. The following six species with more than 15% cover in some of the botanical scans were identified: *Lolium perenne*, *Festuca rubra*, *Dactylis glomerata*, *Agrostis capillaris*, *Taraxacum* sect. *Ruderalia* and *Achillea millefolium*. A further 34 vascular plant species with lower coverage were recorded. Nitrogen fertilization was applied in pastures at 20 kg N ha^{-1} year^{-1}. There was no resowing of the pasture sward. Bulk milk was sampled once a month, with four samples in the confinement period (March, April, November 2007, February 2008) and five samples during a pasture period (May–September 2007). The sampling was made in the morning when the milk tanks contained fresh milk from the morning milking together with a milk from the evening milking of the preceding day. The milk was transported in a cooled state to the laboratory, frozen and analyzed later. Fat, protein, casein and lactose contents were determined spectrophotometrically using Milcoscan FT 6000 (Foss, Hillerød, Denmark). Methyl esters of fatty acids were determined by gas chromatography (GLC) using a Varian 3300 apparatus (Varian Techtron, Australia), with Omegawax 530, 30 m column. In total 64 fatty acids were identified in the samples.

Results and discussion

The following concentrations of milk components (g per 100 g dry matter) were measured in collected samples (N = 9, mean ± S.D.): fat 3.91 ± 0.22, protein 3.20 ± 0.07, casein 2.55 ± 0.06 and lactose 4.73 ± 0.11. Differences between seasons were found only for casein content, which was higher in a pasture period (P < 0.05; t-test). There were significant differences in the proportion of fatty acids between pasture and confinement periods. Mean proportions of major fatty acids (g per 100 g of total fatty acids) are given in Table 1. Pasture milk contained a higher proportion of C18 acids, mainly the stearic acid 18:0 and oleic acid cis-9 18:1, but also the desirable CLA. The proportions were 12.82, 22.42 and 1.01% in the pasture period vs. 9.16, 17.05 and 0.56% in the confinement period (stearic acid, oleic acid and CLA, respectively). The proportion of myristic 14:0 and palmitic 16:0 acids were lower in milk of pastured in comparison to confined cows (9.56 and 26.12% vs. 11.76 and 35.43%, respectively). These changes in major acids are reflected in ratio between mean proportions of total saturated/unsaturated acids: 1.75 in a pasture period vs. 2.50 in a confinement period. The results are consistent with other findings on the impact of grazing on fatty acid composition (Dewhurst *et al*., 2006; Elgersma *et al*., 2006). Intake of a fresh forage results in a higher proportion of long-chain and unsaturated acids including a CLA in milk in comparison to conserved forage or concentrates. Ruminants synthetize very little C18 acids and they must be ingested in feed if they are to be secreted in milk. Fresh forage contains a high concentration of linolenic acid 18:3 (about 50–75 g/100 g total fatty acids) which is biohydrogenated in rumen to trans-11 18:1 and 18:0 acid. These derivates are further desaturated in the mammary gland to cis-9, trans-11 CLA and to oleic acid and released in milk. The general effect of grazing on CLA concentration irrespective of botanical composition of pasture suggest a study of Leiber *et al*. (2005). CLA levels did not differ between milk produced on extensive alpine pastures and on intensively managed pasture in lowlands with poor species diversity. In comparison with other anticarcinogens in the human diet (mainly of plant origin and in trace concentrations) CLA is unique in that it is potent at low levels and it is present in foods from ruminant animals. Milk produced by grazing cows thus merits a special attention regarding its higher health-beneficial potential for consumers.

Table 1. The proportion of major fatty acids (g per 100 g total fatty acids) identified in milk in pasture period (May–October, n = 5) and in confinement period (November–April; n = 4)

Fatty acid	Pasture		Confinement		*t*-test
	mean	S.D.	mean	S.D.	
12:0	2.65	0.48	3.22	0.23	NS
14:0	9.56	1.28	11.76	0.55	G < C *
16:0	26.12	0.99	35.43	1.74	G < C ***
18:0	12.82	0.77	9.16	0.88	G > C ***
18:1c9	22.42	1.93	17.05	0.83	G > C **
18:2c9t11	1.01	0.22	0.56	0.12	G > C *
SFA	63.53	2.91	71.40	1.44	G < C **
UFA	36.40	2.90	28.57	1.39	G > C **

G – pasture period; C – confinement period; NS > 0.05; *P < 0.05; **P < 0.01; ***P < 0.001
SFA – total saturated acids; UFA – total unsaturated acids; mean – arithmetic mean; S.D. – standard deviation

Conclusions

Desirable changes in the fatty acid profile with regard to consumer health were found in milk produced on a pasture in comparison to indoor silage feeding. This mainly comprised a higher proportion of total unsaturated acids and of stearic, oleic and CLA in a pasture vs. confinement milk.

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Farming in the mountains and foothills regions with respect to grasses used for generating energy

Frydrych J. [1], Andert D.[2], Kovaříček P.[2], Juchelková D.[3] and Tippl M.[4]

[1] *OSEVA PRO Ltd., Grassland Research Station, Rožnov-Zubří, Czech Republic*
[2] *Research Institute of Agricultural Engineering, Prague, Czech Republic*
[3] *VŠB - Technical University of Ostrava, Faculty of Mechanical Engineering, Ostrava, Czech Republic*
[4]*Research Institute for Soil and Water Conservation, Prague, Czech Republic*
E-mail: frydrych@oseva.cz

Abstract

The research on the utilisation of grasses for generating energy has been focused on the determination of suitable grass species and their yield potential, and consists of two phases. On the basis of the first research phase the most suitable species of grasses for generating energy were selected (*Agrostis gigantea*, *Festuca arundinacea*, and *Arrhenatherum elatius*). In the second research phase, *Agrostis gigantea*, *Festuca arundinacea*, *Arrhenatherum elatius*, *Phalaris arundinacea*, *Bromus marginatus*, and grass and clover meadow mixtures for humid and for dry conditions were included. In the Czech Republic, the most suitable time for harvesting grasses for generating energy appears to be at the time of the harvesting of their seeds, with the utilisation of threshed-out grass straw for energy generation. On the basis of the results of the second research phase and of combustion experiments in large boilers, it is possible to recommend the burning of grass biomass (straw) in particular in cereal straw-burning boilers.

Keywords**:** soil, soil management, permanent grass vegetation, biomass

Introduction

OSEVA PRO, Ltd., Grassland Research Station Rožnov-Zubří, the Research Institute of Agricultural Engineering, Prague, and the Research Institute for Soil and Water Conservation, Prague, have been dealing with a project of the National Agency for Agricultural Research entitled *Farming in the Mountains and Foothills Regions with Respect to Grasses Used for Generating Energy*. The objective of the project is to design production farming systems in the mountains and in less favourable production areas with a focus on permanent grass vegetation. A particular alternative possibility for farming in these areas is the utilisation of grass species for generating energy. The research and utilisation of grasses for energy generation has been dealt with by OSEVA PRO Ltd., Grassland Research Station Rožnov-Zubří in co-operation with the Research Institute of Agricultural Engineering, Prague, and VŠB - Technical University of Ostrava.

Materials and methods

The research on grasses for generating energy consisted of two phases. In the first research phase, the most suitable grasses for generating energy were checked and determined from a group of selected grass species with respect to their green mass yield, dry mass and dry matter, combustion heat, and calorific value. The following grass species were selected for the first research phase – *Festuca arundinacea* Schreb., *Agrostis gigantea* Roth., *Bromopsis inermis* Leysserl, *Arrhenatherum elatius* (L.) J. Presl et C. Presl, *Phalaris arundinacea* L., *Phalaris canariensis* L., *Miscanthus sinensis* N.J. Andersson, *Panicum miliaceum* L., *Phragmites australis* (Cav.) Stued., *Molinia arundinacea* Schrank, *Calamagrostis epigeios* (L.) Roth., and *Bromus erectus* Huds. An evaluation of the so-called spontaneous fallows on previously intensively managed agricultural land was carried out. In the second research phase the yield parameters were checked (the green mass yield, dry mass yield, dry matter yield, and content) for selected grass species and grass and clover meadow mixtures included into the research one or two months prior to the seed harvesting maturity of the grasses and up to two months after their seed harvesting maturity. For the second research phase *Agrostis gigantea* Roth. Rožnovský, *Festuca arundinacea* Schreb. Kora, *Arrhenatherum elatius* (L.) J. Presl et C. Presl Rožnovský, *Phalaris arundinacea* L., Palaton, Chrifton, and Chrastava (a variety of OSEVA PRO Ltd. Grassland Research Station Rožnov-Zubří), *Bromus marginatus* Nees ex Steud. Tacit grass, and clover meadow mixtures for humid and for dry conditions were selected. For the yield objectives, field experiments were established in both research phases for each grass species on plots of 10 m^2 with N support without fertilisation, and with a minimum dose of 50 kg N ha^{-1}. At the same time the burning of grass biomass in technical appliances was investigated in the second research phase. This part of the research was focussed on the selection of the most suitable energy appliance (boiler) for the burning of grass biomass.

Results and discussion

Results of the first research phase – the selected grass species were examined for their green mass yield, dry mass yield, and dry matter yield. They were analysed for their combustion heat and calorific value. At the same time the so-called spontaneous fallows were also assessed. For this land, a botanical evaluation was carried out. The dry matter yield of these spontaneous fallows was determined. On the basis of the results, three grass species were selected as most suitable for energy generation (*Agrostis gigantea* Rožnovský, *Festuca arundinacea* Kora, and *Arrhenatherum elatius* Rožnovský. The yield for these three grass species was on average 8 to 10 Mg of dry matter per ha for the Zubří area in the fertilised variant. The dry matter yield for spontaneous fallows was very low (up to 2 Mg ha^{-1}). The project ran from 1997 to 2000.

Results of the second research phase – results of the field experiments – the grasses and grass and clover meadow mixtures included in the second research phase were harvested in the form of whole plants at monthly intervals between May and September from 2005 to 2007. For the particular grass and clover meadow mixtures and grass species selected for the research, different dry matter contents in the green mass were established, which increased in particular as a result of the aging of the vegetation and the postponement of the first harvesting. The dry matter content in the green mass was the highest for vegetation harvested in September. The highest dry matter yields in all three crop years were reached for *Phalaris arundinacea* Palaton – 11.89 Mg ha^{-1}, *Phalaris arundinacea* Chrastava – also 11.76 Mg ha^{-1}, *Phalaris arundinacea* Chrifton – 11.20 Mg ha^{-1}, *Agrostis gigantea* Rožnovský – 11.12 Mg ha^{-1}, and *Festuca arundinacea* Kora – 10.69 Mg ha^{-1} out of all the grass species researched (values in brackets for the third crop year). All these yields were achieved for the fertilised variant of 50 kg N ha^{-1} in

Table 1. Results for the combustion heat and the calorific value in 100% dry matter (average for 3 crop years) for grasses selected for the first research phase

Grass species	Combustion heat ($kJ\ kg^{-1}$)	Calorific Value ($kJ\ kg^{-1}$)		
		average	maximum	minimum
Festuca arundinacea	18,849	18,245	18,554	17,984
Agrostis gigantea	19,270	18,661	18,825	18,432
Bromopsis inermis	18,577	17,968	18,205	17,654
Arrhenatherum elatius	17,596	16,987	17,356	16,354
Phalaris arundinacea	18,120	17,504	17,905	17,085
Phalaris canariensis	17,979	17,361	18,005	17,065
Miscanthus sinensis	19,669	19,066	19,186	18,830
Panicum miliaceum	19,321	18,716	19,078	18,510
Phragmites australis	18,469	17,852	18,154	17,542
Molinia arundinacea	18,233	17,625	17,890	17,357
Calamagrostis epigeios	18,895	18,281	18,745	17,958
Bromus erectus	18,516	17,890	18,056	17,468

September 2007. The grasses achieved the highest dry matter yield when harvested in the form of whole plants in the period from July to August, i.e., in the period of the harvest for seed maturity and a month after the harvest for seed maturity. On the basis of these results, harvesting grasses for generating energy during the period of their harvest for seed for all the species selected for the second research phase can be recommended. Later harvesting can be recommended solely for *Phalaris arundinacea* Palaton, Chrifton, Chrastava, for which the losses of dry matter were not significant even two months after the period of harvesting for seed (in September).

Burning of grasses – during the second research phase tests were carried out for the burning of grass biomass in both small and large boilers. For tests in small boilers, the biomass was transformed into pellets. On the basis of the burning tests in large boilers, it is possible to recommend the burning of grass straw, in particular in boilers for straw burning. These are large Verner Golem boilers with a rated output of over 900 kW. Further, the LIN-KA boiler from the Danish producer Danstoker, with a rated output of over 190 kW, was successfully tested in 2007.

Conclusions

An alternative for soil management in the mountains and foothill areas is the targeted growing and utilisation of grasses for generating energy. On the basis of the yield results of the harvest in particular for the majority of grass species suitable for energy generation in the Czech Republic, it is possible to recommend the harvesting of grasses for generating energy (in particular for grass matter used for burning) during the period of the grass harvesting for seed and up to a maximum of a month after this harvesting maturity. On the basis of the results of the burning tests in large boilers it is possible to recommend the burning of grass straw, in particular in boilers used for cereal straw burning.

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Will maize become an important crop for biogas production in Latvia?

Gaile Z. and Bartuševics J.

Latvia University of Agriculture, Jelgava, Latvia
E-mail: zinta.gaile@llu.lv

Abstract

At present maize (*Zea mays* L.) has become important as a biomass crop for biogas production. The greatest potential for biogas production in the future in Latvia is related to the agricultural sector. The first biogas production project in agriculture was realised on the research farm of the Latvia University of Agriculture in 2008, using also maize as a substrate. The aim of this paper is to describe the potential of the maize yield for biomass production, depending on the hybrid used and the time of harvesting on the "Vecauce" research farm, where several field trials were arranged during 2005–2008. The results showed that the variety used had a significant impact on the yield and its dry matter content in the specific year, but in the whole trial period, the meteorological conditions of the year ($P < 0.05$) had a greater impact on the parameters mentioned above than the hybrid used. Our results, similarly to results in other European countries, showed a strong effect of the time of harvesting ($P < 0.05$) on the maize yield.

Keywords: biogas substrate, maize, hybrid, time of harvesting, yield

Introduction

Biogas production from biomass produced in agriculture has an increasing importance as it offers considerable environmental benefits and is a source of extra income for farmers (Amon *et al.*, 2007). In addition, the political demand of the EU to produce energy crops is promoted by extra subsidies in several EU countries in order to enhance energy supply from crops, especially via biogas production. Maize is the dominant crop for biogas production in Central and Western Europe as a result of its high yield potential (Amon *et al.*, 2007; Schittenhelm, 2008).
The proportion of renewable energy resources in the total energy balance must reach 20% of the total energy used in Latvia by 2020. Today only 1% of the electricity produced from renewable energy resources is produced using biogas. In accordance with the programme for biogas production and utilisation in the period 2007–2011 developed by the Ministry of the Environment of Latvia, the greatest potential for biogas production is related to the agricultural sector: of the 13 mill. m^3 of biogas produced in 2011, approximately 64% should be produced using substrates from agriculture. Now five biogas plants are in operation in Latvia, but only in 2008 was the first biogas production project in agriculture realised on the "Vecauce" research farm of the Latvia University of Agriculture, and dairy cattle manure, together with plant biomass (mainly maize), is used as the substrate. No other field crop is being investigated specifically for biogas production in Latvian conditions. The country is located between the latitudes 55° and 58° North and because of this marginal location for maize cultivation every step of the growing process is of high importance. Researchers (Amon *et al.*, 2007; Schittenhelm, 2008) in countries with stronger maize-growing traditions also emphasise the impor-

tance of the maize hybrid used and of the time of harvesting for maximum yield and biogas outcomes. During recent years (2005–2008), the performance of maize hybrids and the best sowing and harvesting times were investigated on the "Vecauce" research farm. As biogas production has already become a reality, the results from this research can be used as indicators for growing maize biomass.

The aim of this paper is to describe the maize yield potential and some quality parameters for biomass production depending on the variety used and the time of harvesting in Latvia.

Materials and methods

A three-factor field trial was carried out during 2005–2008 (1st trial) and a two-factor trial, evaluating especially maize for biogas, was started in 2008 (2nd trial) at the "Vecauce" research farm (latitude: 56°28'N, longitude: 22°53'E) of the Latvia University of Agriculture. Both trials were arranged in a randomised complete block design with an individual plot size of 16.8 m^2. The planted population density was 82,000 plants ha^{-1}. The soil at the site was sod podzolic sand loam (1st trial) and strongly altered by cultivation sand loam (2nd trial). For the 1st trial four maize hybrids (Factor A) with different maturity ratings defined by the FAO number were used (Table 1), but for the 2nd trial 10 hybrids (FAO 180–270) were used. The maize was sown on four dates (1st trial, factor B), starting on April 25 at ten-day intervals until May 25 in each year (data not presented in the current article); the 2nd trial was sown on May 6. Traditional soil tillage was used, which included mould-board ploughing the previous autumn along with cultivation and rototilling before sowing in spring. The fertilisers applied were 34 kg ha^{-1} P, 75 kg ha^{-1} K, and 148 kg ha^{-1} N (18 + 70 + 60). Harvesting took place on four dates for the 1st trial (factor C), beginning with September 1 and continuing at ten-day intervals and on three dates for the 2nd trial (September 5, September 19, and October 3). Only the data on dry matter (DM) and organic dry matter (ODM – calculated after an ashing sample at 550°C) yield and DM concentration in the whole plant yield are analysed in detail in this paper. The average day and night temperature from 25 April to 30 September was 14.4°C in 2005, 15.7°C in 2006, 14.8°C in 2007, and 13.9°C in 2008. The sum of the precipitation during the same years and the same period was 298, 267, 339, and 230 mm, respectively. A spring frost after the emergence of the maize occurred on 1 June 2006. Heavy autumn frosts occurred only on 17 and 18 September 2005, when the maize was severely damaged. The results were analysed statistically using standard analysis of variance.

Results and discussion

The average maize DM yield per four years, hybrids, sowing, and harvesting dates (1st trial) was 13.63 Mg ha^{-1}, which corresponds to a medium yield according to Amon *et al.* (2007). A high DM yield is essential for high methane production per ha (Amon *et al.*, 2007; Schittenhelm, 2008). The dependency of the total DM yield on the hybrid used was not unambiguous when it is considered that different sowing and harvesting dates were used, and the trials performed during four different years. On average the per-four-years hybrid influence was insignificant ($P > 0.05$). The 2nd trial also showed insignificant hybrid influence on average DM yield per three harvesting dates. A strong effect of the time of harvesting on the DM yield was noted ($P < 0.05$) in both trials (1st trial by 39%, 2nd trial by 33%). Most important is an increase in the ODM yield; on the same harvesting date it is heavily dependent on the hybrid (Figure 1). Researchers

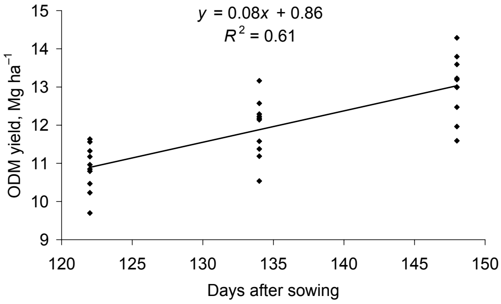

Figure 1. ODM yield depending on time of harvesting after sowing (10 hybrids), $P < 0.05$

(Amon *et al.*, 2007; Schittenhelm, 2008) have noted that the highest yield was obtained at the maize wax ripeness when the DM concentration is 350 g kg^{-1} or more. It is not possible for us to evaluate maize strictly according to ripeness stages, because even the earliest hybrids cannot reach such a high DM content every year in Latvia. The DM content of the whole plant yield is significantly ($P < 0.05$) affected by the hybrid (16%), harvesting date (51%) (Table 1), sowing date (8%), and meteorological conditions in the trial year (14%). Amon *et al.* (2007) recommend using locally adapted maize hybrids, but Degenhardt (2005, cited by Schittenhelm, 2008) recommends using hybrids that mature slightly later (max 50 FAO units later). Our results in 2008 showed that locally suited hybrids (FAO 180-220) reached a DM content above 250 g kg^{-1} on September 19 (134 days after sowing), but hybrids maturing later (FAO 235–270) on average reached a DM concentration of only 247.8 g kg^{-1} even on October 3 (148 days after sowing).

Table 1. Dry matter content (g kg^{-1}) of whole maize plant as affected by hybrid and harvesting date in Latvia, average from 2005–2008

Harvesting dates	Hybrid				Averaged for harvesting dates, $LSD_{0.05} = 6.3$, $P < 0.05$
	Earlystar FAO–160	RM-20 FAO–180	Tango FAO–210	Cefran FAO–340	
September 1	228	219	223	196	216
September 10	255	249	252	216	243
September 20	284	277	282	236	270
October 1	331	308	323	260	305
On average for hybrid, $LSD_{0.05} = 6.3$, $P < 0.05$	275	263	270	227	X

Hybrid × harvesting date: $LSD_{0.05} = 12.6$, $P < 0.05$

Other quality parameters such as crude ash, protein and fibre, cellulose, hemi-cellulose, lignin, NDF and ADF decrease with a later harvesting date, but crude fat increases. The importance of these indicators for the methane yield according to other researchers is conflicting (Amon *et al.*, 2007; Schittenhelm, 2008), but in Latvian conditions their investigation has only started.

Conclusions

A medium-high average DM yield could be obtained from maize in Latvian conditions. The maize yield depended heavily on the conditions of the harvest year and harvesting date, but its quality on all the factors investigated: the hybrid used, the sowing and harvesting dates, and the conditions of the trial year. The evaluation of the parameters which could influence methane outcomes from maize and methane production from maize in laboratory reactors has only started and will be continued; no results are available yet. We can now draw only the preliminary conclusions that locally suited hybrids (up to FAO 220) could be used for biogas production with more persistent success, and that their harvesting should take place as late as possible in any specific year (late September or early October).

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Effect of different fertilization and cutting regimes on the quality of sheep fescue landscape lawns

Golińska B. and Goliński P.

Poznan University of Life Sciences, Department of Grassland Sciences, Poland
E-mail: bgolinsk@up.poznan.pl

Abstract

The aim of this work was to evaluate the effect of different fertilization levels and cutting regimes on the quality of selected sheep fescue cultivars in extensive lawn utilization, which can play an important role in the creation of landscape lawns. An experiment was carried out in the years of 2004–2007 to study the effect of different fertilization levels (without, $N_{30}P_{10}K_{20}$, $N_{60}P_{20}K_{40}$ kg ha^{-1}) and cutting regimes (1, 2, 3, 4 times per year) on the quality of the selected sheep fescue cultivars. In a random block design experiment in three replications on 1 m^2 plots established in 1998, the following 4 Polish cultivars of *Festuca ovina* L. *sensu lato* were analyzed: Sima, Mimi, Noni and Witra. The following parameters were determined: the content of chlorophyll dyes in leaf blades, the yearly weight of the sward and its height in the spring regrowth, and the sward compactness as well as the root weight in the sod layer determined before the end of the vegetation period. Irrespective of cultivars, plant vitality, yearly sward yield and roots weight in the sward layer of sheep fescue, were modified by fertilization levels and cutting regimes.

Keywords: *Festuca ovina*, sheep fescue, landscape lawn, fertilization, cutting regime

Introduction

Sheep fescue is a widespread grass on extensively managed grasslands. This grass is also distinguished for its ability to form sod on difficult sites (Dernoeden *et al.*, 1994). Sheep fescue is a persistent bunch grass that mixes well with wildflowers, without dominating them. For this reason sheep fescue can play an important role in the creation of landscape lawns. In the adaptation of this grass to extremely difficult sites, specific biological features of this grass are very important, especially water efficiency, drought tolerance, and low fertilizer requirements (Aronson *et al.*, 1987; Brar and Palazzo, 1995). The purpose of this work was to evaluate the effect of different fertilization levels and cutting regime on the quality of selected sheep fescue cultivars in extensive lawn utilization.

Methods and materials

A study was carried out during 2004–2007, at the Brody Experimental Station (52º26'N, 16º18'E) of the Poznan University of Life Sciences, to determine the usefulness of selected cultivars of *Festuca ovina* for landscape lawn utilization. The effect of different fertilization levels (factor I: F0-without, F1-$N_{30}P_{10}K_{20}$ kg ha^{-1}, F2-$N_{60}P_{20}K_{40}$ kg ha^{-1}) and cutting regimes (factor II: C1-one, C2-two, C3-three, C4-four times per year) on lawn quality of four Polish cultivars of *Festuca ovina* L. *sensu lato* (factor III: Sima, Mimi, Noni and Witra) were analyzed. The field experiment was established in 1998 in a random block design in three replications on 1 m^2 plots which were situated on sandy soil

(pH_{KCl} – 5.4, N_t – 0.62%, P – 37.6 mg kg^{-1}, K – 93.0 mg kg^{-1}, Mg – 30.0 mg kg^{-1}). The annual mean temperature and amount of precipitation in the investigation period ranged from 8.9 to 9.6°C and from 549.4 to 664.0 mm, respectively. In the vegetation season, short-term drought periods were noticed. Fertilizers were applied each year in spring at the beginning of vegetation period. In the treatment of C4, the sward was cut in the middle of May, end of June, end of August and in the middle of October, while in C1 – only on the last date of cutting, in C2 – in the middle of May and October and in C3 – in the middle of May, end of June and in the middle of October. The quality of sheep fescue lawn was evaluated in spring on the basis of the content of chlorophyll dyes in leaf blades (Smith and Benitez, 1955), the yearly weight of the sward (DM per 1 m^2), sward height (herbometer) in the spring regrowth, the sward compactness (Weber frame) after last cutting as well as the root weight in the sod layer (DM per 1 m^2) on the basis of cylinder samples (8 cm depth, 6 cm diameter) after washing and drying (in 106°C) determined before the end of the vegetation period. The results were given as mean values from the entire from investigation period. Tests of the main effects were performed by *F*-tests. Means were separated by the LSD and were declared different at $P < 0.05$.

Results and discussion

The level of fertilization increased significantly the content of chlorophyll *a +b* in leaf blades of sheep fescue (Table 1). Two-three cutting regimes influenced positively the vitality of plants, while four-cutting utilization decreased slightly the chlorophyll content. Noni cv. showed the highest chlorophyll content in the leaf blades in comparison with other cultivars.

The examined sheep fescue cultivars failed to affect significantly their yearly sward yields, whereas both the applied fertilization levels and cutting regimes influenced them significantly. In comparison with F0 (135 g m^{-2} DM), the F1 and F2 fertilization treatments increased annual sward yields by 21.6% and 71.5%, respectively. The differences between mean values of sheep fescue yields for C1 (145 g m^{-2} DM) and C4 (195 g m^{-2} DM) reached the level of 34.5%.

In the spring regrowth, sheep fescue developed generative shoots, which considerably increased the mean height of sward measured by the herbometer. The F2 fertilization level had a positive effect on the sward height in the spring regrowth (by 22.5%) in comparison with F0 and F1 treatments. The effect of applied cutting regimes on this trait was not significant. Mimi was distinguished as the highest among the analyzed cultivars.

Sheep fescue cultivars were characterized by very good sodding. Sward compactness ranged from 94.3% (Sima) to 97.1% (Mimi). A good sodding potential of sheep fescue on difficult soil reclamation sites was also reported by Patrzałek (2000). It turned out that neither the fertilization level nor the cutting regime had a significant effect on sward compactness of sheep fescue.

Brar and Palazzo (1995) suggest that root attributes strongly correlated with shoot attributes and can be considered in breeding programs of sheep fescue promoting drought tolerance. In the performed study, the root weight in the turf layer was found to be affected by the applied fertilization levels, cutting regimes and cultivars. In comparison with F0 (353 g m^{-2} DM), the F1 and F2 fertilization treatments increased the roots weight by 33.7% and 45.0%, respectively. In the case of cutting regimes, the best roots development (468 g m^{-2} DM) was determined in the two-cut utilization. From among the analyzed sheep fescue cultivars, Mimi showed the highest roots weight in the turf layer and Sima the lowest.

Table 1. Effect of fertilization levels and cutting regime on the selected morphological and biological features of sheep fescue in the extensive lawn utilization (means 2004–2007)

Cultivar	F0				F1				F2				Mean
	C1	C2	C3	C4	C1	C2	C3	C4	C1	C2	C3	C4	
Content of chlorophyll *a* + *b* in leaf blades (mg g^{-1} DM)													
Mimi	3.14	3.21	3.45	3.26	3.78	3.87	3.99	3.95	3.98	4.27	4.55	4.34	3.82
Noni	4.54	4.62	4.36	4.67	5.23	5.34	5.52	5.38	5.64	5.85	5.76	5.82	5.23
Sima	3.32	3.45	3.29	3.26	3.95	4.02	3.89	3.94	4.16	4.47	4.36	4.12	3.85
Witra	3.39	3.56	3.54	3.49	3.78	3.94	3.89	3.74	4.53	4.56	4.35	4.32	3.92
$LSD_{0.05}$ for F = 0.21; for C = 0.32; F × cv. = 0.67; for other interactions = ns													0.38
Yearly sward weight (g m^{-2} DM)													
Mimi	143	130	156	123	157	130	185	206	154	240	223	331	181.5
Noni	118	146	134	130	118	131	220	180	166	248	242	249	173.5
Sima	135	154	115	135	115	150	186	174	198	254	224	287	177.2
Witra	116	159	138	126	189	116	199	169	130	292	232	232	174.7
$LSD_{0.05}$ for F = 20.91; for C = 36.42; for all interactions = ns													ns
Sward height in the spring regrowth (cm)													
Mimi	20.0	20.3	15.1	16.1	15.0	17.5	19.5	18.5	20.8	24.0	25.3	19.6	19.3
Noni	18.1	15.9	12.4	13.7	17.5	15.3	15.9	15.6	20.4	19.1	15.8	16.3	16.3
Sima	18.5	20.2	15.1	17.7	12.5	18.4	16.5	17.5	20.5	23.9	20.2	21.3	18.5
Witra	19.7	16.9	13.4	12.6	17.8	14.4	16.5	17.1	20.5	22.8	16.4	18.5	17.2
$LSD_{0.05}$ for F = 1.65; for C = ns; for all interactions = ns													1.67
Sward compactness (%)													
Mimi	94	95	97	97	97	99	100	98	94	97	99	98	97.1
Noni	93	95	96	97	95	96	95	96	95	96	97	97	95.7
Sima	92	94	95	93	94	95	96	95	93	95	95	94	94.3
Witra	94	95	96	96	96	96	97	98	95	96	97	96	96.0
$LSD_{0.05}$ for F = ns; for C = ns; for all interactions = ns													1.23
Roots weight in turf layer (g m^{-2} DM)													
Mimi	453	470	389	443	580	674	670	680	775	760	710	725	610.8
Noni	360	420	403	426	420	456	476	430	478	530	490	520	450.8
Sima	220	270	250	230	320	435	350	380	380	410	430	425	341.7
Witra	320	310	335	345	350	435	460	430	450	440	432	234	378.4
$LSD_{0.05}$ for F = 13.93; for C = 16.10; F × C = 27.9; F × cv. = 30.0; for other interactions = ns													16.33

Conclusions

Irrespective of cultivars, the morphological and biological features of sheep fescue, particularly the plant vitality, yearly sward yield and roots weight in the sward layer, were modified by fertilization levels and cutting regimes. In the extensive lawn utilization, *Festuca ovina* cultivars showed considerable differentiation of growth and development. Mimi proved the best one from the point of view of its sodding traits and roots weight, although it developed higher sward in the first regrowth. Noni also turned out to be a very interesting breeding creation characterized by a very good sodding and slow regrowth. This cultivar also was characterized by the highest concentration of chlorophyll dyes in leaf blades. The analyzed cultivars of *Festuca ovina* are interesting components in mixtures for establishing landscape lawns, performing especially well in infrequently- or un-mowed, naturalized lawn areas.

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Biogasification of plant and animal biomass substrate

Gonda Ľ.

Slovak Agricultural Research Centre, Grassland and Mountain Agriculture Research Institute, Banská Bystrica, Slovakia
E.mail: gonda@vutphp.sk

Abstract

The insufficient management and utilisation of permanent grassland (PG) can result in a range of negative phenomena in vegetation and landscape development. The production of energy from biomass is a progressive way in which non-utilised agricultural land can be used. The paper presents results recorded during the co-fermentation of cattle slurry with ensiled grass or a grass/clover mixture or lucerne silage. During the experimental measurements, the input substrate composition, the quantity and composition of the produced biogas, and the conditions of anaerobic digestion in the fermentor were monitored. The results were compared with those of pure cattle slurry fermentation as a reference sample. It was found that grass or grass/legume silage were very suitable co-fermentation components for biogas production. The co-fermentation of cattle slurry mixed with 20% grass or mixed grass/clover silage or 40% lucerne silage resulted in a 10.8% increase in methane production, while the production of biogas was higher by 273%.

Keywords: biogas, biogas plant, grassland, energy production, substrate analysis, co-fermentation

Introduction

Since 1990, livestock populations have decreased markedly, e.g. by 65% (–1,023,000 head) in the case of cattle and by 46% (–279,000 head) in that of sheep. According to the data of the 'Slovak Land Fund', grassland currently covers 300,000 ha of non-productive land. A progressive way in which non-utilised agricultural land can be used is to process the grassland biomass for energy production. The paper presents experimental results recorded during the co-fermentation of cattle slurry mixed with ensiled grass or a grass/clover mixture or with lucerne silage using the wet continual fermentation process.

Materials and methods

The experiment was carried out at the Kolíňany biogas plant – a part of the Demonstration Farm of the Slovak University of Agriculture in Nitra. The following substrates were processed in the fermentor: (*i*) cattle slurry (100%) – control treatment; (*ii*) cattle slurry (80%) with lucerne silage (20%); (*iii*) cattle slurry (80%) with mixed grass/clover silage (20%); (*iv*) cattle slurry (80%) with grass silage, i.e. ensiled herbage from permanent grassland (20%), and (*v*) cattle slurry (60%) with lucerne (*Medicago sativa* L.) silage (40%). These parameters were measured in the input substrates: chemical oxygen demand (COD, g l^{-1}), photometrically; total nitrogen content (N_{tot}, mg l^{-1}), photometrically; dry matter content (DM, %), by weighing scales, and the organic load rate of the fermentor (OLR) as kg COD m^3 day^{-1} by calculation. The parameters measured in the output substrates were: substrate temperature (°C) by a digital thermometer; pH with a pH-meter; CH_3COOH (acetic acid, mg l^{-1}) by calculation. The biogas composition was analysed (Schmack SSM 60000) and these four main compounds were measured: CH_4 (methane, % vol.) by means of an infrared two-ray sensor; CO_2 (carbon dioxide, % vol.); O_2 (oxygen, % vol.), and H_2S (hydrogen sulphide, ppm vol.) electrochemically Figure 1).

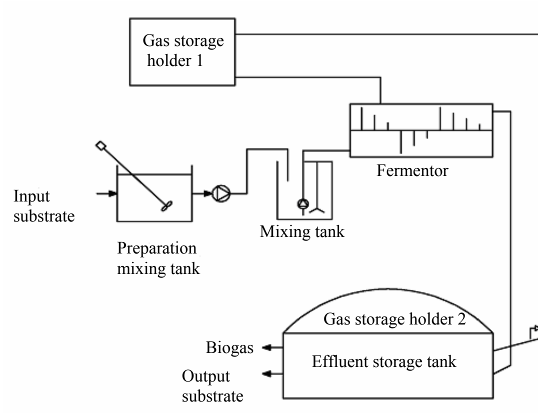

Figure 1. The experimental facility used for biogas production

Results and discussion

The statistically-processed experimental data are given in Tables 1 and 2. A comparison of the COD in the input substrates showed that the substrates mixed with silage con-

Table 1. Analyses of input and output substrates

Substrates	Parameters – Input		Parameters – Output	
i	COD (g l^{-1})	45.5	Temperature (°C)	37.5
ii		88.0		37.9
iii		56.6		37.3
iv		95.3		39.5
v		114.3		40.4
i	N_{tot} (mg l^{-1})	93.0	pH	7.10
ii		117.3		7.63
iii		85.1		7.17
iv		173.0		7.89
v		130.0		7.67
i	DM (%)	4.80		
ii		6.52		
iii		4.35		
iv		4.67		
v		4.04		
i	OLR as kg COD (m^3 day^{-1})	3.2		
ii		3.8		
iii		4.0		
iv		1.9		
v		5.5		

Table 2. Biogas analysis

Parameters	Substrates		Parameters	Substrates	
CH_4 (% vol.)	*i*	58.1	H_2S (ppm vol.)	*i*	253.0
	ii	60.7		*ii*	771.0
	iii	58.0		*iii*	360.0
	iv	60.0		*iv*	2170.0
	v	62.8		*v*	1772.0
CO_2 (% vol.)	*i*	41.4	Biogas production (m_N^3 day^{-1})	*i*	2.42
	ii	34.9		*ii*	4.63
	iii	39.9		*iii*	2.29
	iv	36.4		*iv*	7.82
	v	36.1		*v*	6.60

tained more organic substances than the control. However, the anaerobic decomposition was less efficient in the mixed substrates than in the control. The mean N_{tot} content was also higher in the substrates mixed with silage than in the slurry-only control treatment. The middle pH value increased slightly with the respective addition of 20% of ensiled grass or a grass/clover mixture or 40% of lucerne silage, but was not higher than the optimum pH values of 8–8.5 reported by Braun (2002). Slurry has a high buffering capacity, and high substrate acidity need not change the pH. Consequently, the acetic acid content is a better indicator than the pH for supervising the process (Table 2). The methane content in the biogas was higher when the substrates mixed with the silages were processed than when only the slurry was used. The H_2S content rose with the addition of silage co-ferments. The biogas can be directly burned if the H_2S content is reduced to below 1,000 ppm (Sargova, 2005). The highest H_2S content, as well as the highest production of biogas, was recorded with substrates *iv)* and *v)*, respectively. The substrate *iii)* treatment was an anomaly in the experiment, probably as a result of insufficient mechanical processing of the co-substrate.

Conclusions

The research experiment showed that biomass from non-utilised grassland areas could be processed to produce biogas. The mixtures of cattle slurry with silages from grass (i.e. permanent grassland herbage) or a grass/clover mixture or *Medicago sativa* L. were the most efficient input substrates.

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The root morphology of alfalfa in relation to the position of the roots in soil

Hakl J., Krajíc L, Fuksa P. and Šantrůček J.

Czech University of Life Science Prague, Department of Forage Crops and Grassland Management, Prague, Czech Republic
E-mail: hakl@af.czu.cz

Abstract

The goal of this study was to screen the effect of depth in the arable layer on the root morphology of alfalfa. In 2007, the measurement and sampling were realised in the autumn period in an area 330 × 330 mm^2 with two replicates. The alfalfa roots were separated into the following depths: 0–100 mm, 100–200 mm, and 200–300 mm below the root crown. The following parameters were measured for each individual plant and different layer: lateral root number (LRN), taproot diameter (TD), lateral root diameter (LRD), and root weight (W). The results indicated that TD, LRN, and W decreased significantly with an increase in the depth in the soil but no relationship was detected between depth and LRD. Over 50% of the alfalfa root biomass in the arable layer was situated in the top layer 150 mm under the soil surface. These results are preliminary and the research will be continued.

Keywords: forage, lucerne, arable layer

Introduction

Generally, the morphology of alfalfa strongly influences its characteristics. Katić *et al.* (2003) reported that the morphological characteristics of alfalfa are significantly correlated with yield and dry matter quality. Lamb *et al.* (2000) showed that the productivity of alfalfa was influenced by root morphology, which is in accordance with Hakl *et al.* (2008), who described the significant effect of alfalfa root distribution on forage yield in the spring regrowth period. The distribution of root biomass and soil condition had a significant influence on the nitrogen content in the root (Hakl *et al*., 2006).
According to Klesnil *et al.* (1965), the largest portion of alfalfa root biomass is situated in the layer from 0–500 mm. Approximately 30–50% of the root biomass is in the arable layer. The alfalfa taproot can form lateral roots (Dančík, 1976) which can reach 600–800 mm from the taproot (Klesnil *et al.*, 1965). The weight of alfalfa roots per area unit is strongly influenced by the stand density (Hakl *et al*., 2008). The effect of stand density on alfalfa root morphology was confirmed by Hakl *et al*. (2007). In this experiment, it was shown that the taproot diameter was positively correlated with the number of lateral roots and their diameter and all of these variables were negatively correlated with the stand density. It is possible to conclude that the stratification of alfalfa root biomass in the arable layer influenced its morphology and is connected with stand density. We now report the results of an experiment at the Department of Forage Crops and Grassland Management which investigated the effect of depth in the arable layer on the root morphology of alfalfa.

Materials and methods

In 2004, an experiment with 7 alfalfa entries grown under a four-cut schedule was established at the Czech University of Life Sciences in Prague (50°08'N, 14°24'E), 286 m above sea level. The soil in the experimental area was a deep loamy degraded chernozem with a permeable underlayer. The area is classified as having a moderate-to-warm and mostly dry climate. The average growing period is 172 days, with a mean annual temperature of 7.9°C (30-year mean) and long-term annual average precipitation of 526 mm. The individual plot size was 2 × 1.7 m and the experimental entries were established in a randomised block design with four replicates.

In 2007, the measurement and sampling were realised for the selected variety Jarka in the autumn period in an area 330 × 330 mm square with two replicates. The alfalfa roots of each plant were separated into the following layers: 0–100 mm, 100–200 mm, and 200–300 mm below the crown. The following parameters were measured for each individual plant and layer: lateral root number (LRN), taproot (TD) and lateral root diameter (LRD), and root weight (W) in dry matter (dried in 60ºC). The differences among the evaluated layers in the measured parameters were statistically evaluated by the analysis of variance. All the statistical analyses were performed using Statistica 8.0 (StatSoft, Tulsa, OK, USA).

Results and discussion

The recorded stand density in the two replicates was 160 and 180 plants m^{-2}. The number of plants evaluated was 41 and their root crowns reached a depth approximately 50 mm below the soil surface, so that the layers below the root crown represent a layer 50 mm deeper with regard to the soil surface (see Table 3). The statistic characteristics of the measured morphological parameters in plants with a branching taproot and without a branching taproot are presented in Table 1 and Table 2, respectively. The results show that taproot diameter, lateral root number, and root weight were significantly reduced in the layer deeper than 100 mm in comparison with the layer 0–100 mm below the root crown. The reduction of these parameters in the 200–300-mm layer in comparison with the 100–200-mm layer was observed but not significant. The lateral root diameter was not influenced by stratification in the arable layer. No statistical comparison between plants with branching and non-branching taproots was provided because of the low number of plants with a non-branching taproot. Nevertheless, plants with branching taproots provided a clearly higher TD, which corresponds to the results published by Hakl (2006).

Table 1. Mean values and standard error (SE) of measured parameters in plants with a branching taproot

Layers below crown (mm)	TD (mm)		LRN (pcs)		LRD (mm)		Weight (g plant^{-1})	
	mean	SE	mean	SE	mean	SE	mean	SE
0–100	9.78^{A}	0.63	3.68^{A}	0.34	1.84^{A}	0.18	6.24^{A}	0.82
100–200	5.28^{B}	0.63	2.05^{B}	0.37	1.91^{A}	0.19	2.88^{B}	0.82
200–300	4.47^{B}	0.82	1.00^{B}	0.77	1.80^{A}	0.40	2.61^{B}	1.07
P value	0.0000		0.0009		0.9455		0.0059	

Letters document statistical differences for Tukey HSD, $\alpha = 0.05$

TD = taproot diameter, LRN = lateral root number, LRD = lateral root diameter, weight = g of dry matter, $N = 32$

Table 2. Mean values and standard error (SE) of measured parameters in plants without a branching taproot

Layers below crown (mm)	TD (mm)		Weight (g plant^{-1})	
	mean	SE	mean	SE
0–100	5.89^{A}	0.47	1.85^{A}	0.25
100–200	2.98^{B}	0.52	0.80^{B}	0.26
200–300	2.80^{B}	0.65	0.64^{B}	0.33
P value	0.0006		0.0101	

Letters document statistical differences for Tukey HSD, $\alpha = 0.05$
TD = taproot diameter, weight = g of dry matter, $N = 9$

Table 3 shows the stratification of alfalfa root biomass per area unit in the arable layer in relation to the depth in the soil. This table represents only two replicates in one site but it seems that over 50% of the alfalfa root biomass in the arable layer is situated in the top layer 150 mm below the soil surface. The root biomass decreased quickly in subsequent layers and the layer 250–350 mm below the soil surface represents only 10–20% of the root biomass in the arable layer. The amount of root biomass in the arable layer represents approximately 6 t DM ha^{-1}, which is in accordance with Klesnil *et al.* (1965), who state that approximately 30–50% of the root biomass is in the arable layer.

Table 3. Stratification of alfalfa root biomass in the arable layer in the 5th year of vegetation (root weight = g DM m^{-2})

Layers below soil surface (mm)	Layers below crown (mm)	Replicate 1, 160 (plants m^{-2})		Replicate 2, 180 (plants m^{-2})	
		root weight (g m^{-2})	(%)	root weight (g m^{-2})	(%)
50–150	0–100	350	55	403	66
150–250	100–200	190	30	145	24
250–350	200–300	95	15	60	10
Sum		635	100	608	100

Conclusions

With limited data from one year, it seems that the stratification of alfalfa roots in the arable layer significantly influenced the taproot diameter, number of lateral roots, and root weight. These values decreased with an increase in the depth in the soil, whilst the number of lateral roots and their diameter was not influenced by stratification in the arable layer. Over 50% of the alfalfa root biomass in the arable layer was situated in the top layer 150 mm below the soil surface. These results are preliminary and the research will be continued.

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Multi-component grass/clover mixtures in a mountain area of Slovakia

Ilavská I., Britaňák N. and Hanzes Ľ.

Slovak Agricultural Research Centre, Grassland and Mountain Agriculture Research Institute, Research Station, Poprad, Slovakia
E-mail: ilavskai@isternet.sk

Abstract

A research was conducted to study six complex grass/clover mixtures designed for a temporary grassland system. A five-year period of growing the mixtures showed that fast-growing species (*Trifolium pratense* L., *Lolium perenne* L.) combined with slow-growing ones (*Poa pratensis* L., *Festuca arundinacea* SCHREB.) guaranteed yield during a longer period of time. Dry matter (DM) was mostly produced by *Trifolium pratense* in the first two harvest years, *festucoid* inter-generic hybrids (IGH) and *Trifolium repens* L. were more productive in the following years. The mixtures were not only productive, but indicated the option of growing them on set-aside arable land. They are advantageous also from the economic and ecological points of view, as clovers bind atmospheric nitrogen and, consequently, diminish the cost of fertiliser N and its application. Moreover, the erosion risk is reduced 25- to 100-fold in comparison with arable land. The effect of mixtures used as a fore-crop is neither to be overlooked.

Keywords: botanical composition, grass/clover mixtures, temporary grassland, dry matter production

Introduction

Temporary grassland represents an important group of forage crops, because it has a better productivity and quality than semi-natural grassland. In Slovakia, there are 89 forage grass cultivars and 112 forage legume cultivars officially registered in the National List of Varieties of the Slovak Republic (Listina registrovaných odrôd, 2008) and available for establishing temporary grassland. The aim of the presented research was to assess multi-component grass/clover mixtures designed for growing as temporary grassland in mountain regions of Slovakia.

Materials and methods

Field experiments were established at Liptovská Teplička (a village in a mountain region of Slovakia) with the following characteristics: latitude (λ) 20°06'E; longitude (φ) 48°55'N; altitude 960 m; mean annual rainfall 950 mm; mean rainfall over the growing season 525 mm; mean daily temperature 3.5°C; mean daily temperature over the growing season 9.5°C; soil texture loamy; soil type rendzina; geological substratum carbonates. The temporary swards were established in blocks with four replicates. In the spring before the sowing, the following fertiliser rates were applied: 30 kg P ha^{-1} plus 80 kg K ha^{-1} (as superphosphate and potassium chloride, respectively) and a starting rate of 30 kg N ha^{-1} (as LAV). Every year in the spring, superphosphate and potassium chloride were applied at rates according to dry matter nutrient content (DM). There were six treatments (managed by three cuts): (1) *Trifolium pratense* L. cv. Beskyd, *Trifolium repens* L. cv. Dúbrava, × *Festulolium* cv. Felina, *Lolium perenne* L. cv. Jara, *Poa pratensis* L. cv. Slezanka; (2) *Trifolium pratense* L. cv. Beskyd, *Trifolium repens* L. cv. Dúbrava, × *Festulolium* cv. HŽ 5 DK, *Lolium perenne* L. cv. HŽ III., *Poa pratensis* L. cv. Slezanka; (3) *Trifolium pratense* L. cv. Beskyd, *Trifolium repens* L. cv. Dúbrava, *Festuca arundinacea* SCHREB. cv. Kora, *Lolium perenne* L. cv. Mustang, *Poa pratensis* L. cv. Slezanka; (4) *Trifolium pratense* L. cv. Start, *Trifolium repens* L. cv. Dúbrava, *Dactylis glomerata* L. cv. Niva, *Festuca pratensis* HUDS. cv. Rožnovská, *Phleum pratense* L. cv. Levočská, *Lolium perenne* L. cv. Mustang; (5) *Trifolium pratense* L. cv. Margot, *Trifolium repens* L. cv. Dúbrava, × *Festulolium* cv. Hykor, *Lolium perenne* L. cv. Mustang, *Poa pratensis* L. cv. Slezanka; (6) *Trifolium pratense* L. cv. Vesna, *Trifolium repens* L. cv. Dúbrava, *Dactylis glomerata* L. cv. Rela, *Phleum pratense* L. cv. Timola, *Festuca pratensis* HUDS. cv. Levočská, *Poa pratensis* L. cv. Slezanka. The seed rate ranged between 30 and 32 kg ha^{-1}.

Results and discussion

In the year of sowing, all the treatments were markedly infested with weeds in the period before the 1st cut. The weed proportion was as high as 75%, mainly *Sinapis arvensis* L. (40 to 59%). The 1st cut eliminated the weed infestation, which was shown in the composition of the sward re-grown before the 2nd and 3rd cuts. The species sown as components of grass/clover mixtures performed well in both growth periods. In the 1st harvest year, the sward development confirmed that *Trifolium pratense* L. was a very competitive species. Its proportion in the sward ranged from 77% to 85% and increased even more in the period before the 3rd cut. These research results were in agreement with those reported by other authors (Kohoutek, 1994; Ilavská and Rataj, 1998; Rataj and Ilavská, 1998), who characterised *Trifolium pratense* L. as a very efficient and competitive species that can be grown for a period of two or three years.

The sward condition was different in the second harvest year. *Trifolium pratense* L. was still dominant, but its proportion was lower than in the previous year and the ground cover of grass species increased – mainly *Lolium perenne* L., *Dactylis glomerata* L., and *Festulolium*. In the third harvest year, the tetraploid cultivars of *Trifolium pratense* L. were disappearing from the sward. This is not surprising, as the biological properties predestine this species for growing as long as two harvest years. There are also reports (Gejguš and Kováč, 2001; Ilavská *et al.,* 2007) of cases in which only half of the *T. pratense* proportion was recorded in the sward at the 3rd cut in the 2nd harvest year. The proportion of *Trifolium repens* L. increased in the treatments where that of *T. pratense* declined. Among grasses, a good position in the sward was taken in by the *festucoid* types, namely *Festulolium*, *Festuca arundinacea* SCHREB., *Festuca pratensis* HUDS., as well as *Phleum pratense* L. and *Dactylis glomerata* L. The sward proportion of *Poa pratensis* L. also kept rising. Although it was the third harvest year, bare ground was not found in the treatments. Similar results were found in a similar research conducted earlier (Vorobeľ and Ilavská, 2006). In the fourth harvest year, the botanical composition of the sward complied with the duration of growing. Grasses did well; their proportion was 52–64%, the varieties of *Festulolium* (Treatments 1, 2 and 5) and *Festuca arundinacea* SCHREB. (Treatment 3) were successful again. Among the basic grass species, *Dactylis glomerata* L. showed the highest (30%) proportion (Treatments 4 and 6). Also *Poa pratensis* L. was well-established where it was sown and reached a proportion of 17–20%

in the sward (Treatments 1–3, 4 and 5). At the end of the growing period, legumes were represented mostly by *Trifolium repens* L. (23–27%) and the proportion of *Trifolium pratense* L. was only 3–5%. In the last year, the proportion of herbs markedly increased, and *Taraxacum officinale* WEB. in WIGGERS was dominant in the sward.
The year of sowing was characterised by a low DM yield resulting from the botanical composition of the sward (weed infestation before the 1st cut). In the first harvest year however, the improved condition of the sward notably (2.3- to 3.2-fold) increased DM production (Table 1).

Table 1 Dry matter yield (Mg ha^{-1})

Year/Treatment	1	2	3	4	5	6
Sowing	3.869	3.637	4.528	4.215	4.226	5.223
1st harvest year	12.438	11.095	11.947	9.991	11.026	12.026
2nd harvest year	8.915	9.025	8.835	9.064	10.56	11.637
3rd harvest year	6.783	7.178	7.220	6.915	7.129	6.152
4th harvest year	6.116	6.272	5.941	5.986	6.350	5.793
Mean	7.624	7.441	7.694	7.234	7.858	8.166

This marked increase was related mainly to a very high proportion of *Trifolium pratense* L. (80%). In the second harvest year, DM production decreased, but it was still as much as 8.8 Mg ha^{-1}. In this year, DM yield was influenced by a slightly reduced proportion of *Trifolium pratense* L. and also by continued better establishment of grasses and intergeneric hybrids. In the following years, the sward development resulted in a gradual decrease in DM production. The efficient species disappeared and were replaced by stoloniferous grasses and by *Trifolium repens* L., so consequently DM yield was reduced by a half in comparison with the first harvest year. As can be seen from Table 1, the mean DM production was rather high in the treatments, ranging from 7.234 to 8.166 Mg ha^{-1}. The statistical analysis did not show significant differences in DM production between the treatments in any of the research years. However, significant differences were found between the years, as shown by the boundary differences for the comparison of DM production between the years, namely P = 1.261 ($P < 0.005$) and P = 1.794 ($P < 0.001$).

Conclusions

It is of current interest to grow temporary grassland on arable land that was temporarily set aside. A temporary sward is more advantageous economically (catch-crop forage yield over a number of years), ecologically (root accumulation and soil enrichment, weed control, reduced erosion on abandoned land, photosynthesis of a compact sward) as well as from the landscape point of view.

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The dominance of high grasses and biomass production on *Alopecuretum* after the cessation of long-term intensive fertilization

Hrevušová Z., Hakl J., Mrkvička J. and Martinek J.

Czech University of Life Sciences Prague, Department of Forage Crops and Grassland Management, Prague, Czech Republic
E-mail: hrevusova@af.czu.cz

Abstract

The aim of the experiment was to evaluate the residual effect of the fertilisation of alluvial *Alopecuretum* 17 years after the cessation of intensive management. The experiment, situated in Černíkovice (363 m a.s.l.), in the Czech Republic, has the following treatments: non-fertilised control, PK, N200PK, and N400PK. The botanical composition (reduced projective dominance) was evaluated before the first cut in May; the biomass was harvested three times per year (May, August, and October). The functional group of high grasses achieved the highest cover under the N400PK treatment and it was significantly different than the cover with the non-fertilised control. No significant differences in biomass production were found. The results prove that the effect of long-term intensive fertilisation on *Alopecuretum* can still be recognisable 17 years after the cessation of intensive management.

Keywords: meadow, resilience, fertilisation, *Alopecuretum*

Introduction

The effect of fertilisation on meadow stands often persists long after its cessation. Resilience, defined as the ability of stands to recover, depends on many factors – mainly on the climatic conditions of a stand site and on the doses of nutrients formerly supplied. In areas with a colder climate the effect of fertilisation (mainly P) is significant even after decades (Hejcman *et al*., 2007); in areas with a more favourable climate the resilience is higher. The effect of nitrogen fertilisation 3–9 years after its last application was recorded by Mountford *et al*. (1996). The influence of long-term fertilisation on alluvial *Alopecuretum* grassland 16 years after its cessation is recorded in a paper by Hrevušová *et al*. (2009). This study amplifies previous conclusions in the 17th year and it is focused on the functional group of high grasses – the most productive component of grassland.

Material and methods

An experiment, monitoring the effect of long-term fertilisation on a meadow stand, was established in 1966 in Černíkovice (the district of Benešov, Czech Republic) on an alluvial *Alopecurus* grassland in the vicinity of a brook. The site is 363 m a.s.l., the mean annual precipitation is 600 mm, and the mean annual temperature 8.1°C. The following treatments were evaluated: non-fertilised control, PK, N200PK, and N400PK (doses of phosphorus and potassium were always 40, resp.100 kg ha^{-1}, and doses of nitrogen were 200, resp. 400 kg ha^{-1} according to the treatment). The experiment is arranged in four randomised blocks. In 1992, the fertilisation of parts of the experimental plots ceased (for more details see Hrevušová *et al*., 2009).

In the experiment the botanical composition of the stand (reduced projective dominance) was always observed before the first cut in May; the plant species were divided into the functional group according to Kubát *et al*. (2002). Eight plots (1 m × 1 m) were monitored for every treatment. The above-ground biomass yields were determined in three cuts in May, August, and October. The conclusions obtained in 2008 were compared with data from 1990 (data recording the state of the stand before the cessation of fertilising). The effect of treatment on biomass yields and the domination of the functional group and species was tested using the ANOVA model and Tukey HSD multiple comparison procedure.

Results and discussion

In 1990, a total of 8 species of high grasses was recorded on the monitored plots; in 2008 (17 years after the cessation of fertilisation) it was already 11 species. An increase in the total number of species on a stand site after the termination of fertilising was also published by Olff and Bakker (1991), who associated it with a reduction in the total above-ground biomass. A statistical interpretation of functional group dominance in 2008 showed that the dominance of high grasses was significantly higher in the N400PK plot in comparison with the control and N200PK plots (Table 1).
In Table 2 the major dominance of *Alopecurus pratensis* before the cessation of fertilisation is obvious, in the non-fertilised control too. The decline of this nutrient-demanding grass indicates the general reduction of the productive potential of the stand site, probably in consequence of less frequent spring floods from the brook in the vicinity. The released ecological niche later filled with mainly dicotyledonous species. Of the high grasses those that expanded were mainly the less nutrient-demanding *Holcus lanatus* and *Trisetum flavescens*. In 2008 the residual effect of fertilisation on the dominance of high grasses was recorded only for *Holcus lanatus* ($F = 5.026$, $P = 0.007$), with a higher dominance within N400PK in comparison with the other variants. *Alopecurus pratensis* and *Poa pratensis* also showed higher dominance within N400PK, but these differences were not significant. Above-ground biomass yields in 2008 did not differ significantly between the treatments being monitored and ranged between 10.5–11.4 Mg ha^{-1} of dry matter on control, resp. the N200PK plot (Table 1). An unusual increase in the biomass was recorded, mainly at the 2nd cut, because of favourable climatic conditions, with high summer precipitation. In previous years the yields ranged from approximately 3–7 t ha^{-1} (Hrevušová *et al*., 2009).

Table 1. Results of the ANOVA analyses of average cover of high grasses and annual dry matter yields in 2008

	Cover of high grasses (%)		Annual yield (Mg ha^{-1})	
	mean	SD	mean	SD
Control	22.6^{a}	9.5	10.5^{a}	1.9
PK	27.3^{ab}	10.0	11.1^{a}	0.9
N200PK	25.9^{a}	10.2	11.4^{a}	1.3
N400PK	46.3^{b}	21.3	11.1^{a}	0.5
P value	0.013		0.840	

Treatments with a different letter were significantly different at $\alpha = 0.05$

Table 2. Average dominance of the most expanded species of high grasses (with average dominance > 1%) in the years 1990 and 2008 (%)

	AlopPra		FestPra		FestRub		HolcLan		PoaPra		PoaTri		TrisFla	
	1990	2008	1990	2008	1990	2008	1990	2008	1990	2008	1990	2008	1990	2008
Control	30	2	5	4	0.5	3	15	3	5	4	5	1	0	5
PK	10	2	5	4	0.5	0	5	4	5	4	5	1	0	9
N200PK	60	2	10	4	0	0	5	5	0.5	4	0.5	2	0	5
N400PK	85	4	0.5	4	0	0	0.5	17	10	8	3	2	0	9

AlopPra – *Alopecurus pratensis*, FestPra – *Festuca pratensis*, FestRub – *Festuca rubra*, HolcLan – *Holcus lanatus*, PoaPra – *Poa pratensis*, PoaTri – *Poa trivialis*, TrisFla – *Trisetum flavescens*

Conclusions

The effect of long-term fertilisation on high-productive *Alopecuretum* grassland is still significant 17 years after its cessation. The residual effect of high nitrogen doses is indicated by the higher dominance of the high grasses group, mainly *Holcus lanatus*. The effect on above-ground biomass yields was not recorded.

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Chicory as promising bioactive forage for sheep production

Kidane A.[1,2], Parissi Z.M.[3], Houdijk J.G.M.[1], Athanasiadou S.[1], Tolkamp B.J.[1] and Kyriazakis I.[1,4]

[1]*Animal Health, SAC, Edinburgh, United Kingdom*
[2]*Hawassa University, Department of Animal and Range Sciences, Awassa, Ethiopia*
[3]*Aristotle University of Thessaloniki, School of Forestry and Natural Environment, Thessaloniki, Greece*
[4] *University of Thessaly, Veterinary Faculty, Karditsa, Greece*
E-mail: Alemayehu.Kidane@sac.ac.uk

Abstract

The effect of grazing chicory (*Cichorium intybus* L.) *vs.* perennial ryegrass/white clover (*Lolium perenne* L./*Trifolium repens* L.) on lamb and ewe performance and parasite control was studied in Scotland. Two experiments were conducted from turn-out (32 days post-parturition) to weaning 10 weeks later. In experiment 1, 36 parasitized Scottish Blackface ewes with their twin Scottish Blackface lambs were allocated to parasite free chicory or grass/clover plots. In experiment 2, 36 parasitized Greyface ewes with their twin Suffolk cross lambs were allocated to parasite contaminated chicory or grass/clover plots (n = 6 with 3 ewes per plot in each experiment). Ewe and lamb body weight and lamb parasitism (through assessment of faecal egg count, FEC) were monitored regularly. Grazing on chicory increased ewe body weight in both breeds, by an average (± s.e.d) of 4.5 ± 1.4 kg at weaning. Lambs grazing chicory were 3.0 ± 1.15 kg (Exp. 1) and 5.5 ± 0.53 kg (Exp. 2) heavier compared to those grazing grass/clover. Ewes grazing chicory had higher condition score than ewes grazing grass/clover. Grazing on chicory reduced FEC and need for drenching in lambs in Exp. 1 and Exp. 2, respectively. In conclusion, chicory has a great potential for improved sheep production and parasite control.

Keywords: grazing, chicory, parasite control, weaning, lamb growth

Introduction

Gastrointestinal parasitism is a major challenge to the health and productivity of sheep throughout the world (Sykes, 1994), and is largely controlled through the use of anthelmintics. However, reliance on chemoprophylaxis alone for parasite control is increasingly unsustainable due to increased anthelmintic resistance. Alternative approaches that could reduce parasitism and improve performance are required. Such approaches include the use of bioactive forages with potential anti-parasitic properties. Our objective was to investigate effects of grazing the bioactive forage chicory on ewe and lamb performance and lamb parasitic status.

Materials and methods

The experiment was conducted in Scotland (240 m above sea level, 55°52'16"N and 3°12'59"W) in 2008. The annual precipitation of the area ranges from 800–1,000 mm and its temperature ranges from subzero in January to 19°C in July. Twenty-four plots of 0.24 ha each were established in spring 2007. Half of the plots were sown with Puna II chicory and half with grass/clover. In 2007, half of the plots (six from each forage type) were grazed for a brief period by non-reproducing parasite-free sheep whilst the other 12 were grazed by sheep infected with the abomasal parasite *Teladorsagia circumcincta*. For the reported experiments, these were termed as 'initially clean' and 'already contaminated' plots, respectively.

Two experiments were conducted from turn-out (32 days post-parturition) to weaning 10 weeks later. In Exp. 1, 36 parasitized Scottish Blackface ewes with their twin Scottish Blackface lambs were allocated to the initially clean plots and in Exp. 2, 36 parasitized Greyface ewes with their twin Suffolk cross lambs were allocated to the already contaminated plots (n = 6 plots per forage with 3 ewes per plot in both Exp. 1 and Exp. 2). Animal body weights (BW) were assessed weekly, and lamb faecal egg counts (FEC) were monitored every 14 days using a modified floatation technique (Christie and Jackson, 1982). Ewe body condition score (BCS) was measured at frequent intervals. Lambs were drenched with anthelmintics whenever they showed diarrhoea, BW loss and/or high FEC (> 1,000 epg). In both experiments, animals were given free access to grazing and water. FEC and BW of lambs, and BW and BCS of ewes were analyzed using repeated measures analysis of variance (ANOVA). Weaning BW of lambs and ewes was analyzed using general ANOVA. All statistical analyses were performed using Genstat 11th edition (VSN International Ltd., 2008).

Results and discussion

Figure 1 shows mean ewe and lamb BW and ewe BSC. At weaning, ewes grazing on chicory were (± s.e.) 4.6 ± 1.67 kg and 4.4 ± 1.67 kg heavier than those grazing grass/

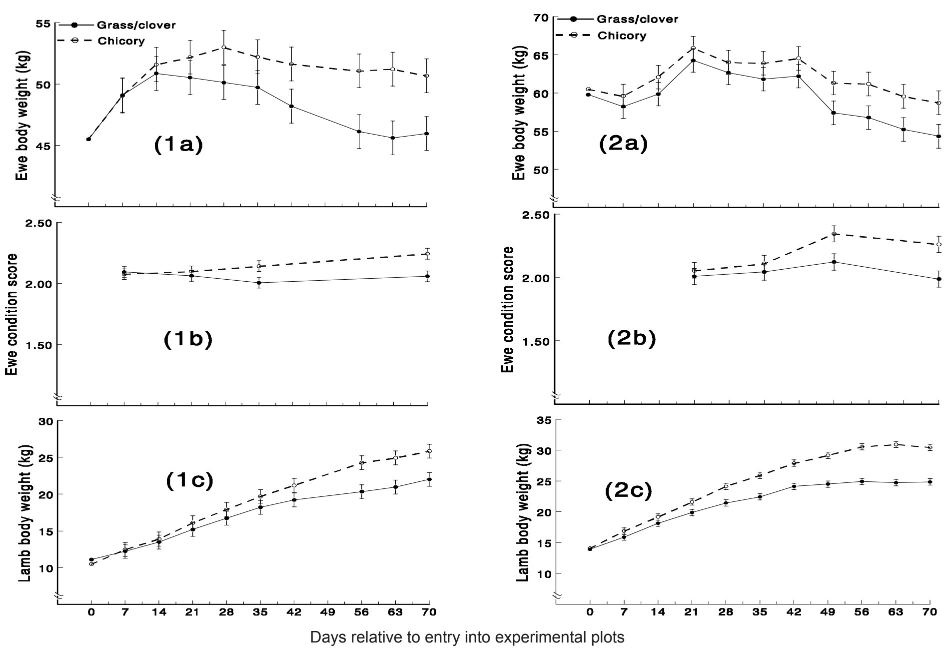

Figure 1. Ewe BW (1a and 2a), BCS (1b and 2b), and lamb BW (1c and 2c) from Exp. 1 and Exp. 2, respectively (vertical bars give s.e.)

clover in Exp. 1 and Exp. 2, respectively (Figures 1a and 2a; $P < 0.05$). Ewes grazing chicory also had better BCS than their grass/clover counterparts in both experiments (Figures 1b and 2b, $P < 0.05$). Lambs grazing chicory were 2.9 ± 1.00 kg and 5.5 ± 0.73 kg heavier at weaning compared to those grazing grass/clover in Exp. 1 and 2, respectively (Figures 1c and 2c, $P < 0.05$).

The improved performance of ewes and lambs grazing on chicory agrees well to previous works on ruminants grazing chicory compared to conventional forages (Komolong *et al*., 1992; Hoskin *et al*., 1999; Athanasiadou *et al*., 2007). To some extent, this may be related to a better nutrient composition of chicory compared to grass/clover (data not shown) and a better balance of nutrients; for example, the ratio of duodenal non-ammonia nitrogen to digestible organic matter intake (Komolong *et al*., 1992).

Lamb parasitism, as monitored through regular FEC, was reduced by grazing on initially clean chicory compared to grass/clover ($P = 0.052$) in Exp. 1, which agrees with similar observations on organic twin-reared lambs grazing initially clean chicory (Athanasiadou *et al*., 2007). In Exp. 2 lambs grazing both chicory and grass/clover required drenches and FEC was not compared, as their patterns were heavily biased by the drench treatments. However, lambs from the already contaminated grass/clover plots required 21% more drenches compared to the chicory ones. Such effects of chicory may arise from reduced larvae intake (Marley *et al*., 2006), direct anti-parasitic effects (Tzamaloukas *et al*., 2005) and/or improved immunity (Tzamaloukas *et al*., 2006).

In conclusion, grazing twin rearing ewes on chicory, compared to grass/clover, reduced parasitism, required less drenching and improved performance. This supports the view that chicory may be used as alternative forage for finishing lambs earlier in the season with reduced dependency on anthelmintic drugs.

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Succession and structure of a mulched and cut lawn

Knot P., Hrabě F. and Vrzalová J.

Mendel University of Agriculture and Forestry in Brno, Department of Animal Nutrition and Forage Production Brno, Czech Republic
E-mail: knot@mendelu.cz

Abstract

The effect was assessed of mulching and mowing in the interaction with nitrogen + PK nutrition on the succession of a lawn mixture after sowing (six grass species, two clover crop species). The root mat cover in the spring of 2007 (1^{st} cut) ranged in all experimental variants from 93–97% (sown species 79–87%; grasses 69–80%). In the autumn (4^{th} cut), the cover was already 100%. In the spring of 2008, the share of the clover crop component in the total degree of coverage increased (48–53% mulched variant; 37–43% mown variant). The total number of species in the spring of 2008 was 10–11 (unsown 2–3) and in the autumn 8–12 (unsown 1–4). Neither the effect of N-fertilisation nor that of mulching was reflected significantly in the species abundance. The dominant species are *Lolium perenne* (cover 27–51% in the 1^{st} cut and 13–44% in the 4^{th} cut) and *Trifolium repens* (cover 73–49% in the 4^{th} cut with nitrogen fertilisation and up to 82% in unfertilised variants). The results show the necessity of suppressing the competitiveness and effect of dominants during the initial stage of turf succession when designing the composition of the mixture.

Keywords: extensive lawns, mulching, mowing, nutrition, stand structure

Introduction

The paper presents an assessment of the initial stage of succession in a clover-grass mixture in relation to mostly extensive exploitation given by the necessary level of trophism, as well as by the acceptable number of harvests during the year (five cuts), and in relation to the alternative use of mulching aimed at a partial return of nutrients into the ecosystem. Fiala *et al.* (2005) and Hrabě *et al.* (2008) provide information about the high weight (6.0 and 8.4 t ha^{-1}, resp.) of dry harvested green phytomass, which indicates a high export of nutrients. The complexity of competitive relations and their manifestation in the succession is discussed by De Witt in Opitz von Boberfeld (1994) and Klimeš *et al.* (2001). As compared with meadow stands, the competition in green stands multiplies as a result of the considerably higher sowing rates, specific response of species to different cutting heights, level of fertilisation, load resistance etc. In addition to the species composition, strong emphasis is put on the choice of appropriate varieties.

Material and methods

The experiment was conducted in the form of a small-plot trial (trial plot of 3.24 m^2) in three repetitions at the Vatín Research Station of Fodder Cropping (Mendel University of Agriculture and Forestry in Brno) in a potato-growing region with a mean annual temperature of 6.1°C and a total precipitation of 737 mm. The research was focused on differences in the cover and structure (abundance of sown and unsown species) of a clover-grass stand with different methods of exploitation and N-fertilisation.

Experimental variants:

1. Stand – clover-grass lawn mixture: *Lolium perenne* 25%, *Poa pratensis* 25%, *Festuca rubra* 30%, *Festuca ovina* 5%, *Anthoxanthum odoratum* 5%, *Cynosurus cristatus* 5%, *Trifolium repens* 3%, *Lotus cornitulatus* 2%
2. Fertilisation amount variants: 1. N_0 – control without fertilisation, 2. N_{50} – 50 kg N ha^{-1} + PK, 3. N_{100} – 100 kg N ha^{-1} + PK
3. Methods of exploitation: 1. mowing 5 times a year; 2. mulching 5 times a year.

Mowing and mulching was done with a rotary cutter. The degree of coverage, species dominance and stand structure were monitored at the first cut (May) and at the fourth cut (September). The dominance was established by the method of projective dominance. The structure is expressed as a share of grasses, legumes and other dicotyledons in the total cover and by the species abundance. The data were analysed using ANOVA at a significance level of $P = 0.05$.

Results and discussion

The root mat cover in the spring of 2007 after sward establishment in the autumn of 2006 was high (93–97%) and increased slightly with the N-fertilisation. The increased degree of coverage in the mulching variant was insignificant. The trend was apparent in the spring of 2008, too. In 2007, the share of unsown species in the total cover amounted to ca 7.3–14.3% (mowing) and 7.3–12.0% (mulching). In 2008, however, the share of unsown species in the total cover was negligible (0.3–0.7%). The effect of N-fertilisation intensity and harvest date on the ratio between the grass and legume components was highly significant. The application of 50 and 100 kg ha^{-1} N fostered (significantly) the cover of the grass component (80–50%) and suppressed the cover of the clover component in the spring period. In the summer-autumn period, in 2008, the so-called "phenomenon of honeysuckle grass" could be observed, i.e. the species' degree of coverage at 37–60% in the first year and 85–58% (mowing) and 76–49% (mulching) in the second year. The reason is apparently a reduction in the amount of light or the allelopathic effect of mulching on the rooting of above-ground clover stolons. Opitz von Boberfeld (1994) points out the high competitiveness of *Trifolium repens* in newly sown turfs. The effects of mowing and the level of mulching on the total abundance of species were not significant. More significant differences in the number of species occurred in the respective years. In the first year, the number of species ranged from 19–21; of these, 50–60% were unsown species. In the second year, the number of species fell to 8–10, with the unsown species ranging only from 20–25%. The abundance of species with dominance D > 1% in the total number of species in both years and in the spring period was narrowly above the boundary of 50%. Species clearly dominant in the first cut include the highly competitive *Lolium perenne* (% D = 38.0–50.7% – mowing and 27.3–41.0% – mulching) and *Trifolium repens* (D = 35.9–40.7% – mowing and 46.3–48.0% – mulching). According to the RSM system, the share of *Lolium perenne* in the sowing rate of extensive lawn mixtures is often reduced to a mere 5–10%. Similarly, *Trifolium repens* is used only in special mixtures intended for so-called "low-input lawns" with the small-leaved "Microclover" form and where the proportion of medium-build forms in the seeding amount of e.g. landscape mixtures is very low (0.2%). According to Lošák *et al.* (2008), the high dominance of the above mentioned species results in a high level of total stand change (e.g. in mulched stands > 40–45%) and in the disturbance of the "normal" course of succession.

Table 1. Total stand cover (%) and the share of sown and unsown species in the clover-grass turf stand Vatín, 2007–2008, 1st and 4th cuts

Species	Method of use	1st cut – 2007			4th cut – 2007			1st cut – 2008			4th cut – 2008		
		N_0	N_{50}	N_{100}	N_0	N_{50}	N_{100}	N_0	N_{50}	N_{100}	N_0	N_{50}	N_{100}
Sown	C	79.3	86.3	86.3	99.3	100.0	100.0	96.3	98.7	98.0	100.0	99.0	99.3
	M	81.0	86.7	87.0	99.7	100.0	100.0	95.0	99.4	98.3	100.0	99.0	99.0
Unsown	C	14.3	10.0	10.7	0.4	0.0	0.0	0.7	0.3	0.0	0.0	0.0	0.4
	M	13.7	10.7	10.7	0.3	0.0	0.0	0.7	0.3	0.7	0.0	0.7	0.3

C – cutting, M – mulching

Table 2. Total number of species; of these, sown and unsown species in the clover-grass turf community in relation to the level of trophism. Vatín, 2007–2008 (5 cuts)

Number of species	Method of use	Harvest date and level of nutrition					
		spring – 1st cut			summer–autumn – 4th cut		
		N_0	N_{50}	N_{100}	N_0	N_{50}	N_{100}
		2007/2008	2007/2008	2007/2008	2007/2008	2007/2008	2007/2008
Total	C	20/11	21/11	20/10	9/12	8/8	12/11
	M	19/11	20/10	19/11	9/12	8/11	9/10
D > 1%	C	10/6	10/6	9/5	4/4	4/4	4/3
	M	9/6	9/6	9/6	4/4	4/3	4/3
Sown	C	8/8	8/8	8/8	8/8	8/8	8/8
	M	8/8	4/6	8/8	8/8	8/8	8/8
D > 1%	C	6/6	5/6	5/6	4/4	4/4	4/3
	M	5/6	5/4	5/6	4/4	4/3	4/3
Unsown	C	12/3	13/3	10/2	1/4	0/1	4/3
	M	11/3	12/2	11/3	1/4	0/3	1/2
D > 1%	C	4/0	5/0	4/0	0/0	0/0	0/0
	M	4/0	5/0	4/0	0/0	0/0	0/0

C – cutting, M – mulching, D – dominance

Conclusion

The inadequate representation of highly competitive species in the multi-species turf mixture, i.e. *Lolium perenne* and *Trifolium repens* (with the exception of the "Microclover" type) is connected in the first stage of succession with a high dynamics of stand changes and with a low number of species (9–12) of which one quarter are unsown species. In the spring aspect, N-fertilisation fostered the cover of the grass component at the cost of legumes. Mulching was observed to increase the level of stand changes. In addition to species composition, attention will have to be paid to the choice of varieties for extensive turfs.

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The competition of grass component within alfalfa-grass mixture in the seeding year

Krajíc L., Hakl J. and Šantrůček J.

Czech University of Life Sciences Prague, Department of Forage Crops and Grassland Management, Prague, Czech Republic
E-mail: krajic@af.czu.cz

Abstract

The use of alfalfa-grass mixtures can reduce the disadvantages of pure alfalfa stands. The goal of this study was to investigate the effect of grass competition on alfalfa development in the seeding year. In 2008, the experiment was carried out with four alfalfa varieties and Festulolium Achilles with the grass being included in the mixture at 0, 10 and 25% by weight of seed. Alfalfa mixtures compared to alfalfa in pure stands demonstrated significantly lower alfalfa yields, but no significant differences in total yield. Grass competition negatively affected alfalfa growth characteristics, mainly the count of alfalfa plants and stems. This effect was increased with increase in grass rate in the mixture. Alfalfa stem length was not significantly affected by the presence of grass.

Keywords: alfalfa-grass mixture, seed ratio, yield, density

Introduction

In forage-animal production systems, legume-grass mixtures provide a number of advantages over legume grown in monoculture (Haynes, 1980). Yields of grasses grown with alfalfa are generally higher in mixture, due to more effectively utilized abiotic factors (Tomov and Petkov, 1989) and transfer of symbiotically fixed nitrogen to grasses (Burity *et al*., 1989). Furthermore, dry matter production is more balanced with grasses being more productive in spring and legumes in summer (Mooso and Wedin, 1990). Among other potential advantages of alfalfa-grass mixtures over monoculture are erosion control (Sheaffer *et al*., 1990) and reducing weed invasion in monoculture (Spandl *et al*., 1999). Competitive interactions between the alfalfa and grass can though create some problems. Competition between alfalfa and grass occurs in the seeding year, in which alfalfa is not a vigorous competitor (McCloud and Mott, 1953). Although alfalfa seeds germinate and emerge more quickly than grass, alfalfa seedlings grow more slowly than grass once emerged. A vigorous grass component may decrease alfalfa shoot production with a reduction in yield and decreased persistence of alfalfa (Nelson *et al*., 1986). The extent of alfalfa depression by grass is usually increased with high grass seeding rates (Chamblee and Collins, 1988). The present study was conducted to investigate the effect of grass component competition on alfalfa development in the seeding year depending on different grass proportions.

Materials and methods

The plot experiment was carried out at the research station of the Czech University of Life Sciences in Central Bohemia (at altitude 405 m, 50°04'N, 14°10'E). The long-term temperature over the vegetation period is 13.8°C and precipitation 333 mm. Temperature and precipitation over the vegetation period for the experimental year 2008 was 14.7°C and 347 mm.

In the spring 2008 pure and mixed stands were established for four alfalfa entries (varieties Zuzana, Oslava, Jarka, and candivar ŽE XLII) and the grass hybrid Achilles. Achilles is early maturity tetraploid hybrid Festulolium, which was created by cross-breeding of Italian ryegrass (*Lolium multiflorum* Lam.) and Meadow fescue (*Festuca pratensis* Huds.). The seeding rate for the pure stand of alfalfa was 7 million germination seeds (mgs) per 1 ha. For the mixtures, two seeding rates were used which represented 10 and 25% ratio of grass by weight. These mixtures were composed of 6.3 mgs alfalfa and 0.7 or 1.4 mgs Achilles per ha, respectively. The treatments were arranged in a randomized complete block design with four replicates. Plot size was 2.5 by 7.2 m.

Measurement and sampling were carried out in the seeding year in July and October from an area of 20 × 20 cm in each plot. The following parameters were defined: total dry matter yield, dry matter yield of individual mixture component, real grass proportion, count of alfalfa and grass plants, count of alfalfa stems and grass stem tillers, weight of alfalfa stems. Furthermore, length of alfalfa stems and grass stem tillers was measured. The results were statistically evaluated by ANOVA and correlation analysis using by Statistica 8.0.

Results and discussion

Our results in the seeding year did not support the finding by other authors that yields are generally higher with alfalfa-grass stands. In comparison to yields of pure alfalfa stands, the total yields of mixtures in the seeding year were 11% lower, although this difference was not significant (Table 1). On the contrary, the results confirmed the fact, that the grass component in the mixed stand negatively affects alfalfa (Chamblee and Collins, 1988). Mixtures with the grass component at 10 and 25% of the seed mixture reduced alfalfa yield about 10 and 23%, respectively (Table 1).

Table 1. Yields of pure and mixture stands for spring and summer cuts in the seeding year

Grass seeding rates (%)	Real grass proportion (%)	Total yield (t DM ha^{-1})	Alfalfa yield (t DM ha^{-1})
25	27	6.90a	5.08a
10	14	6.78a	5.90a
0	0	7.65a	7.65b
P-value		0.2902	0.0001

ANOVA, Tukey HSD test; significant differences at $P < 0.05$

The decrease of alfalfa yield in mixture stands was caused by competition from the grass component, which negatively affected alfalfa growth characteristics. The mean values of evaluated parameters are presented in Table 2.

The effects of the grass component on alfalfa growth characteristics are displayed in the correlation matrix in Table 3. The real grass proportion in the harvested material was used in this matrix instead of the seeding ratio. This analysis showed that the presence of the grass component affected all specified alfalfa parameters except alfalfa stem

Table 2. The main characteristics of measured parameters in the seeding year; mean of spring and summer cuts

	Mean			Standard deviation		
Grass seeding rates (%)	0	10	25	0	10	25
Alfalfa yield (t DM ha^{-1})	3.8	2.9	2.5	1.3	1.0	1.1
Count of alfalfa plants (pcs m^{-2})	609	494	401	269	183	163
Count of alfalfa stems (pcs m^{-2})	900	768	696	362	296	354
Length of alfalfa stems (cm)	48.7	45.4	44.5	10.5	9.1	8.8
Weight of alfalfa stems (g)	0.49	0.43	0.43	0.25	0.20	0.23

length. It had a negative impact on the count of alfalfa stems and plants. These effects were significant with the exception of the correlation between count of alfalfa plants and grass yield. Furthermore, an important negative relationship existed between grass yield and the count of alfalfa stems. However, individual stems were heavier in the presence of grass. Real grass proportion was the next important factor affecting some of alfalfa parameters. Increase in this proportion negatively influenced yield, count plants and stems of alfalfa.

Table 3. Correlation matrix among parameters in seeding year

	Alfalfa yield	Count of alfalfa		Length of alfalfa stems	Weight of alfalfa stems
		plants	stems		
Real grass proportion	–0.34	–0.21	**–0.49**	0.01	0.17
Grass yield	–0.15	–0.15	**–0.48**	0.14	**0.35**
Count of grass plants	**–0.32**	**–0.25**	**–0.41**	0.02	0.11
Count of grass stem tillers	**–0.24**	**–0.23**	**–0.30**	–0.06	0.13
Length of grass stem tillers	**–0.24**	**–0.23**	**–0.32**	0.01	0.07

Correlations significant at $P < 0.05$ are in bold

Conclusions

Alfalfa mixtures compared to alfalfa in pure stands gave significantly lower alfalfa yields, but had no significant effect on total yield. Grass competition negatively affected alfalfa growth characteristics, mainly the count of alfalfa plants and stems. This effect increased with increase in the grass rate in the mixture. Alfalfa stem length was not significantly affected by presence of the grass component.

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Morphological traits and seed production potential of some wild *Trifolium* species in Serbia

Lugic Z., Radovic J., Sokolovic D., Vasic T. and Jevtic G.

Institute for Forage Crops, Krusevac, Serbia
E mail: zoran.lugic@ikbks.com

Abstract

This examination includes five widespread *Trifolium* species (*T. montanum*, *T. alpestre*. *T. hybridum*, *T. pratense*, and *T. pannonicum*) collected from three different sites from 500 to 1,100 m above sea level. The following morphological traits of the ten plants collected were observed: plant height, number of tillers, green mass yield, leaf size, number of heads per plant, number of florets in head, total number of seeds per plant, and the weight of 1,000 seeds. The highest plants and green matter yield per plant were obtained in the *T. pratense* and *T. pannonicum* genotypes (40–65 cm and 125–210 g plant^{-1}), while the smallest plants were present in the *T. montanum* species. Great variability between individual plants was recorded both among and within species. A similar variability in individual plants and species was obtained for all seed yield components. The highest number of blooms per plant was obtained in *T. hybridum* (40–95) and the lowest in *T. montanum* (3–8). *T. montanum* had the highest number of flowers per head (60.80–188.60), while *T. hybridum* had the lowest number of flowers per head (49.80–59.60). *T. hybridum* and *T. pratense* had the highest seed yield potential, while the species *T. pannonicum* and *T. alpestre* had low values for this trait.

Keywords: morphological traits, seed production, *Trifolium* sp., wild species

Introduction

Natural meadows are spread over 1.6 million hectares in Serbia, i.e. about 28% of the total agricultural area. Over 80% of that area is situated in hilly and mountain sites and is mostly used for pasture or hay production. Because of the low intensity of agricultural management and a decrease in the number of inhabitants in hill and mountain areas, the level of exploitation of meadows and pastures is very low. Thus the yield of dry matter varies from 0.5 up to 1.8 t ha^{-1} (Lazarevic *et al.,* 2003.). The number of wild species belonging to the genus *Trifolium,* as a very important component of natural meadows, is about 50 (Cincovic, 1972). According to the results obtained (Mrfat-Vukelic *et al.,* 2003a, b). *T. pratense* is present in a significant degree in 28, *T. repens* in 20, *T. alpestre* in 18, *T. pannonicum* in 7, and *T. hybridum* in 6 out of the 35 grassland communities researched. The presence level of leguminous plants based on a constancy degree in meadow communities showed that *T. pratense*, *T. repens*, and *T. alpestre* were mostly represented in the communities of natural meadows that were analysed.

Materials and methods

On the natural meadows of West Serbia (Zlatibor Mountain) during June 2006 (in the flowering phase), ten individual plants per wild species were collected: *T. montanum* L.

(locality Borova glava, 1,100 m a.s.l.), *T. alpestre* L. (locality Zlatibor, 900 m a.s.l.), *T. hybridum* L. (locality Vodice, 1,000 m a.s.l.), and *T. pratense* L. (locality Tripkovo, 740 m a.s.l.). The collected plants were analysed for the following morphological traits: plant height (cm), the number of tillers per plant, green mass yield (GMY) per plant (g), and the leaf length (cm). Ten individual plants per species in the seed maturity phase were collected at the same localities at the end of July and during August 2006. The following parameters of seed production potential were observed on these plants: the number of heads per plant, the number of flowers per head, number of seeds per head, the weight of 1,000 seeds, and floret site utilisation (FSU). The average values and interval of variation (*IV*) of the traits being researched were analysed and compared to red clover, as economically the most important species.

Results and discussion

According to Cincovic (1972), analysed species from the genus *Trifolium* are differently widespread in plant communities, from natural meadows to the edges of forests in humid and arid areas of Serbia. According to the Brown-Blanquet method, in plant communities *Koelero-Danthonietum armerietosum* red clover had a constancy degree IV, *T. montanum* V, and *T. alpestre* V (Mrfat-Vukelic *et al.,* 2003a. b).

In these investigations, the plant height, as an important competitive ability parameter in plant communities, significantly depended on the plant species. However, the individual plant variability in each species, expressed through the interval of variation, was very high (Table 1). The biggest average plant height was observed in *T. hybridum* and *T. pratense* (52.6 and 52.8 cm) with a high interval of variation. The smallest plants were found in the *T. alpestre* species (33.2 cm). The highest number of tillers was observed in *T. pratense* and *T. pannonicum* (14.2 and 13.2), while the lowest was in *T. montanum* and it rated only 2.3.

Table 1. Average values and I.V. for morphological traits of wild *Trifolium* populations

Species	Plant height (cm)	*IV*	No. of tillers	*IV*	GMY (g plant^{-1})	*IV*	Length of leaf (cm)	*IV*
T. alpestre L.	33.2	24.4–43.8	12.6	6–21	64.2	32.1–94.3	3.8	3.2–5,2
T. montanum L.	41.8	32.5–56.3	2.3	1–3	58.4	30.2–85.4	4.3	3.6–5.4
T. hybridum L.	52.6	43.2–61.5	10.5	7–18	85.7	57.3–107.5	2.6	2.2–3.4
T. pannonicum L.	46.3	34.2–62.8	13.2	6–22	110.2	78.1–210.2	4.9	3.6–7.1
T. pratense L.	52.8	41.5–65.0	14.2	7–24	125.4	68.8–190.5	3.6	3.0–4.8

The green mass yield per plant, as the most important agronomical trait, depended significantly on the species. The highest average GMY was observed in *T. pratense* and *T. pannonicum* (125 and 110 g plant^{-1}), while the plants of *T. montanum* had the lowest values for this trait (58.40 g plant^{-1}). The individual plant variability of each species for this trait, expressed through the wide interval of variation, was extremely high. The green mass yield per plant of different populations in *T. pannonicum* was from 49.40 to 112.65 g plant^{-1}, the average height of the plants was from 37 to 53 cm, and the number of tillers from 20 to 24. The locality had a considerable influence on these traits (Lugic *et al.,* 2006). The highest individual plant variability in each population locality, expressed in terms of the variability coefficient, was obtained for the green mass yield per plant, and the number of tillers per plant varied from 23 up to 28%. Lower variability was obtained for plant height (10–15%) and the lowest for the number of internodes at the main stem (9–12%).

Table 2. Average values and *IV* for seed production components of wild *Trifolium* species

Species	No. heads per plant	*IV*	No. florets per head	*IV*	No seeds per head	*IV*	FSU (%)	Weight of 1,000 seeds (g)
T. alpestre L.	16.3	11–31	62.4	50–74	9.6	2–15	15.38	1.70
T. montanum L.	4.6	3–8	112.3	60–188	46.6	12–73	41.49	0.75
T. hybridum L.	62.3	40–90	52.3	49–60	71.8	28–126	137.28	0.80
T. pannonicum L.	18.4	9–42	85.2	51–133	11.2	8–15	13.14	4.21
T. pratense L.	54.8	41–78	65.5	43–80	19.0	9–25	29.00	1.54

Seed production potential is a very important characteristic and represents the basic prerequisite for the maintaining and spreading of one species or cultivar. The seed production potential of *T. pratense* in France is up to 1,000 kg ha^{-1} (Bouet and Sicard, 1998). The seed yield averages for *T. hybridum* in Canada are between 100 and 200 kg ha^{-1}, though much higher yields are obtained under optimal growing conditions (Frame, 2005). Because of its xenogamic fertilisation and insect pollination, the seed production of the genus *Trifolium* is, to a great extent, influenced by both agronomic practices and climatic conditions. In different cultivars of red clover Tamm and Bender (2003) found a high variability in seed yield, dry matter yield, plant height, and even in quality parameters such as CPC, NDF, ADF, and content of Ca, P, K, and Mg.

In these research efforts, the species *T. hybridum* had the highest number of heads per plant (62.30) but also the lowest number of flowers per head (49–60). However, because it had the highest FSU it reached the largest number of seeds per head (71.8). Plants of the *T. montanum* species had the lowest number of heads per plant, but the highest number of flowers per head, as well as a high FSU value. The lowest seed production potential expressed in terms of the number of seeds per head and FSU was noticed in plants of the *T. pannonicum* and *T. alpestre* species. The biggest 1,000-seed weight was found in the *T. pannonicum* and *T. alpestre* species.

Conclusion

In wild populations of *T. pratense* and *T. pannonicum* the highest values of green mass yield, plant height and number of tillers per plant were obtained, whereas *T. alpestre* and *T. montanum* had the lowest yield potential. High seed production potential was found in individual plants of the *T. hybridum* and *T. pratense* species, while the *T. alpestre* and *T. pannonicum* species had the lowest values for this trait. High variability between individual plants within the population was found in all the traits that were analysed.

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An influence of water stress in first stages of development on germination capacity of selected turfgrass species

Martinek J., Svobodová M. and Králíčková T.

Czech University of Life Sciences Prague, Department of Forage Crops and Grassland Management, Prague, Czech Republic
E-mail: martinekjaroslav@af.czu.cz

Abstract

Two laboratory experiments were conducted to evaluate the germination capacity of selected turfgrass species after inducing water stress during imbibition. Species used: *Deschampsia caespitosa* /L./ P. Beauv (Kometa), *Lolium perenne* L. (Filip), *Poa pratensis* L. (Harmonie), *Festuca rubra* ssp. *commutata* (Barborka), *Festuca rubra* ssp. *trichophylla* (Viktorka), *Festuca rubra* ssp. *rubra* (Petruna). Seeds were imbibed for 1–6 days under day/light regime 16/8 hours, 15/5°C, rh 70%, before water stress (5 days, 35°C, rh 40%). After this period, seeds were wetted and returned to the original regime (temperature, light). The results were evaluated by analysis of variance ANOVA LSD α = 0.05 (Statgraphics programme, version XV). At the beginning (until the tenth day) the lowest number of germinated seeds was in the control variant and the highest in seed imbibed for four days (until the sixteenth day after the stress). The highest total germination capacity (on average of all the species 83%) was in the control variant, whilst. The seed that imbibed for six days had significantly the lowest germination capacity (74%).

Keywords: grass, germination, drought stress

Introduction

The germination capacity of seed is one of the basic criteria for satisfactory turf establishment and its following formation. The process of germination is basically the renovation of metabolic activity of seed and depends on seed features (genetic characteristics, actual quality), and conditions of the environment, i.e. sufficient amount of water, oxygen, optimal temperature and sometimes light (Copeland and McDonald, 1995; Procházka *et al*., 1998; Míka *et al.*, 2002). The imbibition and water uptake are the most important features. With water approaching the seed the giberelins begin to activate the storage capacity (Turgeon, 2002), the synthesis of hydrolytic enzymes occurs – mainly α-amylase breaking the starch (Procházka *et al*., 1998; Míka *et al*., 2002), ribonuclease and phosphatase (Copeland and McDonald, 1995). As a result of these processes the embryo transforms from dehydrated state to the stage with living metabolism (Hosnedl in Houba and Hosnedl, 2002). The process of germination continues, with extension of ridicule cells resulting in the visible phase of germination – breaking the seed walls with radicle.
Abiotic stress, such as drought stress, may not result in the same affect in different phases of development. In principle, if water stress occurs during imbibition, it may not impair the seed embryo. However, if water stress occurs during germination, which is related to cell division, volume growth and germ growth, the failure of germ is most likely to occur (Hess, 1983; Hosnedl in Houba and Hosnedl, 2002). In some species though, there is already mRNA production during imbibition, which means that this process

is not only physical. An additional very important feature of the seed is water holding capacity during short period of increased temperature. Large loss of water may deplete the seed of a large amount of energy, which may result in death by drying (Bláha *et al*., 2003) or high temperature damage.

The aim of this experiment was to appraise the ability of commonly used turfgrass species to restart the process of imbibition – germination – after it was aborted by a period of water stress, and to define the period in which the water stress is most harmful.

Material and methods

The dynamics of the germination of the turfgrass species (*Deschampsia caespitosa* /L./ P. Beauv Kometa*, Lolium perenne* L. Filip*, Poa pratenis* L. Harmonie*, Festuca rubra* ssp. *commutata* Barborka*, Festuca rubra* ssp. *trichophylla* Viktorka*, Festuca rubra* ssp. *rubra* Petruna) was evaluated in a laboratory experiment in a climate box Binder KBWF 240 (four times one hundred seeds). The seed was exposed to imbibition for one to six days (day/light regime 16/8 hours, 15/5°C, rh 70%) before a simulation of water stress (three days, air temperature 35°C, rh 40%) and afterwards (together with the control variant) the original conditions were reimposed. The number of germinated seeds was calculated daily until full germination. The data (in particular days) were evaluated by the analysis of variance ANOVA LSD $\alpha = 0.05$ (Statgraphics programme, version XV).

Results and discussion

The dynamics and total amount of germinated seeds was significantly influenced by the species (Table 1). *L. perenne* germinated most quickly and had the highest germinating capacity (93%), the lowest germinating capacity was found with *P. pratensis* (72%).

Table 1. Proportion of germinated seeds (%)

	Day of germinating after the stress				
	7th	10th	13th	16th	29th
L. perenne	26.0c	67.6 e	85.7e	90.4d	93.4e
F. rubra Viktorka	2.1ab	24.1d	57.0d	73.1c	83.6d
F. rubra Barborka	3.0ab	32.5b	63.5b	78.9c	86.6a
F. rubra Petruna	0.5ab	11.8c	34.6c	49.9c	64.7cd
P. pratensis	0.0a	0.6a	12.0a	39.6a	71.6b
D. caespitosa	4.6b	24.6c	59.5cd	75.3c	82.3c
Imbition days					
1	3.3ab	23.5b	47.7a	65.0ab	79.9b
2	4.8bc	24.9b	50.1a	67.5b	82.4bc
3	5.5bcd	23.9b	47.3a	66.4b	79.9b
4	12.5e	38.8d	61.3b	72.8c	81.5bc
5	8.5d	33.3c	58.6b	72.5c	82.3bc
6	7.4cd	26.4b	47.9a	61.2a	73.8a
Control	0.2a	17.3a	51.5a	68.8bc	82.8c

a, b, c, d – homogenous groups (LSD $\alpha = 0.05$)

The length of imbibition before water stress significantly influenced the total germination rate of the seed. The highest germination capacity (average of all the species 83%) was with the control variant (continuous germinating without a drought stress), whilst the seed imbibed for six days had significantly the lowest germination capacity (74%). The same trend was found for all the grass species with the exception of *P. pratensis*; it was not statistically significant for *L. perenne* – possibly because of its larger seed size (probably different effect of drying) and high energy of germination. The dynamics of germination of the seed differed with the different times of imbibition before the stress – the average number of germinated seeds until the 16th day after the stress was highest with the seed imbibed for 4 days (statistically significant only until the 13th day – Table 1). This difference was not found later on. At the beginning (until the 10th day) the control variant had the lowest number of germinated seeds. The head start of the previously imbibed seed was not pronounced proportionally – all the imbibed seeds started to germinate approximately 2 days earlier than the control seed. Later a detrimental effect of the drought stress (Hess, 1983) was found with some grass species, so that, from the 16th day the lowest average number of germinated seed was noted by the variant imbibed six days before the stress, particularly with *F. rubra* Viktorka, *F. rubra* Petruna, *F. rubra* Barborka and *D. caespitosa* (Figure 1). It was not noted with *P. pratensis* (Figure 1) as it germinates very slowly and 6 days of imbibition were not sufficient to reach the stage of germination in which the seed could be damaged.

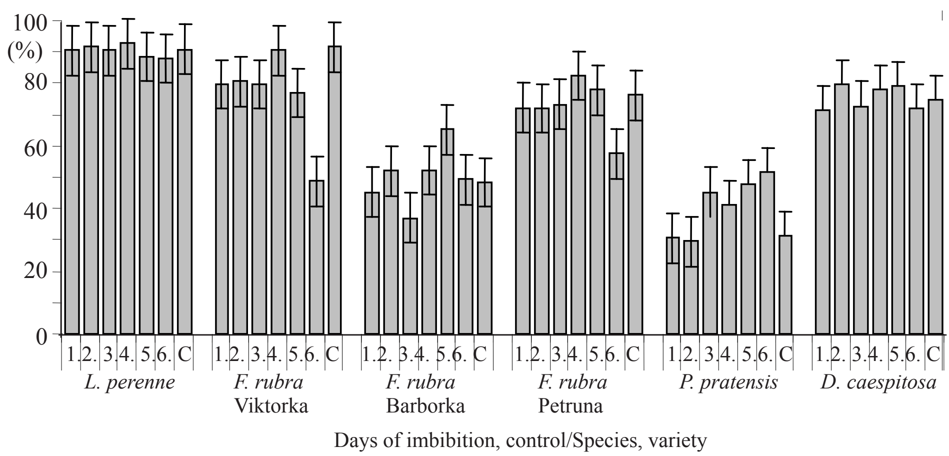

Figure 1. Number of germinated seeds in 16th day after water stress

Conclusions

The results show that not only the total germination capacity of the seed but also the dynamics of germination can be significantly influenced by drought stress during imbibition. The effect depends on the grass species, variety, and temperature regime (Martinek and Svobodová, 2007).

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The response of lawn varieties of *Poa pratensis* to drought stress

Mastalerczuk G. and Borawska-Jarmułowicz B.

Warsaw University of Life Sciences, Department of Agronomy, Warsaw, Poland
E-mail:grazyna_mastalerczuk@sggw.pl

Abstract

Growth as well as the aboveground mass of plants and mass of roots of three lawn varieties of *Poa pratensis* were compared in a greenhouse pot experiment with six replications. The varieties were sown as pure stands. The study was performed on mineral soil at three soil moisture levels: 60%, 70%, 80% capillary water capacity. Half of the pots with plants in the tillering phase were treated by simulated drought for four weeks. In the absence of simulated drought, independent of soil moisture, variety Alicja (PL) had the highest number of shoots as well as the highest aboveground mass and root mass, whereas variety Miracle (NL) was the worst. There was differential response of the varieties to drought. Low tolerance to drought was observed with variety Alicja, which had the worst regrowth of plants (mean 10% only at the lowest soil moisture). The best regeneration after drought was observed with variety Miracle (90–98%) independent of soil moisture.

Keywords: drought stress, *Poa pratensis*, resistance, soil water content

Introduction

Drought is the main environmental factor affecting growth and development of plants. In the face of global warming and reduced fresh water resources it became important to search for any species with good drought resistance. *Poa pratensis* L. is the most widely grown lawn grass in Poland. The water requirement of this species is rather low, but depends on the variety (Schmidt and Everton, 1985). The aim of this paper was to compare the drought resistance of three *Poa pratensis* lawn varieties grown at different soil moisture conditions and to relate this to aboveground mass and root mass as well as the regeneration of plants after water stress.

Materials and methods

The experiment was established in controlled conditions in the greenhouse of the Warsaw University of Life Sciences in 2007. Growth, as well as the aboveground mass and mass of roots, of three lawn varieties of *Poa pratensis* (Alicja PL, Ani PL, Miracle NL) were compared in a pot experiment. The grasses were grown in pots (220 mm diameter and 240 mm deep soil) in six replications. The varieties were sown pure with seed rates of 12 g m^{-2}. The study was performed on mineral grey-brown Podzol at three soil moisture levels: 60%, 70%, 80% capillary water capacity. Water losses were made up using a moisture meter type HH2 (Delta-T Devices Ltd. UK) and the distilled water was applied three times per week. The concentration of available soil phosphorus and potassium was high, magnesium was medium and the soil pH_{KCl} was 6.0. Fertilization was applied before sowing (g per pot): N – 1.12, P – 0.62, K – 0.35 and after every cut (g per pot): N – 0.1. The plants were defoliated once a week during the period of investigation at height of 3 cm. Half of the pots with plants in the tillering phase (20 weeks after sowing) were treated with simulated drought (no water application) for four weeks. The other half of the pots was treated as a control. The number of shoots, aboveground biomass (plants cut at the level of soil) and mass of roots were evaluated before starting and after stress. The number of shoots that survived two weeks from drought stress was also recorded. The grass root mass was assessed by the soil-core method (Troughton, 1981) from one layer of the soil (0–10 cm). The experimental data were evaluated using analysis of variance (one way ANOVA).

Results and discussion

The results presented at Figure 1 indicate that in the control treatments *Poa pratensis* varieties differed in aboveground mass of plants and mass of roots. Alicja variety had higher aboveground mass, independent of soil moisture, by 25–35% compared to Ani and Miracle varieties.
Values on diagram followed with the same letters had no significant differences between them at the probability level of $P = 0.05$ according to Tukey's test.
The mass of roots was also the highest for Alicja variety especially with moisture at 70% and 80% capillary water capacity (0.44–0.40 DM kg m^{-2}), whereas Ani and Miracle had

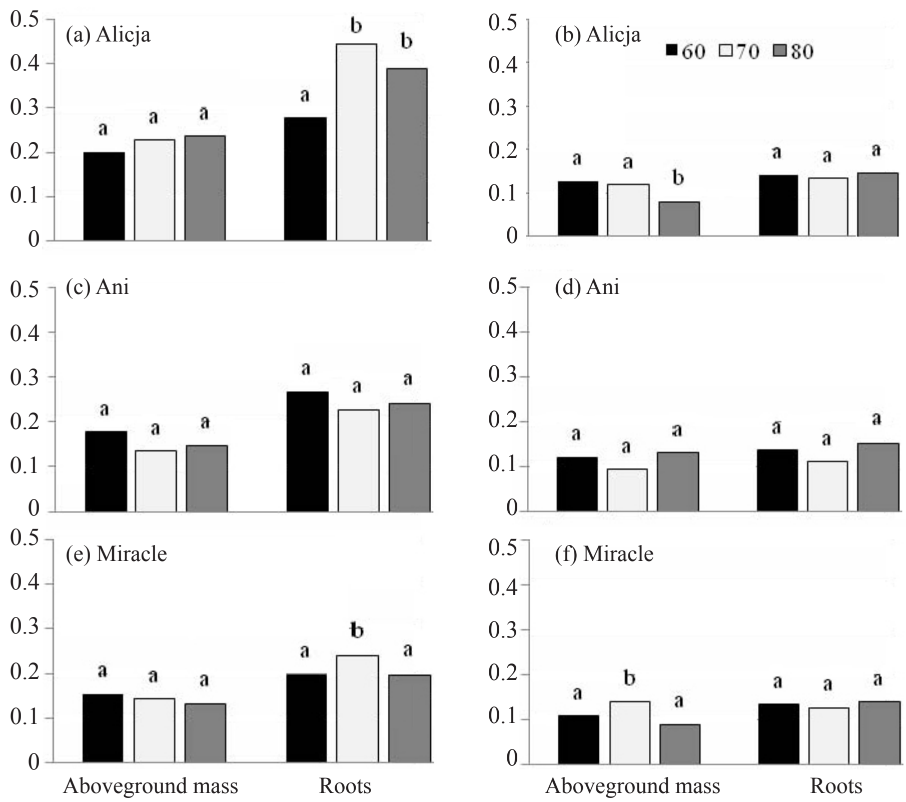

Figure 1. Aboveground mass of plants and mass of roots (DM kg m^{-2}) of *Poa pratensis* varieties (Alicja, Ani, Miracle) at three soil moisture levels (60%, 70%, 80% capillary water capacity) in control (a, c, e) and after drought stress (b, d, f)

similar root masses (0.20–0.27 DM kg m^{-2}). Only with Miracle variety had root mass significantly higher with moisture at 70% CC compared with the other moisture treatments. It was observed that the aboveground mass as well as root mass was clearly affected by simulated drought, with the result that the whole biomass of the plants was reduced. The most strong reaction was found with Alicja (Żurek, 2006), while the Miracle variety was the most resistant to drought conditions. At the same time all of the varieties had similar plant biomass independent of soil moisture treatment prior to simulated drought.
Differences in number of shoots among varieties were observed at each water capacity before stress, in control and after stress (Table 1). Alicja variety had the largest number of shoots (999–1,117) in control independent of soil moisture while Ani variety had more shoots at 60% capillary water capacity and Miracle at 70% CC than in other moisture treatments. Drought stress decreased noticeably the number of shoots of *Poa pratensis* varieties at all soil moisture levels. Low resistance to drought was observed with variety Alicja, which had the worst regrowth of plants (mean 10% only on the lowest soil moisture). The best survival of plants after drought was observed at var. Miracle (93–97%) independent of soil moisture.

Table 1. The number and the survival of shoots (%) per pot of *Poa pratensis* varieties (Alicja, Ani, Miracle) at three soil moisture levels (60%, 70%, 80% capillary water capacity)

Variety	Capillary water capacity (%)											
	60				70				80			
	before stress	control	after stress	survival	before stress	control	after stress	survival	before stress	control	after stress	survival
Alicja	743	999	534	10.0	806	1117	776	0.0	704	1117	537	1.7
Ani	537	858	428	55.0	460	697	258	23.3	562	792	458	56.7
Miracle	511	674	337	97.0	654	729	495	93.3	600	663	324	93.3

Before stress – plants in the tillering phase, 20 weeks after sowing (beginning of the experiment)
After stress – plants in the tillering phase, 24 weeks after sowing
Control – plants in the tillering phase, 24 weeks after sowing at 60%, 70%, 80% CC
Survival – 2 weeks after finish of drought stress

Conclusion

In summary, drought stress reduced aboveground mass of plants, number of shoots and mass of roots of all *Poa pratensis* varieties, independent of soil water capacity. The best regeneration after drought was observed in variety Miracle independent of soil moisture while variety Alicja had low resistance to drought.

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Forage yields in urban populations of Hungarian vetch (*Vicia pannonica* Crantz) from Serbia

Mihailović V.[1], Mikić A.[1], Ćupina B.[2], Krstić Đ.[2], Erić P.[2], Hauptvogel P.[3] and Karagić Đ.[1]

[1]*Institute of Field and Vegetable Crops, Novi Sad, Serbia*
[2]*University of Novi Sad, Faculty of Agriculture, Novi Sad, Serbia*
[3]*Research Institute of Plant Production, Piešťany, Slovakia*
E-mail: vojamih@ifvcns.ns.ac.yu

Abstract

Hungarian vetch (*Vicia pannonica* Crantz) is widely distributed in the wild flora of Serbia and represents an important forage field crop. A small-plot trial was carried out in 2007 and 2008 at the Experimental Field of the Institute of Field and Vegetable Crops at Rimski Šančevi, including ten Hungarian vetch populations collected in diverse urban regions of Belgrade and Novi Sad. All the populations were sown in early October, with a rate of 180 viable seeds m^{-2}, and cut in the stages of full flowering and first pod formation. The population MM 04/34 had the highest average green forage yield (48.7 Mg ha^{-1}), while the population MM 04/32 had the highest average forage dry matter yield (12.0 Mg ha^{-1}). The lowest yields were in the population MM 04/26, with 16.5 Mg ha^{-1} of green forage and 4.0 Mg ha^{-1} of forage dry matter.

Keywords: forage dry matter, green forage, Hungarian vetch, *Vicia pannonica*, yield, yield components

Introduction

Vetches (*Vicia* spp.) represent widely distributed legume species in the regions with temperate conditions. Apart from faba beans (*V. faba* L.), common vetch (*V. sativa* L.), Hungarian vetch (*V. pannonica* Crantz), and hairy vetch (*V. villosa* Roth) are among the most important vetches for agriculture (Mihailović *et al.*, 2005a). Hungarian vetch is traditionally grown in the countries of the ex-Soviet Union, the Balkan Peninsula, Central Europe, and the Eastern Mediterranean (Orak, 2000). Together with other vetch species, where common vetch is the dominant one, Hungarian vetch in Serbia is grown on about 7,500 ha and used exclusively as forage (Mihailović *et al.*, 2005b). Hungarian vetch remains the only cultivated vetch species with no known toxins present in its grain (Matić *et al.*, 2007).

The only Hungarian vetch breeding programme in Serbia is being carried out in the Institute of Field and Vegetable Crops in Novi Sad, with two registered cultivars in Serbia so far (Mihailović *et al.*, 2008), namely NS Panonika (1979) and Panonka (2007). This breeding programme is based upon the utilisation of the Annual Forage Legumes Collection (AFLCNS), which is constantly enriched with new accessions, especially of the wild populations of several vetch species (Mihailović *et al.*, 2007b). At the end of 2009, AFLCNS contained 44 accessions of Hungarian vetch.

The aim of the study was to evaluate forage yields in ten urban populations of Hungarian vetch of Serbian origin.

Material and methods

A small-plot trial was carried out from the autumn of 2006 to the spring of 2008 at the Experimental Field of the Institute of Field and Vegetable Crops at Rimski Šančevi. It included ten wild populations of Hungarian vetch collected at diverse locations in the urban regions of Belgrade and Novi Sad during the regular annual joint expeditions of the Institute of Field and Vegetable Crops and Faculty of Agriculture in 2004. The collected populations were included in the AFLCNS and maintained and multiplied, with the main aim being the evaluation of their agronomic characteristics and their potential utilisation in the development of new cultivars for both forage and grain.

All ten populations were sown in early October, with a rate of 180 viable seeds m^{-2} (Mihailović *et al.*, 2006), a plot size of 5 m^2 and three replicates. Each population was cut in its stages of full flowering and formation of the first pods, as an optimal balance between forage yield and quality, which was in the first half of May in both years (Mikić *et al.*, 2008).

Plant height (cm), the numbers of stems and lateral branches ($plant^{-1}$), the number of internodes ($plant^{-1}$), and the green forage yield per plant (g) were determined from plant samples taken before cutting. The green forage yield per area unit (Mg ha^{-1}) was measured *in situ* immediately after cutting. The forage dry matter yield (Mg ha^{-1}) was determined upon the basis of the ratio between masses of green forage samples after and before drying at room temperature.

The results were processed by analysis of variance (ANOVA), applying the Least Significant Difference (LSD) test using the computer software MSTAT-C.

Results and discussion

Forage yield components. There were significant differences in the average values of all the forage yield components evaluated (Table 1). The average number of plants before

Table 1. Average values of forage yield components in ten urban populations of Hungarian vetch for the years 2007 and 2008 at Rimski Šančevi

Population	Number of plants before cutting (m^{-2})	Plant height (cm)	Number of stems and lateral branches ($plant^{-1}$)	Number of internodes ($plant^{-1}$)
MM 04/25	119	80	9.1	144.2
MM 04/26	130	80	1.3	23.4
MM 04/27	124	78	2.8	81.3
MM 04/28	147	77	2.3	53.9
MM 04/29	133	87	2.1	46.8
MM 04/30	122	65	3.4	69.1
MM 04/31	88	72	16.4	264.7
MM 04/32	94	81	7.2	168.3
MM 04/33	110	84	8.9	216.2
MM 04/34	99	93	10.1	210.0
$LSD_{0.05}$	16	9	2.7	35.6
$LSD_{0.01}$	25	12	4.1	52.1

cutting ranged from 88 m^{-2} in MM 04/32 to 147 m^{-2} in MM 04/28. The tallest plants were in MM 04/34 (93 cm), while the shortest plants were in MM 04/30 (65 cm). The population MM 04/31 had the greatest average numbers of both stems and lateral branches (16.4 $plant^{-1}$) and internodes (264.7 $plant^{-1}$), while the population MM 04/26 had the smallest average numbers of both stems and lateral branches (1.3 $plant^{-1}$) and internodes (23.4 $plant^{-1}$).

Forage yields. The highest forage yields per plant were in MM 04/31, with 54.20 g $plant^{-1}$ of green forage and 13.01 g $plant^{-1}$ of forage dry matter (Table 2). The majority of the populations evaluated, especially MM 04/34 with 48.7 Mg ha^{-1}, had higher green forage yields in comparison to the preliminary results in the same conditions (Mihailović *et al.*, 2007a). At the same time, populations such as MM 04/32, with 12.0 Mg ha^{-1}, had much higher yields than is considered satisfactory for dry, continental regions (Uzun *et al.*, 2004).

Seed yields. Although not a subject of this research, it is notable that all the populations of Hungarian vetch evaluated were characterised by less prominent pod dehiscence than other vetch species and a greater potential for high and reliable seed yields.

Table 2. Average values of forage yields in ten urban populations of Hungarian vetch for the years 2007 and 2008 at Rimski Šančevi

Population	Green forage yield (g $plant^{-1}$)	Green forage yield (Mg ha^{-1})	Forage dry matter yield (g $plant^{-1}$)	Forage dry matter yield (Mg ha^{-1})	Forage dry matter proportion
MM 04/25	27.12	33.7	5.97	7.4	0.22
MM 04/26	12.29	16.5	2.95	4.0	0.24
MM 04/27	13.26	17.8	3.32	4.5	0.25
MM 04/28	14.51	20.9	3.34	4.8	0.23
MM 04/29	15.43	21.2	3.24	4.4	0.21
MM 04/30	22.68	27.3	4.54	5.5	0.20
MM 04/31	54.20	45.7	13.01	11.0	0.24
MM 04/32	48.74	46.0	12.67	12.0	0.26
MM 04/33	40.42	46.2	8.49	9.7	0.21
MM 04/34	46.71	48.7	10.28	10.7	0.22
$LSD_{0.05}$	8.49	7.6	2.21	2.1	0.02
$LSD_{0.01}$	12.04	10.8	2.93	3.7	0.03

Conclusions

The evaluated urban populations of Hungarian vetch show a wide variability of agronomic characteristics related to forage. The relationship between the number of plants before cutting and forage yields demands more detailed research into optimal crop density. The populations with high and stable forage yields may be used for the development of new cultivars of Hungarian vetch, with improved forage dry matter quality and seed yields.

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Forage yields in urban populations of large-flowered vetch (*Vicia grandiflora* Scop.) from Serbia

Mikić A.[1], Mihailović V.[1], Ćupina B.[2], Krstić Đ.[2], Hauptvogel P.[3], Drobná J.[3] and Antalíková G.[3]

[1]*Institute of Field and Vegetable Crops, Novi Sad, Serbia*
[2]*University of Novi Sad, Faculty of Agriculture, Novi Sad, Serbia*
[3]*Research Institute of Plant Production, Piešťany, Slovakia*
E-mail: mikic@ifvcns.ns.ac.yu

Abstract

Large-flowered vetch (*Vicia grandiflora* Scop.) is one of the most widely distributed vetch species in Serbia, often found growing along with narrow-leafed vetch (*Vicia sativa* L. ssp. *nigra* (L.) Ehrh.) and hairy vetch (*Vicia villosa* Roth). A small-plot trial was carried out in 2007 and 2008 at the Experimental Field of the Institute of Field and Vegetable Crops at Rimski Šančevi, including ten large-flowered vetch populations collected in diverse urban regions of Belgrade and Novi Sad. All the populations were sown in early October, with a rate of 150 viable seeds m^{-2}, and cut in the stages of full flowering and first pod formation. The highest yields were in the population MM 05/07, with 40.3 Mg ha^{-1} of green forage and 13.8 Mg ha^{-1} of forage dry matter. The lowest yields were in the population MM 03/17, with 22.7 Mg ha^{-1} of green forage and 5.0 Mg ha^{-1} of forage dry matter.

Keywords: forage dry matter, green forage, large-flowered vetch, *Vicia grandiflora*, yield, yield components

Introduction

Large-flowered vetch (*Vicia grandiflora* Scop.) is one of the most widely distributed of all vetch species. Often found growing along with narrow-leafed vetch (*Vicia sativa* L. ssp. *nigra* (L.) Ehrh.) and hairy vetch (*Vicia villosa* Roth), it is also present in the flora of Serbia (Krstić *et al.*, 2007). Large-flowered vetch is a species that germinates in late summer and early autumn and has a rather prominent tolerance to low temperature and long winters (DeGregorio *et al.*, 1995).
Recently it has been demonstrated that the wild populations of large-flowered vetch have a considerable potential for forage yields (Ćupina *et al.*, 2007). A large-flowered vetch collection has been established within the Annual Forage Legumes Collection (AFLCNS) of the Institute of Field and Vegetable Crops (Mihailović *et al.*, 2008a), which, by the end of 2008, contained 462 accessions (Mikić *et al.*, 2008).
The aim of the study was to evaluate forage yields in ten urban populations of large-flowered vetch of Serbian origin.

Materials and methods

A small-plot trial was carried out from the autumn of 2006 to the spring of 2008 at the Experimental Field of the Institute of Field and Vegetable Crops at Rimski Šančevi. It included ten wild populations of large-flowered vetch collected at diverse locations in the

urban regions of Belgrade and Novi Sad during the regular annual joint expeditions of the Institute of Field and Vegetable Crops and Faculty of Agriculture from 2003 to 2006. The collected populations were included in the AFLCNS, maintained, and multiplied with the main aim being the evaluation of their agronomic characteristics related to forage yields. All ten populations were sown in early October, with a rate of 150 viable seeds m^{-2}, a plot size of 5 m^2 and three replicates. Each population was cut in its stages of full flowering and the formation of the first pods, as an optimal balance between forage yield and quality, that in both years was in the first half of May (Mihailović *et al.*, 2008b).
Plant height (cm), the numbers of stems and lateral branches ($plant^{-1}$), the number of internodes ($plant^{-1}$), and the green forage yield per plant (g) were determined from plant samples taken before cutting. The green forage yield per area unit (Mg ha^{-1}) was measured *in situ* immediately after cutting. The forage dry matter yield (Mg ha^{-1}) was determined upon the basis of the ratio between masses of green forage samples after and before drying at room temperature.
The results were processed by analysis of variance (ANOVA), applying the Least Significant Difference (LSD) test using the computer software MSTAT-C.

Results and discussion

Forage yield components. Significant differences at both the levels of 0.05 and 0.01 existed in the average values of all the forage yield components evaluated (Table 1). The population MM 03/19 had the greatest number of plants before cutting (140 m^{-2}), while the population MM 04/08 had the smallest number of plants before cutting (92 m^{-2}). The average plant height varied between 43 cm in MM 03/17 and 81 cm in MM 03/14. The population MM 06/26 had the greatest average values of both numbers of stems and lateral branches (16.5 $plant^{-1}$) and the number of internodes (202.3 $plant^{-1}$).

Table 1. Average values of forage yield components in ten urban populations of large-flowered vetch for the years 2007 and 2008 at Rimski Šančevi

Population	Number of plants before cutting (m^{-2})	Plant height (cm)	Number of stems and lateral branches ($plant^{-1}$)	Number of internodes ($plant^{-1}$)
MM 03/10	133	75	8.9	114.5
MM 03/14	107	81	14.2	161.2
MM 03/16	122	66	13.2	136.2
MM 03/17	129	43	10.5	98.5
MM 03/19	140	51	9.0	94.5
MM 03/25	127	66	10.2	120.6
MM 04/08	92	78	15.1	179.8
MM 05/07	131	71	10.8	128.7
MM 06/24	128	64	9.4	110.6
MM 06/26	122	64	16.5	202.3
$LSD_{0.05}$	11	8	1.6	25.3
$LSD_{0.01}$	18	11	2.4	42.1

Forage yields. The average values of green forage yields in the ten populations of large-flowered vetch (Table 2) confirm the preliminary results of the evaluation of both the green forage (Mihailović *et al.*, 2007) and forage dry matter yields of this species in the same conditions (Mihailović *et al.*, 2008c). The population MM 05/07 had the highest yields of both green forage (40.3 Mg ha^{-1}) and forage dry matter (13.8 Mg ha^{-1}).
Seed yields. Although not shown within the results of this research, it should be noted that in certain populations there were selected lines with more than two pods per node, resulting in higher and more reliable seed yields, while the majority of the populations are characterised by non-uniform maturity, prominent pod dehiscence, and large seed losses.

Table 2. Average values of forage yields in ten urban populations of large-flowered vetch for the years 2007 and 2008 at Rimski Šančevi

Population	Green forage yield		Forage dry matter yield		Forage dry matter proportion
	(g plant^{-1})	(Mg ha^{-1})	(g plant^{-1})	(Mg ha^{-1})	
MM 03/10	19.86	24.7	6.30	7.8	0.32
MM 03/14	30.00	31.3	8.63	9.0	0.29
MM 03/16	28.57	32.7	7.66	8.8	0.27
MM 03/17	18.28	22.7	4.03	5.0	0.22
MM 03/19	20.13	25.0	4.43	5.5	0.22
MM 03/25	32.11	38.6	8.04	9.7	0.25
MM 04/08	42.16	39.8	12.29	11.6	0.29
MM 05/07	32.45	40.3	11.10	13.8	0.34
MM 06/24	23.94	29.8	7.93	9.9	0.33
MM 06/26	23.17	28.8	6.61	8.2	0.29
$LSD_{0.05}$	6.54	6.5	1.45	1.8	0.03
$LSD_{0.01}$	9.48	9.1	2.11	2.6	0.04

Conclusions

Among the populations evaluated there are many with a promising potential for forage yields and that deserve to be included in the development of the first Serbian cultivars of large-flowered vetch. One of the goals of such breeding programmes must be a significant improvement in both determinant stem growth and maturing uniformity, resulting in increased seed yields.

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Perennial herbaceous species biomass as potential bioenergy feedstock

Pappas I.[1], Koukoura Z.[1], Goulas Ch.[1], Kiparissides C.[2,3] and Tananaki Ch.[4]

[1]*Aristotle University, Faculty of Forestry and Natural Environment, Range Science Laboratory, Thessaloniki, Greece*
[2]*Aristotle University, Department of Chemical Engineering, Thessaloniki, Greece*
[3]*Chemical Process Engineering Research Institute, Centre for Research & Technology Hellas, Thessaloniki, Greece*
[4]*Aristotle University, School of Agriculture, Apiculture and Sericulture Laboratory, Thessaloniki, Greece*
E-mail: pappas@for.auth.gr

Abstract

The purpose of this study was to evaluate several herbaceous perennial species according to their structural carbohydrate content for bioenergy production. The cell wall structural carbohydrate content was assessed using the Van Soest Fibre Analysis System method. Our results revealed that legumes had a lower cellulose and hemicellulose content than grasses and warm-season (C_4) grasses had much more hemicellulose than cold-season (C_3) ones, indicating that perennial species with a high carbohydrate content can be converted into bioenergy by thermochemical and biochemical methods.

Keywords: lignocellulosic biomass, bioenergy, C_3–C_4 grasses, legumes

Introduction

Herbaceous plant biomass is a primary energy source for ruminant feeding and bioenergy production with thermochemical and biochemical methods (Rowe *et al*., 2009). These conversions do not conflict because rangelands and marginal croplands can support them. Plants' cell wall structural carbohydrates, which consist of cellulose, hemicellulose, and lignin, have a major impact on biomass conversion efficiency (Cherney *et al.,* 1988). Perennial plant species (grasses and legumes), as well as cold-season (C_3) and warm-season (C_4) grasses, occupy mountainous areas with stressed environmental conditions because of their high adaptation ability. They have high yield potential despite their moderate-low input and higher cellulose and lignin content than annual species (Dien *et al*., 2006). The purpose of this study was to evaluate several herbaceous perennial species according to their structural carbohydrate content for bioenergy production.

Materials and methods

In our study we investigated the chemical composition of 12 C_3 grasses (*Agropyron cristatum* L., *Bromus inermis* L., *Dactylis glomerata* L., *Eragrostis chloromelas* St., *Festuca valesiaca* Sch., *Hordeum bulbosum* L., *Lolium perenne* L., *Melica ciliata* L., *Oryzopsis miliacea* L., *Phalaris aquatica* L., *Phleum phleoides* L., *Stipa pennata* L.), 4 C_4 grasses (*Andropogon hirtum* L., *Chrysopogon gryllus* L., *Cynodon dactylon* L., *Dichanthium ischaemum* L.), and 4 perennial legumes (*Astragalus austraegaeus* R., *Lotus corniculatus* L., *Medicago sativa* L., *Medicago falcata* L.). Biomass samples were collected about mid-June during the fruit stage. The samples were dried at 60°C for 48 h and then ground in a mill so that they could be passed through a 1-mm screen prior to analyses. The neutral detergent fibre (NDF), acid detergent fibre (ADF), and acid detergent lignin (ADL) were determined using the detergent fibre system (Van Soest *et al.*, 1991). The cellulose content was calculated as ADF minus ADL, hemicellulose as the difference between NDF and ADF, and lignin as the ADL value. One-way ANOVA was used to compare the chemical composition of the growth forms. Further differences were evaluated with the LSD post hoc test, at a level of significance of 0.05. The SPSS 15.0 statistical software was used (Kinnear and Gray, 2008).

Results and discussion

Perennial legumes had a significantly lower cell wall and higher lignin content compared to perennial grasses (Table 1). They had a higher proportion (73%) of their cell walls (NDF) as ADF, indicating a lower hemicellulose content in their tissues, which is in agreement with the results of Fulkerson *et al.* (2006).

Perennial grasses had a much higher cellulose and hemicellulose content than perennial legumes (Figure 1). According to Arzani *et al.* (2006) this could be due to higher stem/leaves ratios of grasses at the time of the sample collection, which was the end of the growing season. Because grasses have hollow stems they might contain relatively more fibrous tissues in their stems compared with other species. The higher proportion of hemicellulose in C_4 grasses than C_3 temperate species is attributed to their anatomical characteristics and different photosynthetic process. According to Heaton *et al.* (2008), the maximum efficiencies with which plants store solar energy as biomass, using the existing pathways of energy transduction into stored carbohydrate, are 6% and 4.6% for C_4 and C_3 plants, respectively. Additionally, Gherbin *et al.* (2006) point out that C_3 and C_4 grasses often differ in their nutritional quality.

Cellulose is a natural polymer composed exclusively of glucose linked via β-1.4 glycosidic bonds. In general, hemicellulose consists of a main chain xylan backbone (β-1.4 linkages) with various branches of arabinose, mannose, and galactose monomeric sugars, which, after pretreatment and hydrolysis, can be converted into ethanol by microbial fermentation (Petersson *et al.,* 2007). Lignin, as the third most common polymer found in plant cell walls, functions as a binding and encrusting material and has a high heating value as a result of its higher carbon content and can therefore be utilised to produce

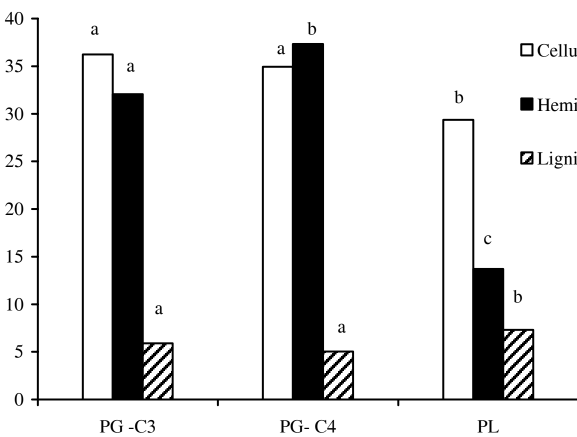

Figure 1. Structural carbohydrates (g kg^{-1} DM) of perennial herbaceous species (PG-C3: C_3 perennial grasses, PG-C4: C_4 perennial grasses, PL: perennial legumes)

Table 1. Cell wall concentration of perennial herbaceous species

Growth form	NDF (g kg^{-1} DM)	ADF (g kg^{-1} DM)	ADL (g kg^{-1} DM)	ADF/NDF
C_3 – grasses	748.7^{a*}	427.2^{a}	62.0^{a}	0.57^{a}
C_4 – grasses	781.1^{a}	408.2^{a}	53.5^{a}	0.52^{a}
Legumes	529.3^{b}	387.9^{ab}	79.4^{b}	0.73^{b}

*Letters in the same column indicate differences at a level of significance of 0.05 using the LSD post hoc test

bioenergy through thermochemical processes (combustion, pyrolysis, and gasification) (McKendry, 2002).

Conclusions

The results showed that the biomass of perennial grasses and legumes species can be used as a renewable biofuel resource because of their high content of structural carbohydrates. Warm-season grasses were found to be more promising than other perennial species.

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Extensively used grassland as a basis of low input livestock systems and as a resource of energy and raw materials

Pötsch E.M.[1], Buchgraber K.[1], Resch R.[1], Häusler J.[1], Ringdorfer F.[1], Pöllinger A.[1], Rathbauer J.[2] and Amon T.[3]

[1]*Agricultural Research and Education Centre Raumberg-Gumpenstein, Irdning, Austria*
[2]*BLT Biomass-Logistics-Technology, Francisco Josephinum, Wieselburg, Austria*
[3]*University of Natural Resources and Applied Life Sciences, Vienna, Austria*
E-mail: erich.poetsch@raumberg-gumpenstein.at

Abstract

In many European countries the traditional agricultural use of extensive grassland seems to be no longer competitive. To avoid grassland abandonment with all its negative consequences for ecology, economy and society, as well as to keep open the cultural landscape, alternative land use concepts have to be developed and tested. Within a comprehensive research project, carried out by the Agricultural Research and Education Centre Raumberg-Gumpenstein at Buchau/Styria, different agricultural and non-agricultural strategies have been investigated. Beside extensive livestock production systems with grazing heifers, suckler cows and sheep, grassland has also been considered and analyzed as a sustainable and potential resource of energy. The focus was given to the use of grassland biomass for methane production and as combustion material. Finally, different methods to keep the landscape open without any productive use have been tested with a special concentration on floristic diversity. Selected results from the first project period of 5 years will be presented.

Keywords: permanent grassland, alternative land use, biogas production, floristic diversity

Introduction

Grassland is a dominant part of cultural landscapes in alpine and mountainous regions of Europe. In some Austrian provinces, the proportion of permanent grassland covers more than 95% of the agriculturally used area. The maintenance and sustainable management of grassland is therefore of great interest both for farmers and the society. Structural changes in rural areas, overproduction and more cost-effective production in favourable regions have led to an increasing abandonment of grassland in disadvantaged areas. About 10% to 15% of the total biomass growing on Austrian grassland is no longer used for traditional milk and meat production. To avoid the invasion of bushes and trees which inevitably leads to the development of forest, alternative concepts of grassland use are required. These concepts should be both practicable and sustainable considering economy and ecology.

Material and methods

Different farming and non-farming concepts of grassland use have been studied within a comprehensive research project carried out on an extensively used grassland area of nearly 20 ha at Buchau/Styria (Table 1). The climatic conditions are characterized by a mean annual temperature of 6.0°C and an annual precipitation of 1,250 mm. In addition to low input production systems with grazing heifers, suckler cows and sheep, grassland has also been considered as a potential resource of energy. Attention was given to the use of grassland biomass for methane production and as combustion material. The methane yield of grassland with different cutting and fertilizing intensities was analyzed by means of batch-trials (Amon *et al.,* 2006). Fuel analyses of grass pellets were carried out considering emissions and thermal efficiency. Finally, different mulching systems to keep the landscape open without any productive use have been tested with a special concentration on technique, labour input and operation method. All the different production systems and treatments were also assessed for soil parameters, root growth, floristic diversity and economics.

Table 1. Production systems/treatments and investigations/analyses in the grassland extensification project Buchau/Styria (2001–2005)

Production systems/treatments	Analyses, surveys
Heifers, steers and suckler cows	yield, forage quality, weight gain, meat quality
Ewes and wethers	yield, forage quality, weight gain, growing and slaughter performance
Biogas production	yield, forage quality, specific methane production, methane yield
Hay pellets	yield, forage quality, combustion emissions, thermal efficiency
Mulching	yield, power requirement, labour input

Results and discussion

Yield and forage quality of extensively used grassland

Grassland yields on the experimental site ranged between 4.8 and 6.4 t of DM $year^{-1}$, depending on the number of cutting and grazing frequency. There were enormous differences in forage quality varying from 6.8 MJ NEL kg DM^{-1} for fresh grass on the pastures to 1.3 MJ NEL kg DM^{-1} for the mulching material. The energy yield varied from 12.7 to 34.3 GJ NEL ha^{-1} $year^{-1}$, which is much lower than the productivity of meadows and pastures in favourable regions.

Fattening performance of cattle

Without any use of concentrates, the average gain of heifers was 1,234 g day^{-1} and that of the steers was 1,281 g day^{-1}. There was no significant difference concerning sex and number of lactation of the dams. The carcass dressing percentage reached 56% in both groups with a significant difference in the carcass judging result between heifers (2.8) and steers (2.5) following the EUROP classification system. Although there were clear differences in some parameters of meat quality between heifers and steers, no significant differences occurred in the cooking properties and tasting results which were excellent overall. The findings indicate that even on extensively used grassland, high gain and outstanding fattening performance can be reached with a well adapted herd and grazing management.

Ewes, wethers and lamb performance

During the first project period, relatively high losses of lambs (19%) occurred, mainly caused by the very extensive management system. The average daily gain of male lambs at 277 g was significantly higher than that of female lambs at 188 g day^{-1}. There were significant differences between female and male lambs in carcass dressing percentage, proportion of fat, tallow and bones but no differences in cooking properties. The average daily gain of wethers which were kept on pastures without any concentrate supplement reached 122 g. The carcass dressing percentage of the wethers was significantly lower than that of the lambs.

Methane productivity of extensively used grassland

The specific methane production presented in normalized litre methane per kg organic dry matter (l_N CH_4 kg oDM^{-1}) showed significant differences between the cutting frequencies and conservation systems. The highest specific methane production was achieved for wet and pre-wilted silage with approximately 300 l_N CH_4 kg oDM^{-1} and the one-cut system showed lower methane productivity with 269 l_N CH_4 kg oDM^{-1} than for more frequent cuts. Independent of the cutting frequency, haylage resulted in significantly lower methane production than for the silages (Table 2).

Table 2. Specific methane productivity of grassland biomass (l_N CH_4 kg oDM^{-1})

Conservation system	One-cut grassland	Two-cut grassland	Three-cut grassland
Wet silage	$280^{a,c}$	$305^{a,d}$	$305^{a,d}$
Pre-wilted silage	$285^{a,c}$	$295^{a,c}$	$300^{a,c}$
Haylage	$243^{b,c}$	$253^{b,c}$	$255^{b,c}$

^{a,b}indicating differences between conservation systems, ^{c,d}indicating differences between cutting regimes

Compared with intensively used grassland and arable crops, the methane yield expressed in normalized m^3 methane per ha (m^3_N CH_4 ha^{-1}) of semi natural grassland was significantly lower, which results in a competitive disadvantage (Pötsch, 2008). The most productive crop is maize which in some countries leads to high losses of grassland areas with many negative consequences for environment and landscape.

Hay pellets combustion

Compared with the national Austrian standards for the quality of wood pellets, hay pellets were characterized by an extremely high ash content, which requires special adaptation of the firing equipment to avoid operational problems with the heat exchanger system. Hay pellets also exceeded the thresholds of water content and abrasion properties. The heating value of hay pellets amounted to 17.2 MJ kg^{-1} which is marginally below the accepted limit of 18.0 MJ kg^{-1}.

Grassland mulching

Different mulching equipment was tested both on flat and steep parts of the project site. The rate of work ranged between 0.4 and 1.5 ha h^{-1} depending on steepness and working width. Whilst mulching is technically possible, this is a non-productive land-management-system which led to costs of up to € 140 ha^{-1} and a negative cost-benefit ratio.

Conclusions

Extensively used grassland in mountainous regions is exposed to a strong competitive pressure. Milk and meat production, being traditional and productive land-use-systems for many generations, are increasingly given up and grassland abandonment is occurring in many regions (Peeters, 2008). The results of this project clearly indicate that there are some practicable alternative land-use-management systems that are both productive and non-productive from an agricultural point of view. Regarding economic and ecological aspects, the use of suckling cows and sheep was significantly better than the energetic/material use of grassland biomass. Independent of costs and productivity all tested systems contributed to the preservation of extensively used grassland, which was very clearly demonstrated by the development of plant communities and floristic biodiversity.

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The ensilage and nutrition quality of *Bromus marginatus* compared to other grasses

Rajčáková Ľ. and Mlynár R.

Animal Production Research Centre Nitra, Slovakia
E-mail: rajcak.vuzvpp@mail.t-com.sk

Abstract

Bromus marginatus is a grass with higher drought resistance, well adapted to low rainfall, high summer temperatures, and severe winters. The results of our study showed that a mountain brome (*Bromus marginatus* Nees ex Steud., cv. Tacit) has a high content of crude fibre and fibre complex. At the end of the elongation phase the content of crude fibre was 278.7 g, and in the full heading phase 342.8 g kg^{-1} DM. With maturation the content of water-soluble carbohydrates increased and the levels of crude protein decreased (from 160.9 to 89.8 g kg^{-1} DM), reducing sugars, fat, and ash. The optimum cut time for silage is the end of the elongation phase, at the latest the phase at the beginning of heading. Its quality is comparable with other grass species in optimum cultivation conditions. A sufficient content of WSC gives the preconditions for the good ensilage capacity of this grass. We recommend using ensilage inoculants to improve the fermentation process.

Keywords: *Bromus marginatus*, nutrition quality, ensilage quality

Introduction

The role of mountain brome (*Bromus marginatus* Nees ex Steud.) is still increasing, especially because of its higher drought resistance and good adaptation to a low amount of rainfall and higher temperatures. It is more tolerant of heat and drought than perennial ryegrass and/or timothy. Its drought tolerance is related to its extensive root system (Míka and Řehořek, 2003). The crop herbage matures more slowly compared to many other grasses and even in its early maturity phases it shows high digestibility of organic matter and excellent nutritive value (Pozdíšek *et al.,* 2002).
At ensilaging the application of biological and biological-enzymatic additives has a positive effect on the quality of the fermentation process and the nutrient levels of mountain brome silages (Rajčáková *et al.,* 2006). The improvement of the fermentation parameters in inoculated silages is manifested in a decrease in the pH value, DM losses, butyric acid, acetic acid, and other volatile fatty acids, alcohol, and NH_3-N of total N content. The inoculation of silages increases the level of lactic acid compared with untreated silage.
The aim of this work was to observe the dynamics of changes in the content of nutrients in mountain brome during the vegetation period and to compare this grass with other grass species from the viewpoint of its nutritive value, as well as its ensilage capacity.

Materials and methods

The field experiment was established at the village of Vígľaš (elevation 350 m above sea level). The average annual temperature was 7.8°C and the average annual rainfall

600 mm. The soil in the experimental area was heavier and aluminous, with a mean content of C_{ox} of 2%. In the spring 50 kg N ha^{-1} (+ 30 kg P, and 20 kg) was applied. The experiment included plots 1 × 10 m in area.
The dynamics of the changes in nutrient contents were studied in a stand which was being used for the second year. The green grass samples of mountain brome, cv. Tacit, were taken four times over May and June to determine the dry matter yield and chemical composition of the herbage. The samples were taken in the following stage of crop development: stem elongation, the beginning of heading, full heading, and the end of heading.
In the second part of the experiment other grass species – Meadow fescue (Levočská), Perennial ryegrass (Jiskra), Festulolium (Perennial ryegrass × Meadow fescue, Perun), and Festulolium (Perennial ryegrass × Tall fescue, Lofa) – were also grown together with mountain brome in the fields. All the grasses were in their first harvest year. The cutting of the grass was performed on the same date (25th May).
The cut matter of all five grass species was wilted and cut and, after homogenisation, it was ensilaged without ensilaging additives in laboratory silos with a content of 1.7 l. Grass silages were stored during fermentation in a dark room, at a temperature of 20–22°C. The experiment finished 120 days after the ensilaging and the parameters of the fermentation process were determined with the silage samples.
Samples of grass matter and silage samples were subjected to chemical analysis. All nutritional and fermentation parameters were determined according to the current norm (MP SR, 2004). Energy concentrations in the silages were calculated as described by Sommer *et al.* (1994). The results were statistically evaluated by one-factorial analysis of variance.

Results and discussion

Table 1. Nutritional value, energy, and yield of mountain brome at different stages of maturity

Parameters	Phenological phase			
	end of elongation	beginning of heading	full heading	end of heading
Dry matter (g kg^{-1} FM)	199.88	219.92	209.67	275.82
Organic matter (g kg^{-1} DM)	917.11	921.90	926.88	935.80
Crude protein (g kg^{-1} DM)	160.89	131.67	121.44	89.83
Crude fibre (g kg^{-1} DM)	278.72	311.78	342.83	343.64
ADF (g kg^{-1} DM)	294.80	330.12	354.58	366.33
NDF (g kg^{-1} DM)	503.84	576.10	591.68	615.96
WSC (g kg^{-1} DM)	120.96	121.73	104.02	140.92
Reducing sugars (g kg^{-1} DM)	66.75	68.23	58.19	62.02
Fat (g kg^{-1} DM)	28.20	28.09	23.95	24.89
Ash (g kg^{-1} DM)	82.89	78.10	73.12	64.20
ME (MJ kg^{-1} DM)	9.51	8.97	8.59	8.37
NEL (MJ kg^{-1} DM)	5.57	5.20	4.93	4.78
PDI (g kg^{-1} DM)	85.20	79.20	76.40	66.90
Yield (t DM ha^{-1})	2.40	3.03	3.77	5.63

Table 2. Nutritional value, energy, and yield of grasses

Parameters	MB Tacit	MF Levočská	PR Jiskra	FL Perun	FL Lofa
Dry matter after wilting (g, kg^{-1} FM)	187.53	237.91	208.14	187.38	187.22
Organic matter (g kg^{-1} DM)	916.39	919.26	927.44	916.57	922.51
Crude protein (g kg^{-1} DM)	116.82	88.63	72.00	95.43	81.40
Crude fibre (g kg^{-1} DM)	335.46	296.51	267.00	274.12	256.10
ADF (g kg^{-1} DM)	335.46	319.07	265.91	282.86	301.87
NDF (g kg^{-1} DM)	544.57	545.75	462.08	504.56	468.61
Total sugars (g kg^{-1} DM)	129.25	159.19	305.62	216.91	266.24
Reducing sugars (g kg^{-1} DM)	71.02	89.25	158.68	118.58	133.12
Fat (g kg^{-1} DM)	25.63	18.97	17.19	21.60	19.98
Ash (g kg^{-1} DM)	83.61	80.74	72.56	83.43	77.49
ME (MJ kg^{-1} DM)	8.40	9.05	10.11	10.01	9.94
NEL (MJ kg^{-1} DM)	4.81	5.27	6.02	5.96	5.85
PDI (g kg^{-1} DM)	69.40	53.60	43.20	57.50	48.90
Yield (t ha^{-1})	27.80	21.87	40.60	34.80	41.00

MB – mountain brome, MF – meadow fescue, PR – perennial ryegrass, FL – Festulolium

The concentrations of the principal organic substances of cv. Tacit during the growth period are given in Table 1. It was confirmed that the concentrations of individual substances were significantly changed. The concentration of dry matter increased at the stage of stem elongation and the end of heading, respectively. The concentration of crude fibre showed a similar tendency, as its level increased from 278.72 to 343.64 g kg^{-1}

Table 3. Fermentation parameters of experimental grass silages

Parameter $n = 6$	MB Tacit		MF Levočská		PR Jiskra		FL Perun		FL Lofa	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
Dry matter (g kg^{-1} FM)	260.75	0.71	304.80	14.18	259.06	13.35	265.27	1.21	250.69	2.93
Losses of DM (%)	13.74	0.27	12.53	4.08	22.00	4.44	15.28	0.30	18.75	0.98
pH	4.56	0.06	4.53	0.01	4.42	0.02	4.38	0.05	4.38	0.02
Acids (g kg^{-1} DM)										
– milk	43.24	6.85	37.33	3.75	60.19	8.16	58.80	4.66	60.21	4.09
– acetic	6.70	0.65	3.25	0.44	4.85	0.16	3.76	1.36	3.78	0.70
– propionic	1.74	0.13	0.77	0.08	1.23	0.26	1.53	0.46	1.27	0.30
– butyric + i.b	4.12	0.43	2.39	0.48	3.25	0.63	1.87	0.60	2.71	0.61
– valeric + i.v	1.19	0.41	1.09	0.13	1.00	0.19	0.67	0.05	1.39	0.04
– capronic + i.c	0.78	0.38	0.13	0.03	0.29	0.08	0.70	0.30	0.20	0.08
Alcohol (g kg^{-1} DM)	6.68	0.74	6.59	1.06	8.52	1.58	7.97	0.47	7.60	0.36

MB – mountain brome, MF – meadow fescue, PR – perennial ryegrass, FL – Festulolium dry matter at the same stage of the development of the crop. The WSC concentration increased slowly during the experimental period of the crop growth. On the other hand, the crude protein concentration decreased gradually during the development of the crop. The content of WSC increased with maturation, and reduced levels of reducing sugars, fat, and ash were noticed too.

The results obtained in this experiment corresponded well with the results of Pozdíšek *et al.* (2002), but it is necessary to stress that the site has a significant role in the concentration of individual organic substances.

On the basis of the results given in Table 2 we can state that mountain brome is a grass comparable with other grass species. At the time of harvesting the mountain brome was in the phase of the beginning of heading, whereas the other grasses were already in full heading. This fact influenced the results obtained in favour of brome.

A sufficient amount of sugars in the stands facilitates the onset of the fermentation process at ensilaging without difficulties (Table 3). Because of the high content of butyric acid in silages we regard the application of biological ensilage additives as suitable. They control the fermentation processes in favour of butyric acid and prevent the creation of undesirable volatile fatty acids.

Conclusions

Mountain brome is a grass with an average level of nutrients and energy. Its advantage is it good tolerance of drought. In optimum cultivation conditions its quality is comparable with other grass species. A sufficient content of WSC gives the preconditions for the good ensilage capacity of this grass. We recommend using ensilage inoculants to improve the fermentation process.

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Response to grazing pressure and supplementation on milk production by dairy cows

Roca-Fernández A.I., González-Rodríguez A. and Vázquez-Yáñez O.P.

Agricultural Research Center, INGACAL, Xunta de Galicia, A Coruña, Spain
E-mail: anair@ciam.es

Abstract

An experiment with two systems of milk production using rotationally grazed pastures of perennial ryegrass and white clover was carried out to study the effect of different grazing pressures in spring/early summer on subsequent herbage composition. Seventy-two Holstein-Friesian dairy cows were randomly assigned to four treatments: two stocking rates were applied, medium (M, 3.9 cows ha^{-1}) and high (H, 5.2 cows ha^{-1}) at two different stages of lactation, spring-calving (S) and autumn-calving (A). Milk yield and composition were analyzed for five months (March to August). Pasture production, quality and sward utilization were measured for each treatment. The objective of this experiment was to achieve high herbage intake per animal, high herbage utilization and to maintain high sward quality throughout the period. Increasing grazing pressure during the spring period resulted in a significant decrease in herbage intake per cow and increase in herbage utilization. This lower intake was compensated for by significantly improved grass quality in HS. Total nutrient intake was sufficient to maintain high milk production per cow. The H stocking rate had increased grass intake and improved grass quality which reduced the substitutive effects of supplementation and maintained high milk production.

Keywords: calving date, herbage intake, management, milk yield, stocking rate, sward quality

Introduction

Milk production systems must be competitive and sustainable to maximize farm resources, reduce costs of production and improve grass quality (González-Rodríguez *et al.*, 2007).
High reliance on grazed herbage offers important economical, animal and environmental benefits (Mayne *et al.*, 2004). Delaby *et al.* (1999) reported that high producing cows can achieve satisfactory levels of performances, with high economic returns, from only a moderate concentrate input, although they do not fully exploit their genetic potential.
Stocking rate (SR) is one of the most important factors to control in dairy production systems (González-Rodríguez, 2003) due to its influence on the critical factors affecting herbage intake-sward quality, the substitutive effects of concentrate as well as its influence on milk production during the grazing season (Peyraud and González-Rodríguez, 2000).
Increasing grazing pressure (GP) as a consequence of reducing concentrate inputs is possible in the humid area of Galicia (NW Spain), improving both grass quality and intake without decreasing milk quality or production per cow (González-Rodríguez, 2008).

To achieve a high milk yield and improve herbage composition, it is necessary to improve sward quality through increased GP in spring/early summer (Roca-Fernández *et al.*, 2008).

The objective of this study was to manipulate the structure of grass swards by imposing two different SR (medium and high) in dairy cows at two stages of lactation (spring and autumn calving) and to examine the consequences on sward characteristics and milk production.

Materials and methods

This study was conducted at the Agrarian Research Centre of Mabegondo, A Coruña, Spain (43º15'N; 81º18'W) from the 16th of March to the 2nd of August in 2007 (Table 1). Forty-four spring calving (S, mean calving date 15th February) and twenty-eight autumn calving (A, mean calving date 30th October) primiparous and multiparous dairy cows were randomly assigned to four treatments maintained in an integrated grazing system on pastures of perennial ryegrass (*Lolium perenne* L.) and white clover (*Trifolium repens* L.). Two different SR were established in spring-calving (MS, 4.3 and HS, 5.8 cows ha^{-1}) and in autumn-calving (MA, 3.6 and HA, 4.6 cows ha^{-1}). The cows grazed a pasture area of 78.6 ha and the concentrate ration was 3.1, 3.3, 1 and 0.9 kg DM day^{-1} in MS, HS, MA and HA, respectively.

Table 1. Number of rotations, days per rotation, total area, residence time and pre-grazing height of the treatment groups

	Spring-calving		Autumn-calving	
	MS	HS	MA	HA
Rotations	4	5	4	5
Days per rotation	31.5 ± 3.9	27.8 ± 3	31.3 ± 2.4	29 ± 1.7
Area (ha)	5.3^{a} ± 0.4	4.1^{bc} ± 0.6	3.9^{cd} ± 0.1	3.4^{d} ± 0.3
Residence time (days)	1.5^{ab} ± 0.2	1.3^{a} ± 0.2	1.9^{b} ± 0.2	1.7^{ab} ± 0.1
Pre-grazing height (cm)	17.2^{a} ± 2.5	15.9^{ab} ± 0.9	15.7^{ab} ± 2	14.6^{b} ± 2.2

M – Medium SR, H – High SR; S – Spring-calving, A – Autumn-calving

^{a,b,c,d}Values in the same row not sharing a common superscript are significantly different ($P < 0.05$)

Measurements: Daily milk yields were recorded throughout lactation and weekly milk samples were analyzed to calculate protein, fat and urea. Body weight (BW) and body condition score (BCS) were measured twice a month. Pre- and post-grazing herbage mass (HM) were measured by cutting five quadrants before and after the cows grazed each paddock. Pre-grazing herbage samples were collected to determine the botanical composition of each sward. Pasture dry matter intake (PDMI) was measured as the difference between pre- and post-grazing HM and daily herbage allowance (DHA) was measured as the pre-grazing HM times the paddock area divided by the number of cows grazing and the residence time. Herbage samples were analyzed by NIRS to estimate crude protein (CP), *in vitro* organic matter digestibility (IVOMD), acid detergent fibre (ADF), neutral detergent fibre (NDF) and water soluble carbohydrates (WSC). Data analysis was performed using the statistical program SPSS 15.0. Data are presented as least squares means ± SEM.

Results and discussion

The H stocking rate was significantly higher than the M with both spring and autumn calving. There were significant differences between treatments for milk production (Table 2). The lower PDMI was compensated for by higher sward utilization (HS, 83 versus MS, 79% and HA, 81 versuss MA, 77%) and this resulted in significantly higher milk production (HS, 25.3 versus MS, 24.3 kg day^{-1}) and reduced substitutive effects of supplementation.

The HS caused a significant increase on grass quality for ADF (HS, 291 versus MS, 310 g kg^{-1}), NDF (HS, 518 versus MS, 529 g kg^{-1}) and IVOMD (HS, 781 versus MS, 757 g kg^{-1}). Fales *et al.* (1995) reported an increased pasture quality with higher SR. Lee *et al.* (2008) showed lower NDF and ADF with higher OM digestibility and WSC in swards grazed more severely in the previous grazing period, with higher leaf proportion and lower senescent material.

The milk urea content was satisfactory in all groups, with values of 203.2 ± 18.1 mg kg^{-1}. There were significant differences between treatments for milk protein (HA, 32 and MA, 30.6 g kg^{-1}) and for milk fat (HA, 39.9 and MA, 37 g kg^{-1}). This could be attributed to the higher pasture CP (HA, 153.8 and MA, 139.7 g kg^{-1}).

Table 2. Stocking rate (SR), milk yield (MY), daily herbage allowance (DHA) and pasture dry matter intake (PDMI) of the treatment groups

	Spring-calving		Autumn-calving	
	MS	HS	MA	HA
SR (cows ha^{-1})	4.3^{a} ± 0.3	5.8^{b} ± 0.7	3.6^{c} ± 0.4	4.6^{a} ± 0.6
MY (kg day^{-1})	24.3^{a} ± 1.3	25.3^{b} ± 1.2	20.5^{c} ± 1.2	18.5^{d} ± 1.2
DHA (kg DM cow^{-1} day^{-1})	16.9^{ab} ± 0.8	15.4^{ab} ± 0.6	18.4^{a} ± 0.9	14.9^{b} ± 1.4
PDMI (kg DM cow^{-1} day^{-1})	13.4^{ab} ± 0.5	12.5^{ab} ± 1.3	14.1^{a} ± 0.7	10.3^{b} ± 0.6

M – Medium SR, H – High SR; S – Spring-calving, A – Autumn-calving

a[,b,c,d] Values in the same row not sharing a common superscript are significantly different ($P < 0.05$)

No significant differences were found between groups for BW and BCS with average values of 575.8 ± 13.6 kg and 3, respectively.

Conclusions

Increasing grazing pressure is recommended to achieve a higher sward utilization and to improve grass and milk quality. The combination of a low daily herbage allowance and a high stocking rate in spring and autumn calving had a positive effect on the quality of the sward resulting in reduced substitutive effects of concentrate in dairy farms from Galicia.

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Milk urea concentration as an index for the diagnosis of nutritive balance in dairy cows

Roca-Fernández A.I., González-Rodríguez A. and Vázquez-Yáñez O.P.

Agricultural Research Center. INGACAL, Xunta de Galicia, A Coruña, Spain
E-mail: anair@ciam.es

Abstract

A study with two feeding regimens of milk production was carried out to examine the effect of grazing or silage conditions on milk urea (MU) concentration. Milk yield and composition were analysed from March to August in three herds of Holstein-Friesian dairy cows (n = 92) at different stages of lactation, two under grazing (G): spring-calving (S) and autumn-calving (A), and one indoors (I) and spring-calving (S) under supplementation. Pasture production, quality, and sward utilisation were measured for the grazing treatments. The objective of this experiment was to evaluate the MU concentration as a management target to balance the ration in dairy cows, which allows us to correct the deficiencies of dairy cattle in pasture conditions, as well as in silage feeding. There were no significant differences in milk production between the GS and IS (24.3 and 25.6 kg day^{-1}, respectively) compared to 18.4 kg day^{-1} for the GA. Estimates of the MU content in the grazing treatments indicated that there was a balance between protein and carbohydrates with high grass quality and total dry matter intake. The MU concentration was significantly higher in the IS than in the GS. Protein deficiencies were detected by a decrease in milk urea in the IS.

Keywords: dairy production, grass quality, milk protein, nutritive balance, supplementation

Introduction

The concentrations of urea in milk, plasma, and in blood can be used to monitor feeding programmes and to predict the nitrogen excretion of dairy cows (Vázquez-Yáñez, 2007).
A proper balance between rumen degradable protein and rapidly fermentable carbohydrate allows the cow to make the best use of protein in its diet (González-Rodríguez and Vázquez-Yáñez, 2008). However, it is difficult to make recommendations for the amount of crude protein to include in the diet of dairy cows, which depends on milk yield, milk protein, growth rate, body weight, energy content, and type, as well as amino acid composition and the degradability of dietary protein in rumen (González-Rodríguez and Vázquez-Yáñez, 2002).
Using MU concentration in dairy farms in Spain is a good opportunity to increase milk production, to reduce feed costs, and to improve the profitability of the herd with a smaller environmental impact from N in manure (González-Rodríguez *et al.*, 2001).
The objective of this study was to evaluate the MU concentration as an index for the diagnosis of the nutritive balance on grazing or silage conditions in dairy cows at two stages of lactation.

Materials and methods

This study was conducted at the Agrarian Research Centre of Mabegondo, A Coruña, Spain (43º15'N; 81º18'W) during 139 days from March to August in 2007 (Roca-Fernández *et al*., 2008). Sixty spring-calving (mean calving date 1st February) and thirty-two autumn-calving (mean calving date 27th November) primiparous and multiparous Holstein-Friesian dairy cows were randomly assigned to three treatments: two outdoors under grazing of perennial ryegrass and white clover (GS, 44 spring-calving and GA, 32 autumn-calving dairy cows) and one indoors (IS) with 16 spring-calving dairy cows. The GS and GA grazed independent areas at two different stocking rates (SR): GS, 5.1 and GA, 3.9 cows ha^{-1}, but similar PDMI (Table 1).

Table 1. Pasture dry matter intake (PDMI), silage and concentrate supplementation of the treatment groups

	Outdoors		Indoors
	GS	GA	IS
PDMI (kg DM cow^{-1} day^{-1})	13.7 ± 0.9	12.9 ± 1	0
Silage (kg DM cow^{-1} day^{-1})	1^a ± 0.8	1.3^a ± 1.2	8.9^b ± 1.5
Concentrate (kg DM cow^{-1} day^{-1})	3.1^a ± 0.6	0.8^b ± 0.7	6.1^a ± 1.2

G – Grazing, I – Indoors; S – Spring-calving, A – Autumn-calving

$^{a, b}$Values in the same row not sharing a common superscript are significantly different ($P < 0.05$)

Measurements: daily milk yields per cow were recorded throughout lactation and weekly milk samples were analysed to calculate milk protein, fat, and urea. Body weight (BW) and body condition score (BCS) were measured twice a month. Pasture production was measured both pre- and post-grazing using five quadrants (each 0.5 m^2). Pre-grazing samples were analysed to determine the botanical composition. Daily herbage allowance (DHA) and pasture dry matter intake (PDMI) were measured. Dry matter (DM), pasture crude protein (CP), and fibre contents were determined by NIRS. The grazing pressure (GP) was used to determine the potential output from the pastures. Data analysis was performed using the statistical program SPSS 15.0. Data are presented as least squares means ± SEM.

Results and discussion

There were significant differences between treatments for BW (Table 2) but not for BCS (average value of 3). The IS increased its BW significantly with a significant increase in its supplementation. However, silage was significantly lower for the grazing treatments.

There were not significant differences between treatments for sward utilisation (GS, 81% and GA, 79%) and grass quality (pasture CP, fibres, and digestibility). The average residence time was 1.4 and 1.9 days in the GS and GA, respectively.

The S milk production was significantly higher than the A under grazing or silage conditions. The milk yield (MY) of middle- to late-lactation dairy cows (GS and GA) showed a steady decline, while the confinement feeding (IS) MY maintained a similar behaviour throughout the lactation (Figure 1a). However, the cumulative loss of milk production for the entire lactation was lower in the GS and there were no significant differences between the GS and IS for MY. The IS initial milk production was considerably lower from March to April as a result of the protein deficiencies resulting from feeding dairy cows under silage conditions and the MU concentration was a decisive parameter in the

Table 2. Body weight (BW), milk yield (MY), and milk protein, fat, and milk urea (MU) concentration of the treatment groups

	Outdoors		Indoors
	GS	GA	IS
BW (kg)	569.4[a] ± 1.8	600.8[b] ± 10.6	613.8[c] ± 10.6
MY (kg day^{-1})	24.3[a] ± 1.3	18.4[b] ± 1.2	25.6[a] ± 0.4
Milk protein (g kg^{-1})	28.8[a] ± 0.1	31.5[b] ± 0.1	28.7[a] ± 0.3
Milk fat (g kg^{-1})	37.1[a] ± 0.4	38.5[b] ± 0.3	37.2[ab] ± 0.7
MU (mg kg^{-1})	191.7[a] ± 13.9	222.2[b] ± 16.6	231.2[b] ± 15.4

G – Grazing, I – Indoors; S – Spring-calving, A – Autumn-calving

[a,b,c]Values in the same row not sharing a common superscript are significantly different (*P* < 0.05).

detection of an imbalance ration and correcting the protein-energy levels in the rest of its lactation (Figure 1b).

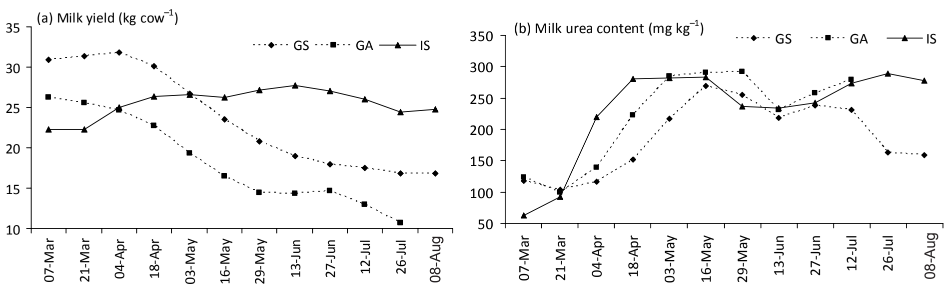

Figure 1. (a) Milk yield and (b) milk urea (MU) concentration of the treatment groups

G – Grazing, I – Indoors; S – Spring-calving, A – Autumn-calving

The evolution of the MU content for each group showed the effect of the different nutritive levels throughout the lactation. The MU concentration was significantly higher in the IS than in the GS. Milk protein was significantly higher in the GA than in the spring treatments. Milk fat was significantly higher in the GA because of its lactation and in the IS because of its concentrate supplementation. Estimates of the MU content in the grazing treatments indicated that there was a balance between protein and carbohydrates with high grass quality and high total dry matter intake (TDMI).

Conclusions

The spring-calving grazing treatment had a balanced diet with high herbage intake, sward utilisation, and grass quality, and this resulted in high milk production. The indoor treatment showed protein deficiencies throughout its lactation and the MU concentration was a decisive parameter in detecting an imbalanced ration and correcting the protein-energy levels. Using the MU content is recommended in dairy farms in Galicia for the diagnosis of nutritive balance.

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An enhanced approach for estimating grassland yield potential under various cutting regimes

Schaumberger A[1], Trnka M.[2], Eitzinger J.[3], Formayer H.[3], Buchgraber K.[1] and Resch R.[1]

[1]Agricultural Research and Education Centre, Raumberg-Gumpenstein, Irdning, Austria
[2]Mendel University of Agriculture and Forestry in Brno, Institute of Agrosystems and Bioclimatology, Brno, Czech Republic
[3]University of Natural Resources and Applied Life Sciences, Institute of Meteorology, Vienna, Austria
E-mail: andreas.schaumberger@raumberg-gumpenstein.at

Abstract

The study introduces a GIS (Geographic Information System) tool that assesses the potential biomass yield of grassland based on data for 6-cut management yield measurements from two long-term grassland field trials with multiple fertilization schemes. Therefore, a two-step approach is developed and implemented in GIS. First, a dynamic daily soil water balance model is applied and its outputs are then used to estimate biomass production. The grassland yield model is based on the statistical model, which takes as predictors accumulated temperature, global radiation and water stress, as well as cutting and fertilization to estimate grassland production. The daily meteorological data are interpolated over the domain using very high resolution. These data are then processed by the water balance model (WBM) in each grid in combination with grid-specific information about soil, growing dynamics and cutting regime frequency in order to obtain grid-specific water stress factors. The result is used by GRAssland statistical Model (GRAM) and combined with the seasonal sum of temperature and global radiation. The major innovation of this approach is the focus on spatial aspects of production potential through incorporation of the model algorithms into GIS.

Keywords: grassland yield potential, biomass production, water balance model, GIS

Introduction

Over the past years there has been an intensive search for alternative uses of agriculture land to provide sustainable sources of renewable energy. One of the more recent options is the utilization of grassland biomass for energy purposes, and thus there is a need to assess the production potential of grassland under various cutting regimes as well as its stability under various weather conditions. As grasslands of different types cover an area of 1.61 million hectares in Austria, which is more than 50% of the agricultural land, the potential benefit is obvious. The scheme could be also viable in other regions where sufficient biomass production could be achieved and where excess land is available due to decline in animal husbandry (e.g. in the Czech Republic). The alternative use of grasslands might require up to six cuts per year (compared with 2–4 cuts in conventional systems) for which relatively few experimental data exist. Therefore, the study introduces a concept that would allow assessment of the potential yield of biomass and its variability under present climatic conditions, as well as to pin-point areas having the highest production potential.

Materials and methods

The key procedure of the water balance model (WBM) is the calculation of the daily reference evapotranspiration as the main soil water balance driver. It is calculated from daily values of temperature, wind, relative humidity, and global radiation and radiation balance respectively, according to FAO Penman-Monteith (Allen *et al.*, 1998, 2005). In order to adjust reference evapotranspiration (which represents the conditions over a well-watered grass sward of 12 cm height) to represent cultivated grassland fields with various cutting regimes, the crop-specific evapotranspiration has to be calculated. Therefore, crop coefficient dependent on growth stages is used to adjust the value of daily reference evapotranspiration. The WBM calculation for the first growth is initiated at the beginning of the thermal growing season, defined as continuous period with mean air temperature above 5°C at 2 m height. In the next step, actual evapotranspiration is derived for each day based on crop evapotranspiration (which represents the water atmospheric demand) and water available to the crop (which represents the supply side of the WBM). Available soil water is determined by actual soil water content that is driven by water balance during previous day and precipitation on the given day. Soil water content is calculated for a model profile that assumes two soil layers each of 20 cm depth, and water transfer is allowed between the layers as well as percolation to the sub-root zone.

The ratio of crop evapotranspiration and actual evapotranspiration indicates the level of water stress. If water stress occurs the growth supporting factor will be reduced due to the intensity of stress. The factor effects the summation of daily temperature and global radiation over the period of each growth through a complex function described by Trnka *et al.* (2006). For example, during drought periods temperature and radiation sum acquired are reduced (assuming that plants cannot utilize solar radiation when lacking sufficient amount of available water), which is translated to lower grassland yield estimates in the GRAM procedure.

The first challenge when developing a spatially oriented system that would be suitable for the complex terrain where most of the grasslands are to be found is the availability of high quality data. As the primary source of energy in the system is global radiation, it needs to be represented with the highest precision possible. This requires taking into account slope and aspect of the terrain, as grasslands are frequently situated either on the slopes or in the deep valleys where solar radiation values are quite different from unobstructed horizontal plain used for measuring global radiation values. Therefore, the ArcGIS tool 'Solar Radiation' calculates the astronomically possible amount of radiation with respect to slope, aspect, and topographical shadowing for each raster cell of a study region. From this result a factor can be derived, which represents only the topographic-dependent variability of radiation. This radiation factor improves the interpolated surface of global radiation because it takes into account both the actual weather (e.g. cloud cover) and the geometric component of radiation caused by sun angle and the position of irradiated surface. The observed temperature at weather stations is interpolated geostatistically by using a Digital Elevation Model (elevation-detrended ordinary kriging). The other main climate parameter for GRAM input, the global radiation, is also

needed as a spatial surface for each day. It is generated from the values of observation stations by an ordinary kriging interpolation.
Temperature and global radiation are not used directly as predictors for the statistical model of yield estimation, but are combined with and changed according to the day-specific value of growth supporting factor. For the spatial application the growth supporting factor also has to be available as a continuous surface, like daily temperature and radiation. Therefore, the reference evapotranspiration is calculated at the weather stations and then interpolated by elevation-detrended ordinary kriging like temperature. The interpolated reference evapotranspiration can be improved by using the radiation factor which represents the topographic variability. For the next step, i.e. the transformation from reference to crop evapotranspiration, it is necessary to specify management aspects of grassland production. A spatial model of cut dates and growth duration respectively is challenging and has to be determined approximately by using regional studies and/or elevation-dependent temperature models. The spatial version of actual evapotranspiration needs the information about soil quality (field capacity) and the precipitation values as a geodata layer with an adequate accuracy. The continuous surface of precipitation can be interpolated from measurements at weather stations by ordinary kriging or taken from weather radar datasets.

Results and discussion

The GRAM model is applied after preparing raster datasets for the individual predictors. The statistical model is developed based on high quality field experiments. This model relates the yield of each growth to fertilization, duration of growth, and the temperature and radiation sum adjusted by the growth supporting factor. The resulting multiple regression function can be used for station-based analysis of grassland yields as well as for a spatial approach. For this study, long-term trial data for multiple cut regimes (including six cuts) with multiple fertilization management at two Austrian sites were used. These included Gumpenstein, for which data from a continuous trial between 1970 and 2003

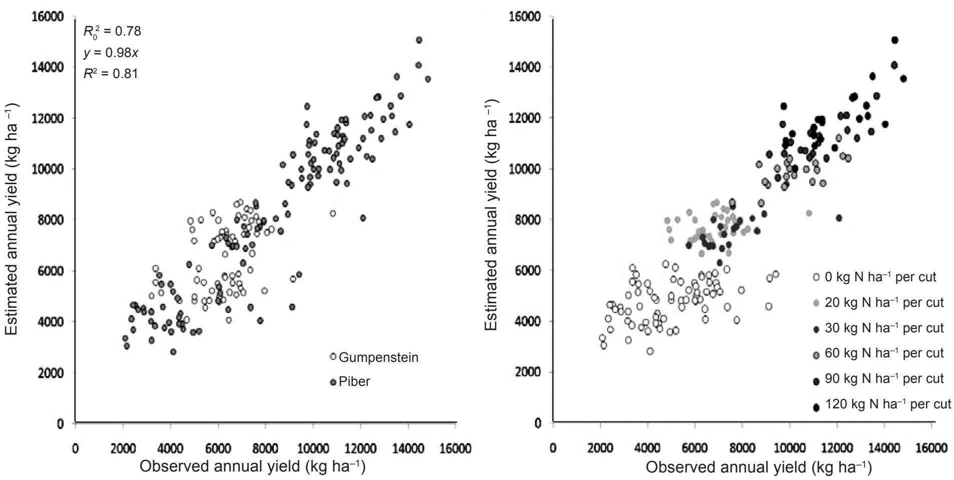

Figure 1. Performance of the statistical model (verification by the independent dataset) at the trial sites Gumpenstein and Piber

are available, and Piber with data available for the period 1970–1993. The results of the model validation for the 6-cut regimes at Gumpenstein and Piber indicate that the model is able to explain up to 80% of yield variability caused by seasonal weather variability, differing fertilization regimes and by the effect of local conditions. It tends to perform better for experiments with higher doses of nitrogen fertilization and at sites (years) when water is a limiting factor.

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Residual effects of green manure legumes on organic seed of *Festuca pratensis*

Slepetys J.

Lituanian Institute of Agriculture, Akademija, Kedainiai District, Lithuania
E-mail: jonas.slepetys@lzi.lt

Abstract

Experiments were designed to study the effects of six legume species ploughed in as green manure on the seed yield of meadow fescue (*Festuca pratensis)*. Legumes were undersown into barley. In the first year of use, legumes were chopped and ploughed in for green manure in June. The sown meadow fescue was used for seed for three years. *Trifolium resupinatum* grew luxuriantly in the year of sowing, however, it completely disappeared after winter. The dry matter yield of the above-ground part of herbage ranged from 1.54 t ha^{-1} (*Galega orientalis*) to 7.48 t ha^{-1} (*Medicago sativa*). The greatest amount of roots (5.23 t ha^{-1}) in the plough layer was left by *Trifolium repens*. Depending on the legume species before ploughing in, the content of nitrogen accumulated in the above-ground parts and roots was 117–286 kg ha^{-1}, phosphorus 10–23 kg ha^{-1}, and potassium 47–152 kg ha^{-1}. According to the data averaged over three years of use, the highest meadow fescue seed yield was obtained from having ploughed in a mixture of the three legumes (*T. pratensis* + *M. sativa* + *T. repens*). Having ploughed in legumes, the positive effect on meadow fescue seed yield was more substantial in the second and third years of use.

Keywords: green manure legumes, organic seed production

Introduction

In accordance with the Council Regulation (EEC) the seed and vegetative plant material for organic farming shall be organic. There is a great shortage of organically grown seed of perennial grasses. The experience of growing such seed is scarce as well as research done on it. Scandinavian countries seem to have the most considerable experience in growing perennial grass seed on organic farms. In Norway, comprehensive studies have been carried out on timothy, white clover, red clover and alsike clover (Aamild, 1999). In Denmark, as in Norway they have tried to grow grass seed together with legumes (Deleuran and Boelt, 2000). Red and white clovers are mostly used for this purpose. However, red clover often suppresses grasses, therefore the crops of the first year are generally used for forage, and grass seed is harvested in the second year of use (Deleuran and Boelt, 2002). Slurry and liquid manure are frequently used for fertilization of grass seed crops, whereas in Lithuania this possibility is limited due to the lack of suitable machinery and unavailability of manure on some organic farms. As a result, alternative ways are sought for the supply of plants with nitrogen (Boelt *et al*., 2002). If manure is unavailable on an organic farm, grasses can be supplied with nitrogen by green manure or by intercropping with legumes. This study has been designed to identify which legume species are best suited for green manuring when growing meadow fescue for seed on an organic farm.

Methods and materials

Experiments were conducted during the period of 2003–2007. Field experiments were set up on a medium-textured *Endocalcari-Endohypogleyic Cambisol* with a thickness of the plough layer of 25 cm, pH 7.0–7.1, humus content 2.16–2.36%, available P and K 119–136 and 141–153 mg kg^{-1} of soil, total nitrogen 0.12–0.16%. Six legume species were tested for green manuring. Herbs designed for green manure were undersown in barley. Legumes were not sown in the plots of the control treatment. A full seed rate of legumes, which is recommended for herbage growing for forage with a cover crop was sown: of red clover (*Trifolium pratensis*) 12 kg ha^{-1}, lucerne (*Medicago sativa*) 12 kg ha^{-1}, white clover (*T. repens)* 8 kg ha^{-1}, goat's rue (*Galega orientalis*) 30 kg ha^{-1}, black medic (*M. lupulina*) 8 kg ha^{-1}, Persian clover (*T. resupinatum*) 8 kg ha^{-1}. The legume mixture (red, white clover and lucerne) was composed of equal share of seed of each species. In the sowing year, having harvested whole crop barley legumes were grown until late autumn. The plots of the control treatment without legumes were tilled (stubble-breaking was carried out). In October, the above-ground herbage mass was chopped and spread on the plots. The following year, in the third ten-day period of June legumes were chopped and ploughed in. Meadow fescue (*Festuca pratensis)* was sown in July with narrow row spacings (12 cm) without a cover crop. The area of experimental plots was 13 × 2.2 m. The plots were replicated four times. Random complete block design was used. Grass seed was harvested for three years of the study. No fertilization and no pesticides were used. The data were processed by ANOVA.

Results and discussion

Legumes undersown in barley influenced the whole crop yield. The content of legumes in the dry matter yield of the whole crop ranged from 5.4 % (black medic) to 16.2 % (Persian clover). In the undersown pure legumes, the highest yield of whole crop was in the treatments where the undersown crop was Persian clover – 7.27 t ha^{-1} and a mixture of red clover with lucerne and white clover – 6.88 t ha^{-1}. Due to the drought conditions weather the autumn yield was very small (0.26–0.73 t ha^{-1}). In the autumn of the sowing year the most luxuriant was the mixture of legumes composed of white clover and lucerne with 278–267 plants per m^{-2}. The thinnest crops were those of goat's rue and Persian clover 142–168 plants m^{-2}. The highest content of dry matter 7.48 t ha^{-1} was accumulated in the above-ground phytomass of lucerne, while red clover accumulated 5.46 t ha^{-1}, mixture of legumes 4.43 t ha^{-1}, goat's rue and white clover with only 1.54– 2.03 t ha^{-1} (Table 1). Under our climate conditions, Persian clover did not survive the winter. In the autumn of the sowing year, Persian clover accumulated 0.54 t ha^{-1} of dry matter. However, the data are not comparable. Other herbs grew longer – until the second ten-day period of June, and the plots of Persian clover were tilled (the stubble was broken) early in spring, having made sure that clover had not survived the winter. The highest content of nitrogen in the above-ground part was accumulated by lucerne 226 kg ha^{-1}, markedly less by red clover and mixture of lucerne, red clover, white clover 141–99 kg ha^{-1}.

The contents of other elements that accumulated in the legume phytomass were proportional to the accumulated dry above-ground phytomass. The largest amount of roots with green stubble 5.23 t ha^{-1} was left in the plough layer by clover, while the least amount was left by black medic and Persian clover 3.10–3.54 t ha^{-1}, respectively. The root mass,

Table 1. Phytomass of dry matter and contents of N, P, K, Ca accumulated in the above-ground mass of ploughed in legumes of the first year of use

Green manure legumes	Phytomass (t DM ha^{-1})	Accumulated (kg ha^{-1})			
		N	P	K	Ca
Trifolium pratensis	5.46	141	11	69	85
Medicago sativa	7.48	226	18	132	132
Trifolium repens	2.03	61	5	28	45
T. pratensis + M. sativa + T. repens	4.43	99	9	69	56
Galega orientalis	1.54	48	4	23	23
Medicago lupulina	2.79	91	8	40	36
*Trifolium resupinatum**	0.54	17	2	17	6
LSD_{05}	0.36	19.5	0.83	5.72	5.86

*estimated in the autumn of he sowing year

compared with the accumulated above-ground phytomass, was relatively high. This can be explained by the fact that big green stubble left near the roots, especially that of white clover, was attributed to roots. Weed roots present in the plough layer were also included here. The roots accumulated relatively less nitrogen, potassium, and calcium than the above-ground plant parts, while phosphorus contents were similar. Depending on the legume species before ploughing in, the content of nitrogen accumulated in the above-ground parts and roots was 117–286 kg ha^{-1}, phosphorus 10–23 kg ha^{-1}, and potassium 47–152 kg ha^{-1}. As a result, the chopped above-ground parts and roots present in the plough layer had the highest contents of dry matter, nitrogen, phosphorus, potassium and calcium when lucerne, red clover and mixture of these grasses with white clover had been grown.

In the first year of use the seed yield of meadow fescue increased significantly, when red clover, lucerne, the mixture of these herbs with white clover and Persian clover were ploughed in as green manure (Table 2).

Table 2. Seed yield of meadow fescue (kg ha^{-1}) as affected by greeen manure legumes

Green manure legumes	Seed yield kg ha^{-1}			
	1st year of use	2nd year of use	3rd year of use	total
Trifolium pratensis	762	522	323	1,607
Medicago sativa	734	519	337	1,590
Trifolium repens	713	526	247	1,486
T. pratensis + M. sativa + T. repens	736	530	362	1,628
Galega orientalis	593	372	270	1,236
Medicago lupulina	667	475	341	1,483
Trifolium resupinatum	744	419	250	1,413
Without legumes	654	355	214	1,223
LSD_{05}	61.3	70.7	37.7	90.7

In the second and third years of use the seed yield increase of meadow fescue resulting from green manure was higher than that in the first year of use. In the second year of use, the yield of meadow fescue was no longer significantly increased by green manure of Persian clover and goat's rue, and in the third year – Persian clover. In the second and third years after ploughing in re-grown lucerne and goat's rue they started to compete with meadow fescue.

Conclusions

During the three experimental years the highest meadow fescue seed yield was obtained through ploughing in lucerne, red clover or mixture of these plants with white clover for green manure. Persian clover significantly increased meadow fescue seed yield only in the first year of use. Ploughed in goat's rue did not give a significant increase in the seed yield in first and second years. Having ploughed in legumes, the positive effect on the meadow fescue seed yield was more substantial in the second and third years of use.

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The impact of different agro-ecological conditions on sod weight and structure of selected tufr grass species

Straková M.[1], Straka J.[1], Binková L.[1], Sloup J.[1], Ševčíková M.[2], Lošák M.[2], Hrabě F.[3] and Knot P.[3]

[1]*Agrostis Trávníky, Ltd., Rousínov, Czech Republic*
[2]*OSEVA PRO Ltd., Grassland Research Station, Rožnov-Zubří, Czech Republic*
[3]*Mendel University of Agriculture and Forestry in Brno, Department of Animal Nutrition and Fodder Production, Brno, Czech Republic*
E-mail: agrostis@agrostis.cz

Abstract

The objective of this paper is to evaluate the impact of different agro-ecological conditions on the development of the root system and sod structure in extensive 5-mow grass growth of *Lolium perenne, Festuca rubra,* and *Poa pratensis*. The results of each second cropping year of the experiment based on three sites with differences in terms of climate and phytogeography, i.e. Rousínov, Zubří, and Vatín, imply a statistically significant difference in the development of the live component of the residual aerial biomass in each of the monitored grass species on the particular sites, while when evaluating a site impact on the weight of the withered component (dead straw) of the residual aerial biomass, a statistically significant difference was recorded only in *Lolium perenne* and *Poa pratensis*. Furthermore, an impact of a nitrogen form on stratification and weight of the root biomass to the depth of 200 mm and overall sod structure was observed in the experiment. The monitoring of the sod composition and weight consisted of division of the residual aerial biomass into a live and a withered component.

Keywords: *Lolium perenne*, *Festuca rubra*, *Poa pratensis*, landscape lawn, roots, sod

Introduction

Landscape turfs constitute a vegetation component, the lack or possibly low quality and neglected condition of which belong among the key environmental issues for cultural landscapes and human settlements. Achieving and maintaining functional efficiency of grass areas is directly related to a wide complex of growing actions and measures. By the intensiveness and frequency of such actions, a growing technology is developed that respects the requirements put on particular types of turf while considering the stress factors affecting the sod. In the most of park grass mixtures seeded, *Lolium perenne*, *Festuca rubra,* and *Poa pratensis* are the base species affecting duration, density, health, resistance to drought, colour, and other performance and aesthetic traits of non-production grass areas depending on the particular percentage in the mixture (Straková and Hrabě, 2001).

The quality and overall appearance of the sod is mainly determined by a sod structure, i.e. the percentage of a withered component and plant remnants, the percentage of a live component with active photosynthesis, and a root system. Root biomass forms 60–90% of the net primary production of grass ecosystems. The larger quantity of active roots means that reserve substances developed and higher resistance of the stand to changes of external conditions as well as stress factors. The longevity of the roots, rooting depth, and weight and stratification of a root system show great species- and strain-specific variations that can be modified depending on the site, level of treatment, and stress impact. The deeper the roots stretch, the better moisture they can get, even from a greater depth, thus resisting the stress caused by drought. Beside the root depth, soil rootness that has recently become a subject of root biomass studies is another important criterion. According to Beard (1973), moderate zone grass root systems can reach a depth of around 45 cm.

This paper evaluates the impact of the effect of different agro-ecological conditions on three climatically different sites on sod development and structure, i.e. residual aerial biomass and root biomass, in 5-mow grass growth of base grass species, *Lolium perenne, Festuca rubra,* and *Poa pratensis,* in relation to the application of nitrogen in fertilizer in forms with different actions and in relation to the application of different levels of nitrogen rate in the course of two cropping years.

Materials and methods

The polyfactorial small-plot experiment was established using a randomized controlled trial method in three repetitions on three climatically different sites in September 2006; see Table 1.

Table 1. Basic climate and soil features of the sites

Locality	Soil sort	Soil type	Altitude (m)	Annual rainfall (mm)	Mean daily air temperature (°C)
Rousínov	Loamy soil	Fluvisol	229	511	9.0
Zubří	Sandy-loamy soil	Alluvial soil	345	865	7.5
Vatín	Sandy-loamy soil	Cambisol	560	618	6.9

From each option of extensive turfs composed of *Lolium perenne* (30%), *Poa pratensis* (30%), and *Festuca rubra* (40%), a solid piece of sod was collected using a sampling trier to a soil depth of 200 mm and residual aerial biomass height of 40 mm immediately upon the last, 5^{th} mowing at the end of the vegetation season. The plot size was 1.8 × 1.8 m. For seeding, a quantity of 25 g m^{-2} of seed was used.

When sampling the roots using the monolith method (Fiala in Rychnovská *et al*., 1987), the basis for evaluating the weight of live and withered residual aerial dry matter production and the weight of the root dry matter production in the layer from 0 to 200 mm was obtained. The data (in particular days) were evaluated with the analysis of variance ANOVA Tukey test $\alpha = 0.05$ (Statistica 8.0).

Results and discussion

The results of each sod component from two cropping years imply the essential impact of a site on not only the weight of the tested traits, but in particular on the sod structure. In Cropping Year 1, i.e. 2007, statistically significant higher values of dried root biomass were achieved in the soil layer 20 to 200 mm on the Vatín site located in the highest altitude, 560 m (Table 1) with the lowest mean daily temperature, 6.9°C compared to other sites at lower altitudes: 429.24 g m^{-2} in *Lolium perenne*, 426.08 g. m^{-2} in *Festuca rubra,* and 327.81 g m^{-2} in *Poa pratensis*. In Cropping Year 2, the variations in the root layer 20 to 200 mm were even more statistically significant, with up to fourfold differences among the sites. In 2008, in every type of tested stand a stagnation or even increase in weight of the root biomass occurred in the layer 20 to 200 mm on the Vatín and Zubří sites, in the driest site, i.e. Rousínov in South Moravia, the root development of *Lolium perenne* and *Festuca rubra* in the same layer even decreased when compared to the previous year, 2007.

Species featuring a supranormal total weight of root biomass include *Festuca ovina*, *Poa pratensis* and *Festuca rubra* according to Straková (2001), which was confirmed by the result history of this experiment as well. The highest mean values of the total weight of root biomass were achieved on the Vatín site in Cropping Year 2, in the *Festuca rubra* (1,120 g m^{-2}) and *Poa pratensis* (1,234 g m^{-2}) species.

When evaluating the residual aerial biomass, statistically significant differences among the sites in Cropping Year 2 were only found in the *Lolium perenne* and *Poa pratensis* stands, in the development of both live and withered residual aerial biomass (Table 2). In the *Festuca rubra* stand, the result history does not imply any impact of a different agro-ecological site on the development of the residual aerial biomass (Table 2).

Table 2. Impact of different agro-ecological conditions on the mean values (in g m^{-2}) of different parts of sod in the *Lolium perenne, Festuca rubra* and *Poa pratensis* stand in Cropping Year 2

Site	Live aerial biomass	Withered aerial biomass	Roots in the layer	
			0–20 mm	20–200 mm
Lolium perenne				
Rousínov	230.50[a]	507.80[a]	332.09[a]	135.64[a]
Vatín	225.42[a]	343.59[a]	576.52[b]	420.50[b]
Zubří	126.09[b]	120.50[b]	316.13[a]	252.94[c]
Festuca rubra				
Rousínov	86.331[a]	402.70[a]	366.48[a]	133.31[a]
Vatín	165.97[a]	397.69[a]	582.35[b]	538.91[b]
Zubří	126.57[a]	265.16[a]	434.55[ab]	387.75[c]
Poa pratensis				
Rousínov	144.18	550.70	542.63	180.73
Vatín	282.44	412.50	811.16	423.66
Zubří	140.02	139.54	456.24	256.26

Conclusions

The Rousínov site is becoming increasingly threatened by drought every year, and despite it being placed among the most fertile areas of the Czech Republic in terms of agronomy, there is a question whether the composition of the mixtures in establishing grass surfaces in South Moravia that has been based on the already established grass species of the moderate zone, i.e. *Lolium perenne*, *Festuca rubra* and *Poa pratensis,* was adequate in the context of the result history of this experiment and the course of climatic conditions on this site in recent years, and whether the species structure of the grass mixtures should be modified with additional regard to other tested grass properties such as colour, density, and overall appearance of the growth towards thermophile plants of type C4 or not.

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Effect of nitrogen fertilization on the botanical composition of newly established extensive turf type grassland

Ševčíková M.[1], Lošák M.[1], Špačková P.[1], Hrabě F.[2], Knot P.[2], Straková M.[3] and Binková L.[3]

[1]*OSEVA PRO Ltd., Grassland Research Station, Rožnov-Zubří, Czech Republic*
[2]*Mendel University of Agriculture and Forestry in Brno, Department of Animal Nutrition and Fodder Production, Brno, Czech Republic*
[3]*Agrostis Trávníky s.r.o., Rousínov, Czech Republic*
E-mail: sevcikova@oseva.cz

Abstract

The effects of type and rate of nitrogen fertilizer application on botanical composition were studied in two types of newly established, extensive turf type grassland sown with a grass mixture (40% *Festuca rubra*, 30% *Lolium perenne* and 30% *Poa pratensis*) or a grass-legume mixture (95% grasses and 5% legumes). The trials were carried out in three different climatic regions of the Czech Republic (Rousínov, Vatín and Zubří). Fertilization treatments consisted of (*i*) three forms of nitrogen fertilizer: soluble, stabilized (with nitrification inhibitor) and slow release nitrogen and unfertilized variant and (*ii*) two application rates: 50 and 100 kg ha^{-1} year^{-1}. The swards were mown in a five cut regime. The total change in stand composition and internal changes of the four main component species (*F. rubra*, *L. perenne*, *P. pratensis* and *Trifolium repens*) are presented to show the early stages of turf development.

Keywords: grass and grass-legume mixture, turf, nitrogen fertilization, botanical composition

Introduction

The proportion of non-productive, turf type grassland with extensive management is generally increasing in the agricultural landscape, parks and urban areas in response to economic changes in many European countries. Such grassland is often based on species-rich mixtures which are continuously used and have to be managed with low resource inputs. Extensive grassland contributes a great deal to both biodiversity and landscape quality (Schüpbach *et al.*, 2004) and for maximum benefit requires environmentally friendly vegetation management that utilizes the interaction between grasses and dicotyledonous species, without dependence on herbicides or chemical fertilizers. However, knowledge is lacking of the impact of different managements on species diversity and turf quality in such grassland. In this paper we report the effect of form and application rate of nitrogen fertilizer on the botanical composition and subsequent changes in newly established swards sown with grass or multi-species grass-legume mixture.

Materials and methods

The multifactorial trials were set up in a randomized block design with three replicates in three different climatic regions of the Czech Republic, at Rousínov (altitude: 229 m, annual rainfall: 511 mm, annual average temperature: 9.0°C), Vatín (560 m, 618 mm, 6.9°C) and Zubří (345 m, 865 mm, 7.5°C) in 2006. The experimental factors comprised (*i*) two types of stand sown with either a grass mixture (40% *Festuca rubra*, 30% *Lolium perenne* and 30% *Poa pratensis*) or a species-rich grass-legume mixture (30% *F. rubra*, 25% *L. perenne*, 25% *P. pratensis*, 5% *F. ovina,* 5% *Cynosurus cristatus,* 5% *Anthoxanthum odoratum*, 3% *Trifolium repens* and 2% *Lotus corniculatus*) at 25 g m^{-2} seed rate; (*ii*) four fertilization treatments, i.e. unfertilized variant (N_0) and three forms of nitrogen fertilizer: soluble (NS), stabilized (with nitrification inhibitor, NI) and slow release nitrogen (NL) form; (*iii*) two application rates: 50 and 100 kg N ha^{-1} $year^{-1}$. The plots were mown in a five cut regime. In all plots, the species list and their ground cover (%) were recorded before the first cut in 2007–2008. The evaluation of vegetation succession was made by using the so called 'total stand changeability' (*C*) method by Klimeš in Hrabě and Buchgraber (2004) to calculate compositional change in each stand and in each component: $C\ (\%) = 0.5\ \Sigma \left| x_i - y_i \right|$, where x_i = ground cover of the i^{th} species in a year (%), y_i = ground cover of the *i*th species in the following year (%). The data were analyzed in Statistica 8.0 (StatSoft Inc., USA) in the module General Linear Model. Multifactorial analyse of variance (ANOVA) was used followed by Tukey tests to determine significant differences (*P < 0.05; **P < 0.01; ***P < 0.001) in species cover as influenced by the different nitrogen fertilization treatments.

Results and discussion

The evaluation of total change of stand composition (*C*) between the 2nd and the 3rd growing year (Table 1) showed that over all fertilizer treatments (*i*) the stands sown with a grass-only mixture were generally more stable (*C* = 17.6%) than the grass-legume stands (*C* = 29.4%) and (*ii*) Rousínov site differed from the other sites by generally having very low change in stand composition (*C* = 12.6% compared to 26.8% and 31.3% on Vatín and Zubří site). Four species (*F. rubra*, *L. perenne*, *P. pratensis* and *T. repens*) characterized by high year-on-year internal change in stand composition, were chosen to demonstrate their contribution to the total stand changeability in both grass (Figure 1a) and grass-legume mixtures (Figure1b).

Table 1. Total stand changeability (%) calculated from ground cover of all species before the 1st cut in two years (2007-2008) by site and nitrogen treatment

Mixture	Site	N_0	NS_{50}	NS_{100}	NI_{50}	NI_{100}	NL_{50}	NL_{100}	Mean
Grass mixture	Rousínov	34.5	24.6	14.5	14.5	11.5	16.0	14.2	18.5
	Vatín	17.9	11.7	11.2	11.5	11.5	14.9	14.1	13.3
	Zubří	17.1	25.9	24.5	21.3	18.4	18.7	22.1	21.1
	Mean	23.2	20.7	16.7	15.8	13.8	16.5	16.8	17.6
Grass-legume mixture	Rousínov	12.9	4.7	4.9	5.3	8.2	6.0	3.9	6.6
	Vatín	35.9	29.1	36.6	41.2	40.1	48.5	51.0	40.3
	Zubří	43.7	36.4	41.6	44.9	46.9	40.9	35.1	41.4
	Mean	30.8	23.4	27.7	30.5	31.7	31.8	30.0	29.4

F. rubra and *L. perenne* significantly contributed to the total changeability of the grass mixture at Rousínov (warm, dry region) in comparison to the other sites. Here *L. pe-*

renne decreased ground cover by 17.5% ($P < 0.001$) and was replaced by *F. rubra*, the strongest competitor, which increased ground cover by 16.6% ($P < 0.001$). On colder, wetter sites (Vatín and Zubří), only insignificant changes in ground cover were recorded amongst sown grasses, except for *P. pratensis* which significantly decreased in coverage by 15.2% at Zubří ($P < 0.001$ compared to other sites). Non-sown *T. repens* started

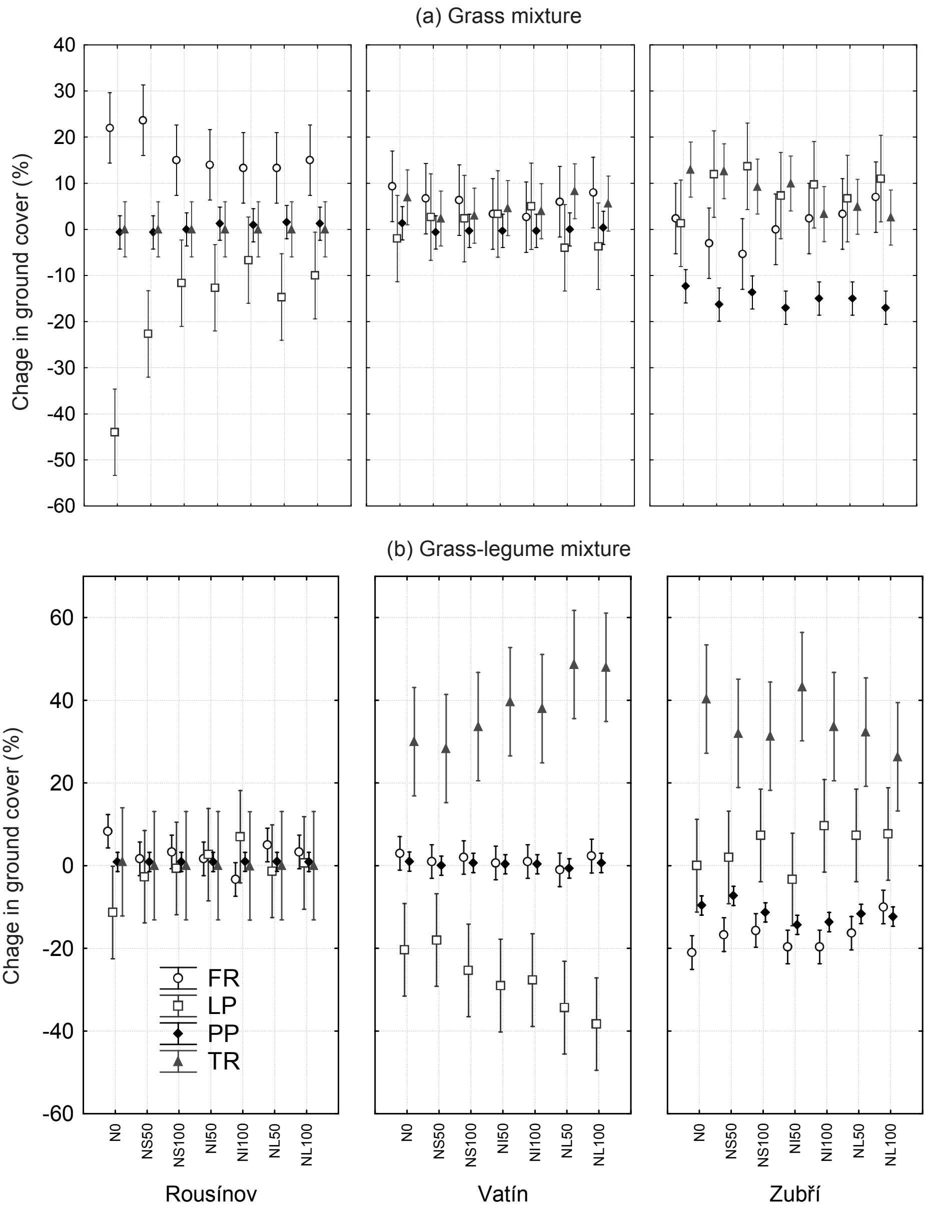

Figure 1. The year-on-year change (between 1. cuts in 2007–2008) in ground cover (%) for dominant species (means ± SE) within different nitrogen fertilizer treatments in (a) grass and (b) grass-legume mixture. The results for four species: *Festuca rubra* (FR); *Lolium perenne* (LP); *Poa pratensis* (PP); *Trifolium repens* (TR)

to spread within the grass-only mixture and reached a coverage of 5.0% ($P < 0.01$) and 7.9% ($P < 0.001$), respectively. The total stand changeability in grass-legume mixtures was very low at Rousínov (6.6%). Here sown legumes appeared sporadically only during the third growing year and were probably limited by the very low rainfall. At Vatín and Zubří, stand changeability was notably higher (mean 40.9%) and was caused by the remarkable increase in coverage of *T. repens* by 38.0% and 34.2% ($P < 0.001$ for both sites) and thus other species were displaced: (*i*) *L. perenne* decreased by 27.6% at Vatín ($P < 0.001$ compared to other sites) while (*ii*) *F. rubra* and *P. pratensis* decreased by 17.0% and 11.4% at Zubří ($P < 0.001$ for both species compared to other sites). The influence of form and rate of nitrogen fertilization on botanical composition of the swards will inevitably become more evident over the longer term. Nevertheless, the greatest initial change in stand composition occurred in unfertilized grass mixture plots. For *L. perenne*, the ground cover decrease was highly significant ($P < 0.001$) compared with all fertilized treatments, which reflected the high nitrogen requirement of this species. *T. repens* is known to be highly competitive, especially in swards established on the arable land (Opitz von Boberfeld, 1994).

Conclusions

Site environmental conditions had the largest influence on the change of botanical composition of newly sown swards of grass and grass-legume mixtures, while the effect of different nitrogen fertilizers and application rates could not be defined clearly at such an early stage in turf development. The experiment is going to continue for further two growing years.

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Distribution and growth performance of suckling cows in a mountain region of the Czech Republic

Voříšková J., Šlachta M., Frelich, J. and Kobes M.

University of South Bohemia, Faculty of Agriculture, České Budějovice, Czech Republic
E-mail: vorisk@zf.jcu.cz

Abstract

The extensive grazing of suckling cows has spread in the Czech Republic in the last two decades. In the south-west Šumava mountain region the data on beef cattle were collected from thirty-one farms from 2002 to 2006. Ten of them reared herds with more than 50 cows; the other herds contained fewer animals. A total of 7,768 calves of seven beef breeds were recorded on the farms during the study. A majority of them belonged to the Aberdeen Angus, Beef Simmental and Charolais breeds (79%), whereas Highland, Hereford, Galloway and Salers were less frequent. On sixteen farms located at lower altitudes from 426 m to 600 m a.s.l. Charolais and Beef Simmental calves prevailed (50% and 21%, respectively), whereas on fifteen farms located at higher altitudes (600 m to 1,074 m a.s.l.) Beef Simmental and Aberdeen Angus calves were the most frequent (41% and 30%). Altitude was revealed as an important factor affecting the growth rates of calves in the Aberdeen Angus, Beef Simmental and Charolais breeds ($P < 0.05$).

Keywords: pasture, Less Favoured Areas, mountains, beef cattle, growth performance

Introduction

The area of the Šumava Mountains, protected by UNESCO, spreads over the south-west boundary area of the Czech Republic and comprises the Šumava National Park (68,064 ha) and the Šumava protected landscape area (99,624 ha). Nearly 80% of the protected landscape area is managed as agricultural land consisting mainly of permanent grasslands (meadows and pastures). The average year temperature is 6°C at 750 m a.s.l. and 3°C at 1,200 m a.s.l. and the sum of precipitations is between 800 and 1,600 mm per year, depending on the altitude and the area. Beef husbandry based on extensive grazing has become popular in the last two decades in the Czech Republic. Twelve breeds with 163,000 cows were registered there in 2008. This comprises a great variety in terms of body constitution, beef performance and adaptability to mountain pasture conditions according to the particular breed. Among the most popular breeds are Charolais, Aberdeen Angus, Beef Simmental, and Hereford. The majority of herds are located in the foothills and mountain areas. The aim of this study was to analyse the altitudinal distribution of beef cattle in the Šumava region and to examine the effect of the altitude on the growth performance of calves.

Materials and methods

Between 2002 and 2006 the data on the breed composition of herds and the growth performance of calves were collected on thirty-one farms located in the Šumava Mts. This comprised most of the farms located in the area being examined. Eleven herds contained less than twenty-six cows, ten herds twenty-six to fifty cows and ten herds more than fifty cows in 2006. The pasture sward appertained to the *Lolio-Cynosuretum* association (Klimeš, 1999; Frelich *et al*., 2006). In total seven breeds were identified on the farms: Aberdeen Angus (A), Beef Simmental (B), Charolais (CH), Galloway (G), Hereford (HE), Highland (HI), and Salers (S). The majority of cows (79%) belonged to the Aberdeen Angus, Beef Simmental, and Charolais breeds. The data on live weight at calving and 120, 210, and 365 days from the calving date were collected for a total of 7,760 calves. The daily live-weight gains (kg calf^{-1}) were calculated for each age interval (calving-120 days, 120-210 days, 210-365 days). The effect of altitude on the daily liveweight gains was analysed in Aberdeen Angus, Beef Simmental, and Charolais separately for each breed using ANOVA with three effects (Statistica, StatSoft, Inc., 2005). The effects were: sex (male, female), period of calving (December–April; May–November), and altitude (lower versus higher). The two categories for altitude (lower versus higher) were distinguished for each breed differently according to the altitudinal distribution of calves so that both the categories contained similar numbers of records, i.e. lower altitude $\leq$ 571 (A), 671 (B), 502 (CH) m a.s.l. and higher altitude $\geq$ 680 (A), 800 (B), 530 (CH) m a.s.l.

Results and discussion

Sixteen farms were located at an altitude between 426 and 600 m a.s.l. and fifteen farms between 600 and 1,074 m a.s.l. The distribution of the breeds among the farms was as follows (some farms kept more breeds): A – ten farms, B – eight farms, CH – seven farms, HI – four farms, HE – four farms, G and S – one farm. The altitudinal distribution of the cows is given in Figure 1. Aberdeen Angus, Highland, Hereford, and Salers prevailed at higher altitudes (> 600 m a.s. l.), whereas Galloway and Charolais were more frequent at lower altitude (< 600 m a.s.l.). Beef Simmental was located evenly along the altitudinal gradient. This distribution well reflects the level of adaptation of breeds to the climatic and nutritional conditions and the intensity of breeding. Charolais and Beef Simmental breeding is generally aimed at a good beef performance and pasture swards with a higher nutritional quality are required. These are located at lower altitudes (Klimeš, 1999). At a higher altitude the breeding is generally aimed at grassland utilisation and the more resistant breeds of Highlander, Hereford and Salers are preferred there for more extensive breeding management. Aberdeen Angus is a specific case of a well-resistant breed with a very good beef performance, thanks to which it also became popular with Czech farmers in more intensive breeding systems at lower altitudes. On sixteen farms located from 426 to 600 m a.s.l. the Charolais and Beef Simmental calves prevailed (50% and 21%, respectively). On the rest of the farms located between 600 and 1,074 m a.s.l. the Beef Simmental and Aberdeen Angus calves were the most frequent (41% and 30%). The effect of the altitude on the growth performance of the calves was analysed for the Aberdeen Angus, Beef Simmental and Charolais breeds, i.e. in breeds reared mainly for a good beef performance (Table 1). The average daily gains were between 0.96 and 1.19 kg in the calving-to–120-days category, between 1.16 and 1.67 kg in the 120–210-days category, and between 0.82 and 1.19 kg in the 210–365-days category.

The effect of the altitude was revealed as being significant in the calving-to–120-days period for Aberdeen Angus ($P < 0.001$), in the 120–210-days period for Beef Simmental ($P < 0.001$) and in the 210–365-days period for Charolais ($P < 0.05$). The lower-altitude calves had higher growth rates than the higher-altitude ones in these three age categories

Table 1. The growth rates of calves (arithmetic means) in three periods of age (0–120, 120–210, 210–365 days) according to the breed and altitude

Breed	Altitude	Daily live-weight gain (kg calf^{-1})								
		Calving–120 days			120–210 days			210–365 days		
		mean	S.D.	*n*	mean	S.D.	*n*	mean	S.D.	*n*
A	low (≤ 571)	1.19***	0.24	400	1.36	0.53	373	1.05	0.87	200
	high (≥ 680)	1.08***	0.25	989	1.25	0.38	864	1.13	0.84	450
B	low (≤ 671)	1.15	0.31	747	1.67***	0.75	760	1.19	0.71	328
	high (≥ 800)	1.18	0.25	994	1.43***	0.70	835	0.93	0.87	275
CH	low (≤ 502)	0.96	0.33	221	1.30	0.61	216	0.82*	0.89	73
	high (≥ 530)	1.00	0.30	1143	1.16	0.44	1029	1.01*	0.77	594

S.D. – standard deviation; significant differences: *$P < 0.05$; ***$P < 0.001$
A – Aberdeen Angus; B – Beef Simmental; CH – Charolais

(the least square means given by ANOVA). The results should be interpreted with caution because the effect of the farm could not be considered in the evaluation because of the unequal distribution of animals between the farms and the altitudes. Apart from the nutritional quality and the allowance of pasture sward, which was largely determined by the altitude, the breeding management (stocking rate) and genetic intra-breed variability contribute significantly to the live weight gains achieved (Chassot and Troxler, 2005). The significance of the effect of the altitude found in some categories of calves in this study suggests, however, the importance of this factor in general, although a number of farm-specific factors need to be taken into consideration as well.

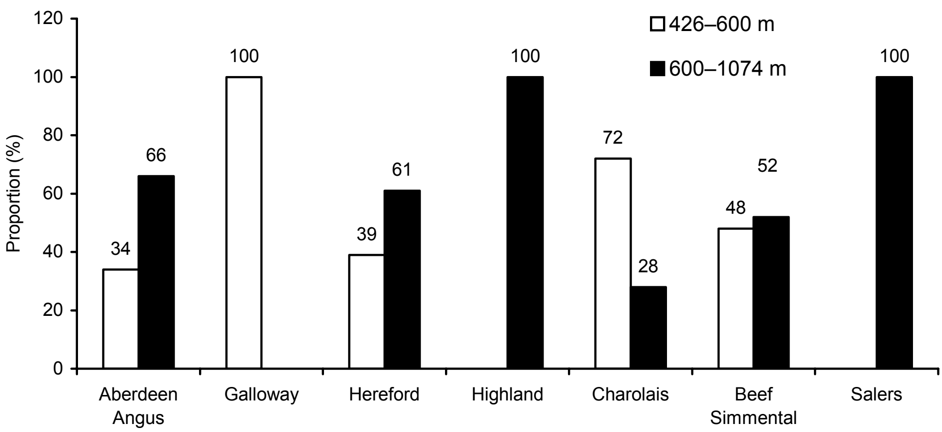

Figure 1. Altitudinal distribution of breeds in the sample of thirty-one farms examined in the Šumava region in 2006

Conclusions

Beef cattle husbandry based on extensive pasturage has become popular in mountain areas of the Czech Republic. Seven beef breeds were indentified on thirty-one farms in the Šumava region. Altitude was revealed as an important factor contributing to the growth rates of calves there.

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Grasslands in Poland and their potential for use for biogas production

Wasilewski Z. and Gutkowska A.

Institute for Land Reclamation and Grassland Farming at Falenty, Raszyn, Poland
E-mail: z.wasilewski@imuz.edu.pl

Abstract

Permanent grasslands may be one of the most important providers of biomass for the production of biogas, though on most farms they are the main source of bulk fodder for ruminants in Poland. In the year 2007 grasslands occupied 3.3 million ha, i.e. 20.2% of agricultural land, with 15.4% being meadows and 4.8% of pastures. Their productive potential varies between 4 and 11 Mg dry weight per ha, depending on habitat conditions, mainly on the soil type and moisture. Without damage to fodder production ca 600 thousand ha of meadows and 300 thousand ha of pastures might be a base for biogas production. Additionally, biomass may be acquired from mown leftovers in pastures and from the so-called lands of ecological use (unused economically). Biogas from meadow sward is rich in methane, which may reach 83% of the total volume of gas. The rest is carbon dioxide (ca 14%) and other gases (dihydrogen sulphide, hydrogen, carbon oxide, nitrogen). It is estimated that 500 m^3 of biogas may be obtained from 1 Mg dry weight of grass. The potential for obtaining biogas from permanent grasslands is estimated at 1.240 to 2.280 million m^3 $year^{-1}$, depending on the intensity of production.

Keywords: biogas, grasslands, renewable energy resources

Introduction

The impulse for increasing interest in energy acquisition from renewable resources was the environmental protection and decreasing resources of non-renewable energy in Poland. The Minister of the Economy issued a directive on 19 Dec. 2005 (Dz. U. Nr 261, poz. 2187) that laid down an obligation to purchase energy from renewable resources. The share of renewable energy should increase from 2.65% in 2003 to 9% in 2010. The directive was amended in 2006 by increasing the target percentage for 2010 to 10.4%. Biomass was the most important renewable resource in 2007 (91.3% – GUS 2008b). Other renewable resources, such as energy from water, wind, solar radiation, biogas, sea tides, and geothermal energy, are used on a smaller scale. Biogas used for energy purposes in Poland is produced in the process of the anaerobic fermentation of waste water sludge in sewage treatment plants (66.5%), of organic wastes from dumping sites (32.5%), and of other substrates of mainly agricultural origin. The last sources, now seldom used, are animal faeces (manure and liquid manure), plants on farms, and waste from the food-processing industry.

Not all substrates are suitable for biogas production. Biomass from permanent grasslands might be a valuable source for biogas production since it contains much organic matter. Biogas from meadow sward is rich in methane (up to 85%). The rest is carbon dioxide (14%) and other gases (dihydrogen sulphide, hydrogen, carbon oxide, and nitrogen). Biogas containing more than 40% methane might be used to produce heat or electric power (540–600 kWh of electric energy may be obtained from 100 m^3 of biogas).

Potential for the use of permanent grasslands for biogas production in Poland

Grasslands might be one of the most important providers of biomass for biogas production, despite the fact that on most Polish farms they are the main source of bulk fodder for ruminants. Multispecies (with the domination of grasses) and permanent plant communities formed in grasslands are able to produce large amounts of above ground biomass of high nutritive value. In the year 2007 grasslands occupied nearly 3.3 million ha (Figure 1). In the last 8 years their area has decreased by 573 thousand ha, mainly because of a decrease in pasture area (as much as 556 thousand ha). The area of meadows has decreased by only 17 thousand ha.

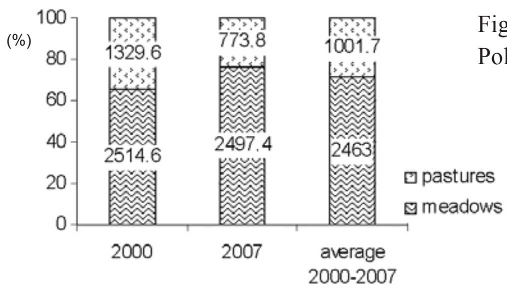

Figure 1. The area of permanent grasslands in Poland (thousand ha)

The fragmentation of the ownership and habitat variability resulting from diversity and the mosaic character of soils and their moisture and location (mainly in the river valleys) are the characteristic features of grasslands in Poland. This diversity translates into significant differences in their productive potential, estimated at 4–11 Mg dry weight per ha. The actual yield is ca 5 Mg dry weight per ha from meadows and ca 3.5 Mg dry weight per ha from pastures (Figure 2).

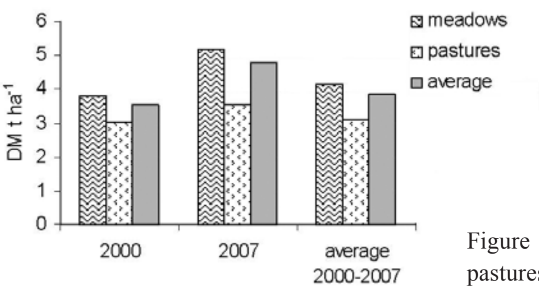

Figure 2. Yields from permanent meadows and pastures (DW t ha^{-1})

The structure of meadow utilisation in 2007 is presented in Table 1. It appears that the majority of meadows (76.3% of their area) are used for fodder production (2- and 3-cut meadows); meadows cut once (mainly to obtain direct subsidies) cover 12.8% of the area and unused meadows 10.9%.

Data from the year 2007 indicate that, without damage to the fodder balance, the biomass acquired from 23.7% of meadows (ca 592 thousand ha) could be used for energy purposes (biogas production). Three million Mg dry weight of biomass can be obtained from that area, providing the present mean yield of meadows is maintained. Biomass in such an amount translates into the production of 840 to 1,500 million m^3 of biogas (Table 2). On the basis of the means from the 8-year-long period these values might even be higher. Various sources indicate that biogas productivity from meadow sward ranges between 280 and 550 m^3 from 1 Mg dry weight (www.agroenegetyka.pl, www.bio-energie.de).

Table 1. The structure of meadow utilisation (% of total area)

Land use	Years		
	2000	2007	mean 2000–2007
Meadows for fodder production	56.0	76.3	56.4
Meadows used for other purposes	23.3	12.8	25.1
Unused meadows	20.7	10.9	18.5

Authors' own calculations

Despite their decreasing area, pastures may also provide biomass for biogas production. According to present assessments ca. 60% of pastures are now grazed by animals. If so, then biomass for biogas production may be obtained from ca 310 thousand ha (= 1.1 million Mg dry weight). This biomass may be supplemented by the mown biomass of leftovers from ca 464 thousand ha of pastures, which makes an additional ca 330 thousand Mg dry weight. Assuming the same biogas productivity as for meadows, biomass from pastures may bring 400 to 780 million m^3 of biogas.

Table 2. Possible biogas production from grasslands

Source	Thousand m^3
Meadow sward	840–1.500
Pasture sward	310–600
Leftovers	90–180

Authors' own calculations

Permanent grasslands playing their basic role as fodder providers may also be an important source of cheap biomass for the production of biogas in the amount of 1.240 to 2.280 million m^3.

Apart from grasslands, there are lands of ecological use in Poland (unused economically) from which the acquisition of additional biomass is also possible. Since they are mainly wetlands, their potential for use is, however, very limited.

Conclusion

The basic role of grasslands in Poland is to provide bulk fodder for ruminants. Grasslands occupy 3.3 million ha, which is 20.22% of agricultural lands. It has been estimated that, without damage to fodder production, the biomass obtained from 23.7% of meadows (ca 592 thousand ha) and from 40% of pastures (ca 310 thousand ha) might be used for the production of renewable energy including biogas in the amount of 1.240 to 2.280 million m^3. Biogas produced from meadow sward is rich in methane (up to 85%) and therefore it is suitable for the production of heat or electrical energy.

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Session 3

Methods of grassland preservation

Ecological principles for the re-creation of species rich grasslands in agricultural landscapes

Jongepierová I.[1] and Mitchley J.[2]

[1]*Administration of Bílé Karpaty Landscape Protected Area, Veselí nad Moravou, Czech Republic*
[2]*University of Reading, School of Biological Sciences, Centre for Plant Diversity and Systematics, Whiteknights, Reading, United Kingdom*
E-mail: j.mitchley@reading.ac.uk

Abstract

This paper describes case studies in the creation of species rich hay meadows on ex-arable land using the White Carpathians Protected Landscape Area (PLA) Czech Republic. Grassland recreation is necessary due to the extreme habitat losses over the past 50 years. Results of seed collection and propagation has been used to development of a regional seed mixture for the WCPLA. This work emphasises the value of brush harvester technology from the point of view of nature conservation to collect seed, especially on meadows situated close to a site that is to be re-created. More than 400 hectares of arable land in the White Carpathians have been re-created with regional seed mixtures. An analysis of successes and failures in establishment and persistence concludes that that the most successful species in sown grassland are perennial, competitive species with broad ecological amplitude, tall stature, extensive root system, and large seeds with a long viability and fast germination. Regarding spontaneous succession, between 2005 and 2006 the species composition of re-created sites and their surroundings was analysed in the Czech Republic, including the White Carpathian Mts. Regrassing method was the most important factor determining the species composition of re-created grasslands on arable land. Sites regrassed with regional seed mixtures were significantly different from the natural regeneration sites and from the sites sown with a commercial species-poor seed mixture. Ruderal and grassland species were the most successful in colonising regrassed areas. However, many grassland species do not easily disperse and colonise new sites making spontaneous succession less effective and the use of regional seed mixtures more valuable. Best practice in re-creation of species rich grasslands should consider the following: the use of regional seed mixtures, the use of agricultural or other subsidies to fund re-creation, the assessment of local conditions prior to applying the re-creation methods, the most cost-effective methods, the monitoring of re-created sites after sowing and in the longer term to assess the successful re-creation of species rich grassland as functioning ecosystems.

Keywords: rich hay meadows, seed mixture, local conditions, White Carpathian Mts.

General introduction

Ecological restoration is increasingly being used to restore biodiversity to the agricultural landscapes of Europe (Hobbs and Harris, 2001; Sutherland, 2002). Grassland restoration techniques depend on the starting point, which may be either a neglected grassland or an arable field or other land use. Species rich grasslands can be restored on neglected grasslands by reintroducing mowing and/or grazing management with removal of scrub if necessary (habitat restoration or rehabilitation). Species rich grasslands can be restored on arable land by allowing natural regeneration processes or by seeding with appropriate follow up management (habitat re-creation). Re-creation of species-rich grassland is usually a long-term process, which can be hampered by lack of plant diaspores and, on more nutrient-rich soils, by competition from broad-leaved weeds and grasses. In the seedbank of abandoned arable fields, weeds dominate over grassland species. Without human intervention the development of arable land towards grassland may be slow or temporarily blocked due to excess soil nutrients or to lack of colonisation by grassland suitable species (Bakker and Berendse, 1999). In such cases, sowing seed mixtures of local plants can help. This paper focuses on the creation of species rich hay meadows on ex-arable land using the White Carpathians Protected Landscape Area (PLA), Czech Republic as a case study. It further focuses on plant species and vegetation while more information on soils and animal communities can be found in Jongepierová (2008).

Grassland re-creation in the White Carpathians

In the past 50 years several hundred hectares of grassland have been ploughed in the White Carpathians. Due to changes in agriculture after the Velvet Revolution in 1989, the need to restore dozens of large arable fields arose. Some were left to spontaneous succession, but the majority was turned into grassland using commercial clover-grass seed mixtures. However, these mixtures are prepared with high production in mind and are not tailor-made to suit specific local conditions. They lack most of the common grassland herbs, some of which are medicinal and nutritionally important to animals. This, as well as concerns about loss of species and genetic diversity (Smith *et al*., 2009), were the reasons why, in the early 1990s, a local environmental NGO, ZO ČSOP Bílé Karpaty, started developing a regional grass-herb seed mixture.

Obtaining seed

Between 1993 and 1995 seeds of 99 common grassland species were collected on species-rich White Carpathian meadows, mostly by volunteers. The seeds were dried and cleaned at the Grassland Research Station (VST) at Zubří and by some farmers in the region to be later reproduced in seedbeds at several local farms. The cultivation and biology of most species was studied at VST Zubří and in three Masters theses (Poková, 2001; Březinová, 2002; Slováková, 2002). The results include data for germination, cultivation and harvesting features, and seed production of 41 species. The selection is still being refined and extended and the production target is for seed to restore 60 ha per year at a rate of 20 kg ha^{-1}.

In the first years, due to a lack of grasses, some commercially cultivated grasses (*Festuca rubra*, *Poa pratensis*, *Trisetum flavescens* and *Arrhenatherum elatius*) were added to the mixture. In 1999–2006 a combine harvester was used to harvest local grasses, especially *Bromus erectus*, *Anthoxanthum odoratum* and *Briza media* seed. It collects rather clean seed in a simple and quick way. However, due to different ripening times, seed sizes and plant heights, it renders a limited amount of seed. The use of a combine is also complicated by slopes and uneven terrain.

Since 2007 seeds have been harvested with a brush harvester, which was constructed according to a model developed by the British company Emorgate Seeds (http://www.

Figure 1. Collecting *Bromus erectus* seed with a brush harvester at Radějov, June 2007

wildseed.co.uk/). It does not cut the vegetation but "combs" the seed from the plants. An advantage of this machine is that the same stand can be harvested several times. In this way grass seed is collected in early summer and seed of herb species later on. Moreover, the height at which seeds are harvested can be adjusted, so that later still hay can be made from the site. From the point of view of nature conservation it is ideal to collect seed this way, especially on meadows situated close to a site that is to be re-created.

Principles of re-creation

Seed mixtures prepared regionally with particular sites in mind must differ according to geographical position, altitude, natural conditions, and the purpose for which they are used (http://www.floralocale.org/). Also the amount of seed available for each species in the year when the mixture is being prepared may play a role. In our case, the grass-herb composition was based on the conditions provided by the well-preserved White Carpathian meadows. Further the cost was an important factor, as grasses are much cheaper than herbs. Until 2004 the mixtures contained 90% grasses, 3% legumes and 7% herbs. In 2005 the legume ratio was increased to 5% and the herb ratio to 10% (weight percentage). According to availability, 20–30 species are included in the mixture.

Based on our experience to date, three main principles for the re-creation of arable land in the White Carpathians have been recognised: (1) The optimum seed rate is 17–20 kg ha^{-1} (with less seed the sward will be sparser, at least in the short term, while using more than 20 kg ha^{-1} is not cost-efficient). (2) The mixture can be sown with a cover crop or without it. (3) The most appropriate sowing time is April and May.

Two case studies for re-creation practice

CASE STUDY 1: Monitoring of regrassed plots (Montágová, 2007)

Since 1998 more than 400 ha of arable land in the White Carpathians have been re-created with regional seed mixtures. The further development of these grasslands was studied in 2006 in order to assess colonisation success of sown and unsown species in such grasslands.

Methods

A total of 14 sites re-created by sowing a regional seed mixture in the SW part of the White Carpathians in 1998–2005 were monitored. The compositions of the sown mixtures were slightly different. During May and June 2006 a total of 152 relevés of 25 m^2 (5–16 per site, depending on the size of the site) were made. Sown and unsown species were evaluated separately.

Results and discussion

Establishment of species varies from extremely successful to completely unsuccessful and the effects are not always predictable, i.e. a species may do well at one site while the same species may do poorly at another site due to chance weather and seed quality effects. To avoid wasting resources it is important to try to define likelihood of success for a range of species to be included in seed mixtures.

Unsuccessful species

Out of 56 sown species 15 were not found at all, and another 14 were recorded in fewer than 10 relevés. Most of these were sown at only one or two sites, thus decreasing their probability of being recorded. Some species had been rare in the seed mixture itself, e.g. *Astragalus cicer*, *Campanula persicifolia, Helianthemum grandiflorum* subsp. *obscurum, Knautia kitaibelii, Primula veris, Pyrethrum corymbosum,* and *Trifolium medium*. Species sown in large quantities were usually more successful than those sown in small amounts. This is because their cover was likely to be lower, and so their chance of being recorded decreased. They may also have died in later years, since the population size of a species limits its successful reproduction and abundance in the following year, especially with cross-pollinating species. The poor establishment of some species may be explained by their low germination rates. Fraňková and Tichý (2008) showed that this might be the case for *Trifolium medium*, *Plantago media,* and *Primula veris*. However, *Astragalus cicer*, which established poorly at the sites showed good germination rates in her study. *Campanula glomerata*, *Cirsium pannonicum,* and *Lathyrus latifolius* were sown at 5 or more sites and the quantity of seed was comparable to other species, but they did not establish well. In these cases, neither seed quantity nor the number of sites can be the reason for this. Species with small seeds often have a low viability (Hopkins *et al*., 1999), because they are sensitive to factors such as moisture or amount of nutrients in the soil. This is, however, not true of *Lathyrus latifolius.* Other factors complicating the establishment of some species are dormancy and high seed mortality (Pywell *et al*., 2003). Of the unsuccessful species, *Helianthemum grandiflorum* subsp. *obscurum* and *Primula veris* are dormant.

Successful species

The most successful regional grasses were *Bromus erectus* and *Festuca rupicola*. The abundance of *Bromus erectus* depended on the amount of sown seed and the age of the re-created grassland. *Festuca rupicola* was most abundant at a sowing rate of 1.5 kg ha^{-1} in 3 to 7-year old swards. The cover of other regional species depended mainly on age of the re-created grassland. Trends are, however, biased, because some species were not sown every year. Results from the youngest grasslands showed which species were able to establish early and these included *Anthyllis vulneraria*, *Aquilegia vulgaris, Betonica officinalis*, *Centaurea jacea*, *Dianthus carthusianorum*, *Onobrychis viciifolia*, *Plantago lanceolata*, *Prunella vulgaris*, *Salvia verticillata,* and *Trifolium rubens*.

Early establishment is only one part of the re-creation issue, persistence in the longer-term is critical (Pywell *et al*., 2003). To assess the persistence of a species it is necessary to look at the oldest grasslands. These sites show not only whether a particular species germinated and established but also if it subsequently persisted and formed a viable population. The species with best persistence rates included *Bromus erectus, Betonica officinalis*, *Centaurea jacea*, *C. scabiosa,* and *Leontodon hispidus*. The abundance of *Leontodon hispidus* in older sown grasslands is also reported by Pywell *et al*. (2003). The same authors, as well as Hopkins *et al*. (1999), also found that *Leucanthemum vulgare* agg., *Plantago lanceolata,* and *Prunella vulgaris* increased in abundance in older grasslands. Coulson *et al*. (2001) states that although *Leucanthemum vulgare* has a limited spreading ability and its seeds ripen late, it establishes well if sown. Most of our results agree with the general conclusion (Hopkins *et al*., 1999; Pywell *et al*., 2003) that the most successful species in sown grassland are perennial, competitive species with broad ecological amplitude, tall stature, extensive root system, and large seeds with long viability and rapid germination are the most successful in sown grasslands (Table 1).

Table 1. Sown species according to their frequency in the relevés

Recorded in 10 or more relevés (assessed)
Agrimonia eupatoria, *Anthyllis vulneraria*, *Aquilegia vulgaris*, *Arrhenatherum elatius**, *Betonica officinalis*, *Bromus erectus*, *Centaurea jacea*, *Centaurea scabiosa*, *Dianthus carthusianorum*, *Festuca pratensis**, *Festuca rubra**, *Festuca rupicola*, *Holcus lanatus**, *Hypericum perforatum*, *Leontodon hispidus*, *Leucanthemum vulgare* agg., *Onobrychis viciifolia*, *Plantago lanceolata*, *Poa pratensis**, *Prunella vulgaris*, *Salvia pratensis*, *Salvia verticillata*, *Senecio jacobaea*, *Trifolium montanum*, *Trifolium pratense**, *Trifolium rubens*, *Trisetum flavescens**
Recorded in fewer than 10 relevés (not assessed)
Anthoxanthum odoratum, *Briza media*, *Campanula glomerata*, *Cirsium pannonicum*, *Cynosurus cristatus**, *Dorycnium herbaceum*, *Galium verum*, *Koeleria pyramidata*, *Lathyrus latifolius*, *Lotus corniculatus**, *Medicago falcata* subsp. *sativa*, *Primula veris*, *Ranunculus polyanthemos*, *Tragopogon orientalis*
Not recorded
*Agrostis capillaris**, *Astragalus cicer*, *Campanula persicifolia*, *Helianthemum grandiflorum* subsp. *obscurum*, *Inula salicina*, *Knautia kitaibelii*, *Lolium perenne**, *Plantago media*, *Prunella laciniata*, *Pyrethrum corymbosum*, *Securigera varia*, *Silene vulgaris*, *Trifolium alpestre*, *Trifolium medium*

*commercial grass and legume species

CASE STUDY 2: The use of spontaneous succession for creating species-rich grasslands

Between 2005 and 2006 the species composition of about 300 re-created sites (established several and twenty years before) and their surroundings was analysed in 12 regions of the Czech Republic, including the White Carpathian Mts. The study aimed at comparing sites re-created by sowing commercial (species poor) or regional (species rich) seed mixtures and spontaneous succession (Střelec *et al*., 2008).

Methods

The surroundings of each re-created meadow were demarcated at 150 m from its boundary. The relative cover of each species for both the meadow and its surrounding was recorded on a 4-point scale (≤ 1%, ≤ 25%, ≤ 50% and > 50%). The regrassing method, composition of the sown seed mixture and date of regrassing were noted.

Results

Regrassing method and age of the vegetation are the two most important factors determining the species composition of grasslands re-created on arable land. Sites regrassed with regional seed mixtures were significantly different from the natural regeneration sites and from the sites sown with a commercial species-poor seed mixture. A group of species associated with sites regrassed with a regional seed mixture were clearly identified; *Briza media*, *Trifolium rubens*, *Carum carvi,* and *Pimpinella saxifraga*, as opposed to more common grassland species which indicated sites re-created with a commercial species-poor seed mixture, such as *Taraxacum* sect. *Ruderalia*, *Cirsium arvense*, *Lathyrus pratensis*, *Daucus carota,* and *Anthriscus sylvestris*. The most successful species were often very common in grasslands of the studied area. However, there were some widespread species which were not able to reach re-created sites. In the White Carpathians the frequency of each species was, therefore, compared with its general success in reaching regrassed sites from their surroundings. The aim was to assess the "potential" of the White Carpathian meadows for enriching re-created sites in the area (Table 2). The results show that some species which are very common in the area are not successful in reaching re-created sites – about a third of the most common species had a success rate of only 10–30%, e.g. *Centaurea jacea*, *Lathyrus pratensis*, *Pimpinella saxifraga*, and *Galium verum*.

Discussion and conclusions

Despite the fact that regrassed arable land is spontaneously colonised with species from the surroundings and some species are able to colonise such sites, the method of regrassing is the most significant factor determining the resulting species composition. Species typical of ruderal and grassland sites are the most successful in colonising regrassed areas. Ruderal species quickly reach the site and survive the initial, more "ruderal" stage of early succession. Grassland species, on the other hand, have the ability to survive subsequent competition from the developing grassland vegetation, while ruderal species cannot. Species like *Achillea millefolium* agg., *Cerastium holosteoides*, and *Plantago lanceolata*, thus almost certainly reach the newly established grassland and do not have to be included in a seed mixture. Typical grassland species whose spontaneous colonisation rate reaches only about 20%, e.g. *Centaurea jacea*, *Knautia arvensis*, and *Galium verum*, should be sown.

The results show considerable differences in species composition between the sites regrassed with species-rich seed mixtures and the sites re-created spontaneously or regrassed with a commonly available seed mixture. For this reason, creating and sowing regional seed mixtures seems to be an efficient method for restoring grassland communities on arable land. The vegetation resulting from such re-creation is much richer in species than the vegetation which would have resulted from spontaneous succession. The data from the White Carpathians further support this conclusion, because there are many species that do not easily disperse and colonise new sites despite the high species-richness of the local grasslands, thus making spontaneous succession less effective.

Table 2. Grassland species most frequently recorded in the White Carpathians grasslands compared to their success in reaching new sites (based on data from the whole of the Czech Republic)

Species	Frequency WC (%)	Success CR (%)
Trifolium pratense	70.2	v
Galium mollugo agg.	66.3	47
Dactylis glomerata	64.4	v
Arrhenatherum elatius	64.4	v
Plantago lanceolata	63.5	71
Leontodon hispidus	58.7	28
Trisetum flavescens	58.7	62
Cirsium arvense	56.7	48
Festuca pratensis	53.8	v
Poa pratensis	53.8	v
Lathyrus pratensis	52.9	29
Leucanthemum vulgare agg.	52.9	54
Taraxacum sect. *Ruderalia*	51.9	89
Achillea millefolium agg.	51.9	84
Tanacetum vulgare	51.0	34
Lotus corniculatus	51.0	v
Myosotis arvensis	49.0	48
Tripleurospermum inodorum	49.0	33
Anthriscus sylvestris	48.1	59
Symphytum officinale	48.1	8
Hypericum perforatum	45.2	38
Centaurea jacea	44.2	2
Festuca rubra agg.	43.3	v
Plantago major	43.3	36
Daucus carota	42.3	14
Campanula patula	40.4	52
Ranunculus acris	40.4	55
Primula veris	39.4	→ 0
Trifolium repens	38.5	v
Colchicum autumnale	37.5	→ 0
Geum urbanum	37.5	19
Vicia cracca	37.5	55
Pimpinella saxifraga	35.6	19
Veronica chamaedrys agg.	35.6	81
Trifolium medium	34.6	21
Heracleum sphondylium	34.6	33
Vicia sepium	33.7	37
Equisetum arvense	33.7	18
Urtica dioica	32.7	43
Galium verum	31.7	11
Cerastium holosteoides	31.7	80

Grassland species with a much lower spreading capability than was expected from their abundance in the White Carpathians are highlighted; v – sown

General conclusions towards best practice in re-creation of species rich grasslands

Use regional seed sources. Regional seed mixtures should be used in restoring the ecological stability of a landscape, eroded sites, buffer zones of nature reserves and drinking water sources, and waste dumps, wherever this is feasible. Landowners can also use them for new orchards, gardens, and 'greening' of new buildings. They guarantee a long-term stable solution for these sites, as the sown species are adapted to the local conditions.

Use agricultural or other subsidies to fund re-creation. As the price of the regional mixture is much higher than that of commonly used mixtures it is necessary to use subsidies. For instance, in the Czech Republic the use of regional seed mixtures has been subsidised through the Landscape Management Programme of the Ministry of the Environment of the Czech Republic and also by Agri-environmental schemes through the Ministry of Agriculture of the Czech Republic.

Assess local conditions before applying the re-creation methods. It is neither sufficient nor efficient to adopt a 'one size fits all' approach to grassland re-creation. Instead each site should be evaluated on its merits with an assessment before recreation methods are a instigated. The assessment should include assessment of soil conditions, seed bank (if funds allow) and characteristics of species in the immediate surroundings, e.g. in existing species rich grassland or fragments, indicating the species pool which might be available to colonise the site. Very small sites surrounded by species rich grasslands may be re-created through spontaneous succession alone. However large sites and sites more distant from existing species rich grasslands will be more effectively restored by sowing a regional seed mix including the species least likely to find their own way to the site. Alternatives to regional seed mixtures include hay transfer (e.g. Kiehl and Pfadenhauer, 2007) and the optimal method for any site or series of sites should be carefully evaluated at the outset of any restoration programme.

Be cost-effective. Cost effective grassland re-creation means do not sow species which are common in the surroundings and which can disperse and colonise new areas. This principal underlines the need for pre-re-creation site assessment (above) to identify the species most likely to recolonise the site spontaneously and therefore not needed in the seed mixture.

Monitor re-created sites after sowing: Monitoring provides information on success and failure which can feedback into future 'adaptive' management. Monitoring also provides information which can be published and used to inform grassland restoration theory and practice in other localities and countries around the world.

Monitor successful re-creation of functioning ecosystems. Finally, studies elsewhere have asked if and when restored grasslands on former arable land resemble the ancient (original) targets (Fagan *et al.,* 2008). This emphasises the need for regional seed mixtures to increase the chance of successful re-creation. However, it also emphasises the need for longer-term monitoring, including the monitoring of animal groups (Jongepierová, 2008), to evaluate the level of success beyond establishment and persistence of species towards a functioning ecosystem.

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The use of semi-natural grassland as donor sites for the restoration of high nature value areas

Krautzer B. and Pötsch E.M.

Agricultural Research and Education Centre, Raumberg-Gumpenstein, Irdning, Austria
E-mail: erich.poetsch@raumberg-gumpenstein.at

Abstract

There has been a dramatic change in the attitude of people to their environments in recent years. The maintenance of biodiversity has become a special concern of agrarian- and environmental policy. In agriculture as well as in landscape planning, consideration is given to biodiversity and procedures and treatments that are as close to nature as possible have gained special significance. Ecological restoration projects with the objective of creating a site specific vegetation cover have obtained increased importance throughout Europe in recent years. Above all in recultivation activity during the realisation of extensive building projects (roads and tourism infrastructure, areas of opencast mining, areas of erosion, ski runs), this type of restoration comes to the fore in broad spheres of the project areas. Semi-natural grassland is the only existing source to provide ecological restoration of grassland with appropriate seed or plant material. In recent years, a large number of different harvesting methods and application techniques have been developed for exploitation and application of site specific seed or plant material. To guarantee the use of site specific plant or seed material, regional land register of potential donor sites as well as approved certification procedures for such material have to be developed.

Keywords: high nature value farmland, biodiversity, seed production, restoration

Introduction

Grasslands cover more than 40% of the earth's surface and are found in nearly every region of the world (FAO, 2005). Grasslands are found most commonly in semi-arid zones (28% of the world's grasslands), followed by humid (23%), cold (20%), and arid zones (19%). In Europe (EU-27) there are various types of grasslands covering 56 million hectares, which is more than a third of the agriculturally used area (Smit *et al.*, 2008). According to Annex 1 of the Habitats Directive (EEC, 1992) the most important types of grasslands in Europe are as follows:

– Natural grasslands including nine grassland habitats that thrive without direct human intervention and are limited by specific ecological, soil and climatic conditions, e.g. Alpine grasslands.
– Semi-natural dry grasslands and scrubland facies, including 12 grasslands habitats that are to some extent managed, ranging from Mediterranean grasslands to Pannonian steppe and Fenno-Scandinavian grasslands.
– Sclerophillous grazed forests with only one grassland habitat known in Portugal as montado and in Spain as dehesas – semi-natural savannah-like open woodlands with scattered oak trees and extensive grazed grasslands.
– Semi-natural tall-herb humid meadows represented by six grassland habitats that have some soil water presence.

– Mesophile grasslands with three grassland habitats all comprising meadows.

The total grassland area in the EU declined by nearly 13% from 1990 to 2003 (FAO, 2006). There is an increasing pressure on more productive grassland by conversion to arable land driven by higher profitability of arable farming and by the rising production of biofuels. On the other hand, extensively used grasslands are endangered both by abandonment and afforestation.

Definition, functions and development of semi-natural grasslands

Different definitions of semi-natural grassland can be found in literature and there is still some inconsistency and need for a common approach (CBM, 2008). Most of the definitions assume that semi-natural grasslands are dependent on human intervention (disturbance through livestock grazing or mowing) but are not intensively fertilised. Although semi-natural grasslands are human-influenced habitats, they provide several values such as cultural, aesthetical, functional, economical and biological (Emanuelsson, 2008).

When semi-natural grasslands are managed with traditional farming methods they support more diverse plant and animal communities and are also important for birds and invertebrates. The preservation and monitoring of semi-natural grasslands has therefore a high priority in conservation in the European Union. Several of the habitat types found within semi-natural grasslands are recognised on a European level to be of conservational value, i.e. habitats within the Natura 2000 network programme (Anonymous, 1979, 1992).

In the early 1990s the 'High Nature Value Farmland' concept developed from a growing recognition that the conservation of biodiversity in Europe depends on the maintenance and continuation of low-intensity farming systems (Beaufoy *et al.*, 1994; Bignal and McCracken, 2000). This concept assumes that biodiversity conservation goals in Europe cannot be met only by protecting particular habitats or species, or designating certain areas for their management, such as Natura 2000 sites. Low-intensity farming and land use that favour the dynamics of natural processes and create opportunities for biodiversity to flourish across large, contiguous areas of land should therefore be supported (Bosshard, 2003).

Semi-natural grasslands are an important part of High Nature Value Farmland (HNVF) that itself is a fragment of the 'High Nature Value Farmland' concept. HNVF has been nominated an objective-related baseline indicator according to the EU Common Monitoring and Evaluation Framework for the rural development programmes of the EC (IEEP, 2007). The most widespread type of HNVF consists of semi-natural vegetation under low-intensity use for keeping livestock. The grazed semi-natural vegetation may be grassland, scrub or woodland, or a combination of different types. Farmland that is predominantly grazed semi-natural vegetation has been labelled Type 1 HNV farmland. The estimation of HNVF distribution in Europe on the basis of Corine land cover (European Commission, 1994) makes clear that the prevalence is in less productive areas, for example in southern Europe and mountainous regions. HNVF is unevenly distributed and makes up about 15–25% of the utilised agricultural area (UAA) in Europe (EEA, 2004). Although the development of HNVF has to be provided by the EU-member states from 2010, there is still a lack of a clear and exact definition of this indicator and of the term nature value.

Based on draft mappings of HNVF by EEA and JRC (2006), a comprehensive study on national verification and identification of HNVF in Austria has been elaborated (Bartel and Schwarzl, 2008). Nationwide data on the distribution of threatened habitat types

– dependent on extensive agricultural land use – and of bird species associated with agricultural land – have been compiled. This analysis was performed on the spatial resolution of a 6 × 6 km grid, which has also been used for the floral mapping of Central Europe. By means of IACS data (Integrated Administration and Control System for the Management of CAP Payments) of land use in 2007, the potential agricultural area where certain habitat types or bird diversity occur was visualised. A cell was defined as High Nature Value Farmland if the proportion of habitat-appropriate land use exceeded 25% of UAA, the sum of habitat-appropriate land use was larger than 100 hectares and the number of bird species was 25% above the expected mean number of species. In compliance with these three assumptions, about 50% of the UAA in Austria (3.25 mill ha) can be characterised as potential HNVF. It can be concluded that a combination of both biodiversity assessment and well-defined agricultural management indicators is necessary to provide and develop a clearer picture of what can be addressed as high nature value farmland.

In most European countries a dramatic decrease in the number of farms with grazing animals can be noticed in recent decades and the traditional agricultural use of semi-natural grasslands seems to be no longer competitive. Milk and meat production, being traditional and productive land-use systems for many generations, are increasingly given up and grassland abandonment is occurring in many regions (Peeters, 2008). In alpine and mountainous regions of Europe, grassland is still the dominant element of cultural landscapes. The increasing loss of semi-natural grasslands is therefore a very serious threat to rural development resulting in negative consequences for ecology, economy and society. Alternative land use concepts must be tested and developed in future to counteract this trend. There are different options including productive agricultural land use (e.g. suckler cows, heifer and oxen fattening, sheep and goats) and new forms of cooperative management systems. Productive, non-agricultural land-use systems (e.g. grassland-based biogas production, hay pellets combustion, fibre material, amino- and lactic acid) can also contribute to keeping the landscape open and to avoid the development of forest (Pötsch *et al.*, 2009).

It is evident that semi-natural grasslands are an important and essential source of biodiversity. Organisms associated with semi-natural grasslands include almost every group of species, mainly vascular plants, insects, birds, lichens and fungi (Grabherr and Reiter, 1995). In respect of vascular plants, semi-natural grasslands can be extremely rich in species and include a large number of Red List species (Bohner *et al.*, 2002; Pötsch and Blaschka, 2003; Öster, 2006). The use of semi-natural grasslands as a source of biodiversity can therefore be seen as an additional option both maintaining and conserving these valuable areas. If such semi-natural grasslands are under protection of Natura 2000, or similar programmes, approval must be obtained from the responsible authorities or management services.

Semi-natural grassland in connection with the agri-environmental schemes in Austria

More than 90% of the Austrian farmland, grown with grasses, clover and herbs, is permanent grassland, which by the definition of Schechtner (1978) is at least 20 to 25 years old and has never been ploughed and renewed within that period. Due to climatic (low temperatures, frost periods, long period of snow cover) and topographical constraints (steepness) as well as for shallow and stony soils, most of the Austrian grassland must be described as obligatory grassland (Schechtner, 1993; Taube *et al.*, 2002).

Table 1. Structure, development and botanical potential of grasslands in Austria (Pötsch and Blaschka, 2003; BMLFUW, 2008)

Land-use system (ha)	1960	2005	Average number of vascular plant species	Max.	*n*
One cut glassland	282,186	40,095	49	91	235
Extensive pasture	289,186	92,619	54	111	120
Alpine meadows/pastures	921,004	731,391		59/115	43
Litter meadows	24,242	9,646		62	50
Extensively used/semi-natural (% of total permanent grassland)	1,517,251 –66%	873,751 –49%			
More cut meadows	726,504	795,166		52–88	1.05
Cultivated pastures	54,153	112,738		86	73
Intensively used grassland	780,657	907,904			
Total permanent grasslands	2,297,898	1,781,655			

The data in Table 1 indicate a strong decrease of permanent grasslands since 1960, of which extensively used grassland has been most affected. The strongest reduction can be noted for one-cut grassland and extensive pastures but also for alpine meadows and litter meadows. These semi-natural grasslands provide a high number of plant species and are basically potential donor sites in respect of their inclination and machine access.

In Austria 72% of all agricultural holdings, with 94% of the total farmland, participate in the Agri-Environmental Programme ÖPUL that is aiming at an environmentally friendly, extensive agricultural land use and maintenance of the countryside. The actual ÖPUL programme consists of more than 30 specific measures with interdependent modules, most of which are offered in all parts of Austria.

Positive effects could be identified within the evaluation framework in terms of the subjects examined (soil, water, biodiversity, diversity of habitats, genetic diversity, landscape, socio-economy). The evaluation analysis indicated a significant shift to higher-level measures (e.g. organic farming, nature-conservation areas, maintenance of orchard grassland and groundwater protection). The measures 'organic farming' and 'renunciation of yield-increasing inputs' provided clearly positive effects on biodiversity. Due to its high level of acceptance and the extent of area covered by it, the bundle of 'keeping cultivated landscapes open' (meadows on sloping sites) measures as well as 'alpine pasturage and herding', is of enormous importance.

Semi-natural grassland as donor sites

In Austria, as in all European countries, many thousands of hectares are restored each year following such infrastructural intervention as road building, flood protection, construction of torrent- and avalanche barriers or as a part of compensation measures (CIPRA, 2001; Kirmer and Tischew, 2006; Krautzer and Wittmann, 2006). But also other areas like roughs on golf courses (Burgin and Wotherspoon, 2008), sporting fields, cemeteries, railway reserves, and public areas would be interesting open space that could be used to provide offsets for biodiversity.

Even if the requirements for restoration and/or reforestation in the countries affected (or also in individual provinces as in Austria) are differing, as before it is common to use seed- or plant materials for restoration that are composed of cultivated varieties used in agriculture or also those of non-local provenance. Only in Austria about 2,000 tons of seed, predominantly cultivated varieties used in agriculture, are used for restoration in landscape construction every year (Krautzer *et al.,* 2007). Cultivated varieties generally require good conditions in respect of water and nutrition supply at the restoration site. The result is that in practice restoration measures are very often undertaken to adapt the given site conditions to the needs of the species being contained in the restoration mixture. This leads, in road building for example, to the spreading of massive layers of humus on roadside banks, which results in an unwanted intensive growth of biomass. Expensive cultivation measures, such as frequent mulching or the removal and composting of the cut material, or also removal of the arising biomass next to roads carrying heavy traffic, are necessary. Under extreme site conditions such cultivated varieties can establish only with great difficulties. Erosion processes and increased cultivation expenditure is the logical result.

Site-specific ecological varieties are well adapted to local conditions. With the proper selection of species, erosion-stable and often high-quality nature-conservation plant stands can be performed even under extreme site conditions (low nutrition content, long dry periods, extreme pH values). The positive ecological and economic effects of such site-specific restoration could already be proved in the course of a great number of trials (Scotton *et al.*, 2005; Kiehl *et al.*, 2006; Donath *et al.*, 2007; Jongepierova *et al.*, 2007; Leps *et al.*, 2007; Woodcock *et al.*, 2007; Krautzer and Klug, 2009; Schmiede *et al.* 2009).

Semi-natural grassland is in most regions the only possibility to use regional site-specific plant material. The removal of plants and soil would lead to the disturbance or destruction of these mostly high-value nature-conservation and thus protected areas. Therefore the basic methods of site-specific restoration can be rarely used. The use of diaspore-rich mowed material by threshing is the best possibility to win material for site-specific restoration in practice. Manifold positive effects can be achieved through the use of these materials combined with natural restoration methods. The valuable nature-conservation potential of extreme site conditions can at the same time be extensively retained with all of the positive results, such as the settlement of rare species and vegetation types or the integration of isolated biotypes.

Prevailing in the German- and English-speaking world is a Babylonian confusion of tongues (Zerbe *et al.*, 2009) in respect of terms and definitions (e.g. near natural, semi-natural, site-specific, native, local, regional, indigenous …), for which reason some of the terms used in this work are defined as follows:

Ecological restoration: this is the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed (SER, 2004).

Non-local provenance: wild species which are not found on open terrain in the area concerned or which have not been found there for more than 100 years (Kirmer and Tischew, 2006).

Natural area*:* an area that is uniform and individual in its overall physical character (geology, climate, vegetation), which can be demarcated against and differentiated from the neighbouring areas (Kirmer and Tischew, 2006).

Site-specific vegetation (ÖAG, 2000): A plant society is site-specific when it is generally and permanently self-supporting or self-stabilising following extensive use, or non-use, and when among such plant societies agricultural production is not in the foreground. With the exception of production or development cultivation, or possible further extensive use, this vegetation requires no further cultivation measures. Further differentiation is given in respect of site specificity. Vegetation created by humans is then site-specific in a stricter sense when the three following criteria are fulfilled:

(1) The ecological amplitudes (the 'needs') of the plant species applied are appropriate to the characteristics of the site.

(2) The plant species used are considered 'indigenous' because in the geographic region (e.g. the Inn Valley, Hohe Tauern) in which restoration measures take place, but at least in the same natural area, they exist or have existed in relevant uncultivated sites within nature.

(3) On the one hand seeds or plant material are used that originate from the immediate vicinity of the project area, and on the other are won in habitats appropriate in their essential site parameters for the type of vegetation to be produced. This means that not only value is placed on the use of proper, well-established and site-specific matching species during restoration, but local ecological types and small families of the respective plant species are also used.

Exploitation of site specific seed and plant material

Origin of seed or plant material

The availability of material that fulfils the site-specific criteria is limited in practice. In principle several interesting species suitable for site-specific restoration may also be commercially available, but they are generally to be described as being of non-local provenance. Through negative interaction with still available local provenances their introduction may lead to undesired results such as hybridisation or displacement (Kirmer and Tischew, 2006). Also to be indicated is the contradiction prevailing in some countries, which repeatedly leads to conflicts between seed law (which promotes the planting of certified varieties) and nature-conservation law (which prohibits the planting of species of non-local provenance and origin in open terrain).

The most differing methods for winning seed and plant material for site-specific restoration processes have developed above all in the English- and German-speaking world in recent decades. The availability of a donor area which provides material that can be won for either direct use in restoration or for the further production of suitable material is definitely of importance. A description of the essential characteristics of potential donor areas is very helpful in this respect and appropriate registers are already being discussed in several countries (Table 2).

The following methods for the recovery of restoration material **from donor sites** are regularly used in practice:

Manual collection

With the aid of manual collection individual species can be harvested at the respective optimum time. With small-scale restoration activities this is the simplest method of acquiring site-specific material. This method is also very suitable for the collection of basis seed for seed multiplication or the nursery production of plants. Finally, it is also possible to specifically mix rare or especially valuable species with restoration material harvested with other methods.

Fresh cutting, Hay mulching

Another widespread method is the cutting of suitable donor sites at the time when most of the desired species are at an optimum stage of seed maturity. To avoid excessive losses, the material is cut preferably early in the morning when it is moist with dew and then immediately taken to the restoration area (receptor site) and spread there. Another possibility is to dry the cut material and its later use for restoration. Nevertheless, this method requires increased manipulation expenditure, whereby a large part of the diaspore material is lost.

Threshing
A very efficient measure is the use of threshed material from suitable donor sites. Threshing takes place with an appropriately adapted combine harvester at the time of optimum seed maturity. The threshed material is subsequently dried and as required, roughly cleaned. Through harvesting parts of several areas, a wide spectrum of species can be received at the right moment and stored for a period of years if required. The seed yield is about 150–200 kg ha^{-1} and the relationship of donor area to restoration area is about 1:1 to 1:2.

Mulch mowing and extraction by suction (vacuum harvesting)
This is a rarely used method where the donor area is mulched and the waste material vacuumed (STMUGV, 2009) together with many insects that normally do not find a basis for survival in the restoration area. With the single extraction by suction, the plant stand on the donor area remains undamaged, only the high-quality mature seeds are vacuumed.

Seed stripping, seed brushing
This method is used above all in North America and England without cutting the plant stand. With the aid of a rotating brush, the mature seeds are brushed from the plants into a container and the harvested material can be reused either fresh or dry.

Salvaging donor soil and plants from a native plant community
The use of diaspore-rich soil, such as acquired from the vegetative parts of plants, is among the most destructive methods of winning restoration material. They are therefore used in the course of constructional measures through which valuable vegetation units are destroyed. Usable are 10 to a maximum of 20 cm of the topsoil. For small areas of restoration it is certainly possible to remove little soil or plant material from donor areas resulting in a minimum number of patches which become overgrown themselves.
The following methods for the recovery of restoration material **from local/regional production** are regularly used in practice:

Production of local plants
Plant material or seed is taken from suitable donor areas and plants that will be used on restoration areas are cultivated in nurseries. This method may well ensure the use of site-specific materials in the strictest sense, but due to high production costs can be used only rarely or on small areas only.

Regional seeds from seed growers
A good method that is meanwhile practiced in several countries is the nursery or large-area production of seed of suitable species with the aid of agricultural techniques. Above all species used often and in larger amounts can be produced at a comparatively reasonable costs and implemented on appropriately large project areas. This method, for example, is now used in Austria and Switzerland throughout for restoration above the treeline (Krautzer *et al.*, 2006). There are also successful activities in several countries for the use of landscape construction (Krautzer and Hacker, 2006).

A substantial problem in the acceptance of high-priced seed material is partly to be found in the lack of transparency in respect of the area of origin of the material used. To be able to give consumers appropriate assurance, several countries implement certification procedures with seals of quality that guarantee the area of origin of the seed, either in creation (A), or already in use (D, CH). In this way the origin and the requirements of the external appearance of the seed quality (purity, viability) are guaranteed.

Restoration of semi-natural grassland

General objectives

The stability and durability are very important objectives of ecological restoration and are most likely to be achieved when the similarity of the site origin and the sowing site of the plants are as large as possible (adaptation to climate, special site characteristics ...). Essential parameters to be observed in planning are the substrate and, if necessary, the instructions for cultivation measures. The substrate properties in suitable areas generally lie in the damp to wet or semi-dry to very dry range (Table 2). Due to the substrate properties the tendency for the development and spreading of bushes is comparatively slight and is generally avoided through extensive cultivation, respectively, agricultural measures (mowed annually or biannually).

Table 2. Recommended methods for ecological restoration of semi-natural grassland

– Seeding of collected or propagated local seeds
– Fresh-cutting (‘green hay’) or hay mulch seeding
– Threshed hay seeding
– Topsoil transfer
– Application of local plant material (grass-swards or pre-cultivated plant elements)

Varieties of wild plants changed through cultivation must not be used. The plant species set out must have no negative influences on the plant stands in the vicinity and not confuse the ‘natural’ distribution pattern of a small variety of plants – as would be the case, for example, if strongly divided subspecies (such as *Achillea millefolium* agg.) from completely different regions were set out. The compilation of the mixtures should be taken from the succession procedures in nature, which lead from short-lived plant species to the establishment of enduring species.

Seeding restoration sites

In respect of the prevailing regulations of nature conservation, the use of seed for site-specific restoration is to be controlled by the individual countries. Thus in most nature-conservation laws the implementation of plants of non-local provenance into open terrain without permission given by the nature-conservation authorities is forbidden, whereby there are usually rules of exception for normal agriculture and forestry. A problem in the use of site-specific seed material for nature-conservation improvement of existing grassland areas or the new construction of HNVF is given by the limitations of the national seed laws as an EU skeleton law. Within the sphere of the agricultural utilisation of areas, the use of varieties is prescribed and laid down in seed law. Accordingly, the use of threshed materials from a donor area for the construction of new HNVF areas is in most cases not permitted.

With respect to site types, possible types of target vegetation and possible erosion risk, the suitable restoration methods can be very different. The most suitable methods for the most common vegetation types are listed in Table 3. However, every planning of ecological restoration measures has to follow some important steps (Table 4) that guarantee the selection of the most suitable method under the given conditions (time span, area, site conditions, availability of site specific seed and plant material, risk of immigration of neophytes, costs, budget, etc.).

Table 3. Biotope types and suitable methods for the restoration of semi-natural grassland

Degree of moisture	Biotope type	Most suitable methods
Semi-dry	Silicious or calcareous poor pastures/meadows	Top soil transfer Seeding of local ecotypes (with mulchlayer) Hay mulch, hay threshing
Mesic	Rich pastures/meadows	Seeding of local ecotypes
	Rough pastures/meadows	Hay threshing
Moist	Moist pastures/meadows	Top soil transfer Seeding of local ecotypes Hay threshing
	Litter meadows*	Hay mulch, hay threshing
	Reeds and tall sedge swamps*	Application of local plant material Hay mulch, hay threshing

*no forage

Simple dry seeding

One sees simple dry seeding as the introduction of seeds in a dry state with no additional support substances. It is very suitable for level terrain (use of diverse sowing machines), but can also be used on banks with a rough topsoil. Another possibility is the manual or mechanical overseeding of a seed mixture in a grass sward (Hofmann and Isselstein, 2005). On steep slopes, an additional mulch protection can be necessary (Krautzer and Wittmann, 2006). In the mulch seeding treatment, soil and seeds are covered and protected with various organic material. For optimum growth the depth of the layer of mulch should not be higher than 3–4 cm and pervious to light. The most common mulch materials are hay and straw. An additional protection by cover crop is another possibility to protect the seeding against erosion. Winter rye, oats or barley (the latter is only suitable in spring and summer) are sown together with the seed mixture. Due to the rapid accumulation of the cover crop in the soil, a rapid covering of the open areas of earth takes place. At lower altitudes the cover crop must be mowed and cleared on time.

Wet seeding or hydro-seeding

This method can be combined with a covering of the topsoil by means of a layer of mulch, netting or seed matting (Krautzer and Klug, 2009). In this seeding method seeds, fertiliser, mulching material, soil adjuvant substances and gluten are mixed with water in a special container and sprayed over the areas to be restored. Even steep banks with a smooth surface can be restored in this way, whereby the rapid emergence of the seeds has above all proved to be advantageous against erosion.

Table 4. Steps of planning for ecological restoration measures (Kirmer and Tischew, 2006)

Analysis of the site conditions (Substrate, profile, exposure, water balance, danger of erosion)
⇓
Research regarding the aim of use and care options (regional users and managers)
⇓
Contact with regional experts Literature research regarding target communities typical of the site and the natural area
⇓
Analysis of existing donor biotopes and/or resources of seeds and planting material of local provenances
⇓
Selection of the appropriate method of restoration, if necessary propagation
⇓
Selection of suitable donor biotopes and/or compilation of lists of species (site-specific modification of basic mixtures)
⇓
Concrete planning of measures regarding the transfer of hay mulch or topsoil *or, as an alternative*: Establisment of ratios of mixtures and quantities of seeds; selection of plants and preparation of planting

Slot seeding, harrowing and over-sowing

This method is very suitable for the enhancement of grassland diversity. It can be used for grassland that is accessible by tractor. Seeds of a suitable mixture or material from hay threshing are established using the technique of slot-seeding equipment. Pyvell *et al*. (2007) do not recommend slot-seeding without an additional herbicide band spray in productive grassland. In contrast, both slot-seeding with herbicide band spray and simple harrowing are equally effective means of establishing sown species. Slot-seeding requires more specialised machinery, but uses a lower seed rate.

Hay-mulch seeding, hay transfer

With the availability of appropriate donor-sites, the seed material can also be won through special mowing. These mowing dates should be determined by an expert. The hay won in this way, and the seeds it contains, is to be applied to the restoration area in a uniform layer to a maximum depth of 2 cm. Over-intensive application has to be avoided to prevent anaerobic decomposition processes in the distributed seed material. With the availability of suitable donor (mowing) areas, this method is excellent for the introduction of site-specific vegetation (Donath *et al.,* 2007), whereby some special types of vegetation can also be created.

Threshed-hay seeding

An efficient method is the application of threshed hay from suitable donor fields. If the harvesting time is well chosen so that the highest possible number of desired seed species is mature, the harvested material can be of high quality (Kirmer and Tischew, 2006). Mixing with hay from intensive grassland should be avoided. If the application of the threshing material is not possible immediately after harvesting, it must be dried or stored at a dry place.

Topsoil transfer

The use of donor soil from a suitable native plant community or development site can sometimes (e.g. in case of building or road destruction) be a valuable source of diaspore material. The top 10 to a maximum of 20 cm of soil can be removed and transported to the restoration site. If the donor site is to remain intact, then small amounts of soil can be removed from different appropriate zones and spread thinly in specific areas at the restoration site. The transfer should be carried out directly, without interim storage. The necessary amount of material ranges from 5–20 l m^{-2}. Incorporation into the top soil layer is not necessary, additional erosion protection with a mulch layer can be useful.

Restoration with plant material

Application of parts of plants (e.g. shoots, rosettes)

Shoots or rosettes (mostly mechanically separated vegetation turfs) are loosely distributed. Distribution can take place mechanically in areas that can be driven on. In this way, a much larger area can be restored with well-established vegetation than with grass swards. Restoration, however, is significantly more sparse, and the danger of erosion is higher.

Grass swards or larger pieces of vegetation won during levelling or path construction, are placed in groups following completion of the work. They are very suitable for the rapid and site-specific restoration of damaged areas. On steeper banks, the grass turfs must be affixed with wooden nails. With the coordination of building, it is very often possible to avoid the intermediate storage of grass swards. Ideally, the pieces of vegetation are removed from a point planned for building and used directly for re-cultivation at another place within the same building plan.

Combined seed-sward process

In this special restoration technique, the coverage with grass swards, or other pieces of vegetation, is combined with dry or wet seed. The grass swards (2–5 m^2) are placed in groups in dry locations to prevent them from drying out and placed grid-like in areas with high precipitation. Site-specific seed is applied to sparse patches between the swards. This seed has a stabilising effect on the vegetation-bearing layer. Due to the short distances between the covered grass swards, it is possible for well-established vegetation to move into the intermediate spaces. In this way, these patches will also be restored and inhabited in a natural way by species not available as seeds (Krautzer *et al.*, 2006).

Planting of individual species or pre-cultivated plant elements

The plants are pre-cultivated and planted with a well-developed root stock at the restoration site. Site-specific species with a good vegetative growth are used for this. One can also turn to mother plants taken directly on site by experts. Questions of legal nature-protection ownership are to be cleared-up beforehand. With the appropriate choice of species, excellent results can be achieved at extreme sites in this way. The supporting use of this method as a post-improvement measure against sparseness in the restoration area is favourable.

Conclusions

Ecological restoration made enormous progress in recent years (Krautzer and Hacker, 2006). Twenty years ago, restoration identical to nature was considered impossible. In the meantime, there are numerous excellent examples of ecological restoration from wetlands to opencast mining areas up to high zones.

The only available resource of seed or plant material, which can fulfil the demands of nature conservation, regional aspects and site-specificity, is semi-natural grassland. Nevertheless, in recent years a large number of methods for the winning and reproduction and use of this material have been developed. To secure the regional availability of site specific plant or seed material, a land register of potential donor sites should be developed, including information about site conditions, plant communities, exploitation methods and limitations. To guarantee the use of site specific plant or seed material, approved certification procedures for such material have to be developed.

A basic problem is that the latest technological developments for site-specific restoration in Europe are defined very differently and the knowledge of special restoration methods is insufficiently available. The legal sphere dedicated to extensive restoration methods also lacks uniformity. What is common in some countries is strictly forbidden in others. Above all, due to the manifested prohibitions, mostly given in nature-protection laws, the use of vegetation alien to the site is in practice often ignored due to a lack of the knowledge of alternatives. Although in almost all of the affected states, nature-protection permission for building projects are obligatory, realisation of the laws are not or less than strictly controlled.

Moreover, with such building projects it has repeatedly been indicated that many projects related to site-specific restoration are not exactly defined. In this respect there are either no relevant guidelines or also no norms available, or in different countries the most different standards are used and that the 'latest technological developments' are generally insufficiently defined. Also from an overall European perspective it would be urgently necessary to work on a uniform definition of terms and an efficient distribution of the latest technological developments in site-specific restoration processes.

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Effect of inoculation, plant density and plant stand development on the seed multiplication of *Trifolium alpinum*

Peratoner G.[1], Scherer E.[2], Pramsohler M.[1] and Gallmetzer W.[2]

[1]*Research Centre for Forestry and Agriculture Laimburg, Auer/Ora, Italy*
[2]*Department of Hydraulic Engineering, Autonomous Province of Bozen, Bozen, Italy*
E-mail: giovanni.peratoner@provinz.bz.it

Abstract

In difficult environments, the use of site-specific seed is very important for the achievement of a successful and enduring restoration following natural or anthropic disturbance. *Trifolium alpinum*, a clover species with good consolidating properties, is one of the few legumes found at high altitude under strongly acidic soil conditions. For this reasons, its use in such environments would be desirable. However, its seed multiplication has repeatedly proved to be very difficult in practice, because of slow growth and phytosanitary problems. A three-year field experiment was conducted in Prettau/Ahrntal (South Tyrol, Italy) at 1,600 m a.s.l. to assess the influence of original soil used as an inoculum and of different plant densities on plant growth, seed yield and seed quality. The crop survived two winters with minor losses. Inoculum and plant density had no effect on seed yield, although greater cover values were achieved by inoculated treatments. Inflorescence density, seed yield and seed quality showed variability over time.

Keywords: site-specific species, *Trifolium alpinum*, seed multiplication, seed yield, seed quality

Introduction

In mountain areas, plants used to re-vegetate disturbed areas are subjected to climatic and edaphic constraints limiting their growth and survival. The use of site-specific plant material, being adapted to such environments, is an important issue for successful restoration in the long term. *Trifolium alpinum* is one of the few legumes occurring above the timberline on acidic soils. Its deep and strong taproot and his effective contribution to the nitrogen cycle through nitrogen fixation in the natural environment make *Trifolium alpinum* a desirable species for restoration of siliceous sites at high altitude (Krautzer *et al.*, 2004). Seed multiplication of mountain species at low altitudes reduces the time to attain the reproductive stage and generally leads to higher seed yield and better seed quality (Krautzer, 1995). However, repeated failures of lowland seed production due to high mortality rates and extremely slow growth of *Trifolium alpinum* have been reported (Hegi, 1964; Peratoner, 2003). Greenhouse experiments showed that this species is susceptible to nematodes of the genus *Pratylenchus* and that the use of autochthonous soil as an inoculum source for soil microorganisms beneficially affect plant growth (Peratoner *et al.*, 2007). As *Trifolium alpinum* is currently used in South Tyrol for re-vegetation in sites affected by hydraulic engineering, a local experiment was established, in order to verify the suitability of a propagation site at an intermediate altitude and to estimate the seed potential of this species.

Material and methods

A field trial was established in July 2006 in the upper montane belt at the nursery garden Prettau of the Province of Bozen (12°7'38"E, 17°2'51"N, South Tyrol, Italy) in a north-exposed field at an altitude of 1,600 m a.s.l. Plants of *Trifolium alpinum* were grown from surface-sterilised seed of a locally collected ecotype (Meran 2000, Hafling, South Tyrol, Italy) according to Peratoner *et al.* (2007) in plastic containers (Rootrainer, model Rannoch B, Ronaash Ltd., Kenno, UK) with a commercial substrate (46011 Stato Hum, Gebrüder Patzer GmbH, Sinntal/Jossa, D). Half of the plants were inoculated at sowing with a top layer (2 cm thick) of original topsoil obtained from the site where the seed was collected. After 5 months, the plants were transplanted into the field. The acidic soil (pH 5.6) was rich in P (174 mg kg^{-1}) and K (66 mg kg^{-1}) and had a relatively high humus content (81 g kg^{-1}). Two factors were investigated: the inoculation with original soil (present/absent) and two different planting densities (67 or 89 plants m^{-2}). The experiment was laid out as a split-plot block design with four replications with planting density as the split factor. The plot size was 1.35 m^2 and the desired planting densities were obtained by varying the plant distance within the rows, while the distance between the rows (15 cm) did not change. The trial was manually weeded once in 2006 and twice in 2007 and 2008. Plant density was determined each year through plant counting within whole plots. This assessment could not be performed in 2008, because at this time the single plants could no longer be distinguished one from another. The projective cover of the crop plant was estimated in each plot within a frame of 0.25 m^2. At each seed harvest date, the number of ripe and unripe inflorescences was counted and ripe pods were manually harvested within the same area. They were dried for four days at a temperature of 30°C. The seed was then cleaned by hand. In 2008 the percentage of infertile flowers was determined on 3 samples of 100 flowers per plot. Thousand seed weight (TSW) was determined in 3 replicates per plot according to the guidelines of ISTA (1996). Germination tests were performed with a Jacobsen-apparatus (Cavallo Comm. Giuseppe, Costruzione apparecchi scientifici, Milano, I) at a temperature of 20°C in the darkness using scarified seeds with two replicates of 50 seeds for each plot according to the guidelines of ISTA (1996). Effects were statistically tested by means of a mixed model with inoculation, planting density, assessment date, block and all their interactions as fixed effects, while the interaction block*inoculation was regarded as a random effect. Single plots were considered as the subject of the repeated factor assessment date. Multiple comparisons were performed by Least Significant Difference. Data failing to fulfil requirements of normal distribution of residuals and variance homogeneity were subjected to the Friedman-test for several related variables. Multiple comparisons were performed with the Wilcoxon-Wilcox-test. All tests were carried out at $\alpha = 0.05$.

Results and discussion

None of the investigated factors affected the relatively low mortality rate recorded in the first winter (16.4%). Plots with smaller spacing within rows showed at this time a higher plant density (74.8 against 59.0 plants m^{-2}, $P < 0.001$). Nevertheless, planting density did not affect any of the other assessed traits, showing that less dense plant stands took advantage for their growth from the larger available space. Inoculation had the only treatment effect on the cover of *Trifolium alpinum*, with the cover of inoculated plants being slightly higher than that of untreated plants at all assessment dates (Table 1).

Table 1. Plant cover (%) of *Trifolium alpinum*: changes over time and inoculation effect

Inoculation	Assessment date				
	02. 09. 2006	08. 10. 2006	04. 07. 2007	24. 08. 2007	08. 08. 2008
Yes	43.6^{Da}	45.9^{Da}	66.1^{Ba}	84.1^{Aa}	54.6^{Ca}
No	37.1^{Db}	41.2^{Db}	54.4^{Bb}	79.4^{Ab}	44.3^{Cb}

Means without a capital letter in common within a row and means without a small letter in common in a column do significantly differ one from another.

In the first vegetation period the cover increased slowly and was below 50% at end of the season. In the following year relatively high values around 80% were achieved. However it decreased to about 50% in the course of the third vegetation period due to the competition of weeds, accounting for 49% of the total cover at harvest time.

Neither inoculation nor planting density affected the yield-related traits, which showed instead a definite change over time (Table 2). The lack of an effect of inoculation may be due to the high nutrient availability in soil.

Table 2. Ripening progress, seed yield and seed quality of *Trifolium alpinum* at different harvest dates

Trait	Harvest date		
	22. 08. 2007	20. 09. 2007	09. 08. 2008
Ripe inflorescences (No m^{-2})	223^{b}	153^{c}	622^{a}
Unripe inflorescences (No m^{-2})	238^{a}	41^{b}	3^{c}
Seed yield (kg ha^{-1}) †	82.5^{b}	28.0^{c}	189.3^{a}
TSW (g)	4.67^{a}	4.60^{a}	3.89^{b}
Seed germination (%) #	97.2^{a}	86.8^{b}	83.3^{b}

†Calculation with logarithmus-transformed data. Back-transformed means are shown

#Friedman-test, mean separation by Wilcoxon-Wilcox-test

Means without a letter in common significantly differ one from another

The reproductive stage was attained in the second vegetation period. In the first harvest year an indefinite ripening took place with the second harvest date yielding about one third of the earlier one. Altogether 110.5 kg ha^{-1} of seed was harvested. In the second harvest year, ripening was compact and the seed yield further increased up to about 190 kg ha^{-1}. Such yields are comparable with those of other alpine clover species, such as *Trifolium pratense* ssp. *nivale* or *Trifolium badium* (Krautzer *et al.,* 2004). However, seed yield did not increased proportionally to the increase of the density of ripe inflorescences, as there was a large proportion of infertile flowers (37%) and because of a decrease of the TSW. Seed germination decreased over time, possibly because of a greater occurrence of incompletely ripe seeds, which could be also responsible for the lower TSW of the last harvest.

Conclusions

The potential yield of *Trifolium alpinum* is comparable with other alpine clover species, if phytosanitary problems do not occur and proper soils are chosen for cultivation, even if grown in mountain areas. However, this species showed once again a poor competitive capacity, with current state-of-the-art weed control remaining a difficult task. Also the indefinite ripening of the first harvest year poses some limitations to maximising the seed yield. Efficient and affordable harvest methods should be developed.

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Re-introduction of grassland species still successful after a decade

Korevaar H. and Geerts R.H.E.M.

Plant Research International, Wageningen, the Netherlands
E-mail: hein.korevaar@wur.nl

Abstract

One of the limiting factors in restoration of species-rich grasslands is the availability of seeds from species of the original vegetation. Intensive grassland management and conventional farming practices have resulted in the disappearance of many semi-natural grassland species. As a consequence, seeds of these species are absent in the seed bank. In order to restore species-rich grasslands we started in 1995 with re-introduction experiments using seeds of twelve native grass and herb species. In other experiments we studied productivity and grass quality of species-rich grasslands. We conclude that top soil removal in combination with seed introduction was successful. Most of the species, which successfully established themselves at the start of the experiment, were still present after a decade. A mild fertilization application scheme did not affect species richness, made flowering more pronounced, improved grass production, while grass quality remained at the same level. Under low or unfertilized conditions, species-rich grassland can compete with *Lolium perenne* swards for production, although grass quality may decrease.

Keywords: re-introduction, species-rich grasslands, restoration management

Introduction

During the last decades the biodiversity of grasslands has decreased dramatically due to ongoing intensification. After a long period of intensive grassland management with frequent grassland reseeding, high fertilization rates and use of pesticides, most species of semi-natural vegetation types have disappeared. Reduction of soil fertility is generally not sufficient for restoration of species-rich grasslands. One of the limiting factors in restoration of species-rich grasslands is the availability of seeds from species of the original vegetation in the seed bank. In order to restore species richness we started in 1995 on De Veenkampen in Wageningen with re-introduction experiments using seeds of 12 species. Previously, all of these species were native to grasslands belonging to the *Cirsio-dissecti-Molinietum* community. In an earlier publication (Korevaar *et al.*, 2004) we presented results for the years 1995–2003. We concluded that germination and establishment of a number of the introduced species was quite good, but establishment of re-introduced species was strongly determined by the weather and initial growing conditions. However, as the persistence of re-introduced species remains unknown, this was the topic of our current study. Therefore, we now investigate this persistence by combining the results of three different studies.

Materials and methods

I. The first experiment started in autumn 1995 and 1996 on three types of grassland on wet peat soils: an unfertilized hayfield, a grazed and heavily fertilized grassland and

an unfertilized hayfield with increased groundwater levels. Seeds of 12 species *(Briza media, Danthonia decumbens, Molinea caerulea, Carex hostiana, Achillea ptarmica, Centaurea jacea, Cirsium dissectum, Filipendula ulmaria, Gentiana pneumonanthe, Prunella vulgaris, Rhinanthus angustifolius, Succisa pratensis)* were collected from a *Cirsio-dissecti-Molinietum* community in a nature reserve in the Wageningen region and then sown. At each type of grassland, four different treatments were applied (Korevaar *et al*., 2004):
Treatment C: control: maintaining existing sward without introduction of seeds;
Treatment Si: introduction of seeds in an existing sward in cultivated, 20 cm width, strips;
Treatment Rw: 10 cm topsoil removal without introduction of seeds;
Treatment Ri: 10 cm topsoil removal and introduction of seeds.
The numbers of the established species were scored in 1997, 2000, 2003 and 2006.

II. The second experiment was laid out on two farms on sandy soils in the eastern part of the Netherlands, near the municipality of Winterswijk. In the autumn of 2002 two fields were ploughed and a species-rich seed mixture (from an *Arrhenatheretum elatioris* community) was sown. After sward establishment, we introduced three different treatments: a) control: no fertilization, b) application of cattle slurry (15 t ha^{-1}), and c) fertilization with 11 kg ha^{-1} phosphorous (P) and 83 kg ha^{-1} potassium (K). Fertilization was applied in summer after the first cut. Total number of plant species, DM production and feeding value of the grass were measured in 2005–2008.

III. In 2006 an experiment was started that compared differences in productivity and feeding value of species-rich grass with *Lolium perenne* swards. This experiment took place on a farm in the municipality of Landhorst on a sandy soil. Three different seed mixtures were sown:
Treatment 1. a seed mixture of 9 grass species, 3 legumes and 4 herbs;
Treatment 2. seeds of 9 grass species mixed with native seeds harvested from an *A. elatioris* community; this mixture was comparable to the one that was used in Experiment II;
Treatment 3. a seed mixture of 4 grass grasses dominated by *Lolium perenne.*
Each seed mixture was combined with three different sub-treatments: (a) no application of fertilizer (control); (b) application of cattle slurry (20 t ha^{-1}): (c) application of 83 kg ha^{-1} potassium (K), no phosphorous was applied, as the P-content of the soil was already high.

Results and discussion

I. The study of Korevaar *et al.* (2004) describes the results of 7–8 years of the first experiment. Introduced species performed best after top soil removal (Ri). Moreover, the re-introduction of plant species in small strips (Si) seemed rather successful. However, since 2000 this situation changed and only some *A. ptarmica, C. jacea, P. vulgaris* and *S. pratensis* survived the competition with grass species of the existing sward (Table 1). Removal of the top soil remained a successful measure, even after 10–11 years. *M. caerulea, A. ptarmica, C. jacea, C. dissectum, P. vulgaris, S. pratensis* have establishedsuccessfully. Four species (*B. media, D. decumbens*, *C. hostiana, F. ulmaria*) are still present, although in limited numbers. Two species (*G. pneumonanthe, R. angustifolius*) disappeared. In the first years after removal of the top soil without seed introduction

(Rw), the sward was still open. Some species exploited this opportunity and spread out, but after 2000 the sward was more dense, thus offering fewer gaps for new species.

Table 1. Number of introduced species per treatment in 1997, 2000, 2003 and 2006

Year	C	Si	Rw	Ri	LSD ($P \leq 0.05$)
1997	0.00[a]	6.31[f]	1.38[b]	8.69[h]	
2000	0.06[a]	4.38[e]	2.63[cd]	8.94[h]	0.93
2003	0.00[a]	1.81[bc]	3.37[d]	7.13[fg]	
2006	0.00[a]	1.56[b]	2.94[d]	7.25[g]	

Different letters: species numbers are different $P \leq 0.05$

II. The data of the second experiment (Table 2) demonstrate that a limited application of cattle slurry or PK does not harm species-richness of these grasslands. As expected, grassland productivity increases. Because of the larger size of the flowers, the visual attractiveness of the fertilized treatments is higher compared to the unfertilized parts

Table 2. Number of plant species, DM production and feeding value of grass on two farms; average figures for years 2005–2008

Treatment	Fertilization (kg ha^{-1} yr^{-1}) N	P	K	Total number of species (100 m^2)	DM production (kg ha^{-1} yr^{-1})	Net energy (MJ kg^{-1} DM)
Control	0	0	0	27.4[a]	5,653[a]	5.02[a]
Slurry	35	9	80	26.6[a]	7,896[b]	4.99[a]
P + K	0	11	83	27.9[a]	7,260[b]	4.97[a]
LSD ($P \leq 0.05$)				1.9	1,337	0.14

Different letters: parameters are different $P \leq 0.05$

Table 3. Number of plant species, DM production and feeding value of species rich swards compared to a grass sward dominated by *Lolium perenne;* results of 2007

Seed mixture	Sub-treatment	Fertilization (kg ha^{-1} yr^{-1}) N	P	K	Total number of species (90 m^2)	DM production (kg ha^{-1} yr^{-1})	Net energy (MJ kg^{-1} DM)
1. Species rich with legumes and herbs	Control	0	0	0	22.67[a]	6,747[de]	4.55[abc]
	Slurry	38	14	100	23.33[ab]	5,836[cde]	4.48[ab]
	K	0	0	83	20.33[a]	7,466[e]	4.66[bc]
2. Species rich with native species	Control	0	0	0	29.67[bc]	4,025[abc]	4.42[a]
	Slurry	38	14	100	31.67c	5,337[bcd]	4.70c
	K	0	0	83	31.33c	4,253[abc]	4.60[abc]
3. Grass seed mixture (*L. perenne)*	Control	0	0	0	20.67[a]	3,190[a]	4.98[d]
	Slurry	38	14	100	19.33[a]	4,428[abc]	5.03[d]
	K	0	0	83	20.00[a]	3,368[ab]	4.73[c]
LSD ($P \leq 0.05$)					6.40	2,106	0.21

Different: parameters are different $P \leq 0.05$

of the fields. Grass quality, presented as net energy in the DM, was not affected by the treatments.

III. In the third experiment, three different seed mixtures were compared. As expected, each seed mixture has its own specific characteristics. The second seed mixture has resulted in the largest diversity of plant species. The first mixture is the most productive, presumably stimulated by the legumes (fixation of nitrogen, N). The quality of the grass in terms of net energy is highest when using mixture 3. As is shown in Table 3, limited fertilization neither does affect species numbers, nor production nor grass quality.

Conclusion

We combine the results of three different experiments. The first experiment demonstrates that those plant species that successfully establish themselves after the start of the experiment were still present after more than a decade. Top soil removal in combination with seed introduction (Rw) was more successful than seed introduction in small strips (Si). The second experiment shows that limited application of fertilizer does not affect the diversity of plant species, but improves grassland production and makes flowering more pronounced. Meanwhile, grass quality remains at the same level. The third experiment demonstrates that under unfertilized or low-fertilized conditions, species-rich grasslands can compete with *L. perenne* swards for production, but not for grass quality.

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Conservation of grasslands in the light of regulations through the example of the Polish Sudetes

Fatyga J., Nadolna L. and Żyszkowska M.

Institute for Land Reclamation and Grassland Farming, Lower Silesian Research Centre, Wrocław, Poland
E-mail: janina.fatyga@gmail.com

Abstract

The study presents the main EU and Polish legal acts that aim at the conservation of grasslands. They include the following regulations: LFA rules, increasing forestation, agri-environmental schemes, and the Ecological Network "Nature 2000", which were applied in the Polish Sudetes. It appeared that within the study region LFAs include 38,548 ha of grasslands in the mountain zone (> 500 m a.s.l.) and 38,516 ha of areas affected by specific handicaps (350–500 m a.s.l.). The agri-environmental schemes cover most grasslands, including three packages that address them directly and three packages that do so indirectly, e.g. sustainable agriculture schemes. Within the Ecological Network "Nature 2000" the chosen region was divided into 24 areas of 13,326 ha. It appeared that the introduction of the aforementioned regulations had curbed abandonment and grasslands lying fallow, which currently constitute not more than 15% of the area. However, the general tendency of withdrawal from mountain agriculture may pose a certain threat to the stability of the situation.

Keywords: the Polish Sudetes, grasslands, conservation, threats

Introduction

The conservation of grasslands has recently become one of the main targets of the EU agricultural policy. It results from the diminishing role of meadows and pastures in feeding ruminants for economic reasons, so that they are ploughed or abandoned, which reduces their area in many countries both in Europe and elsewhere in the world.

The process also affects mountain areas, which so far have represented grass and forest formation areas. Setting grasslands aside results in the degradation of turf and uncontrolled self-forestation. It reduces the value of the landscape and the biodiversity of the flora and fauna present in it. The study presents the EU legislation aiming at the conservation of permanent grasslands and its representation in Polish conditions, concerning in particular the mountains. It concerns the following regulations: LFAs, setting the agricultural-forest border, agri-environmental schemes, and the Ecological Network "Nature 2000". The study presents the threats to the conservation of the grasslands in the region and the need for it.

Materials and methods

The area researched includes the Polish Sudetes. In the south, the area is delineated by the main mountain ridge on the Polish-Czech border, and in the north-east by the Sudetic Marginal Fault, which coincides with the 300 m a.s.l. contour lines.

In the study the following were used: a digital elevation model (DEM), a database of soil factors and use, and a meadow and pasture valorisation index dividing them into very good, good, and poor categories. The study presents the EU regulations concerning LFAs, setting the agricultural-forest border, agri-environmental schemes, and the Ecological Network "Nature 2000".

Results and discussion

Region characteristics. The total study area is 317,910 ha, which includes 83,813 ha of grasslands, i.e. 48% of farmlands. In the zone 350–500 m a.s.l. the grassland area is 38,516 ha and above 500 m a.s.l. 38,548 ha. The region typically includes medium-quality grasslands – 57,608 ha; poor-quality grasslands cover an area of 26,000 ha and good-quality grasslands only 205 ha.

The process of the abandonment of meadow and pasture areas increased in Poland at the beginning of the '90s of the last century. According to the data of the Statistical Office (Agricultural Census, 2002), fallows in grasslands in 2002 were 25,920 ha, i.e. 30% of their total area. The process increased to the greatest extent in valleys, which are characterised by the best conditions for agricultural production.

The main EU Common Agricultural Policy measures that influence the exploitation and protection of grasslands include the following.

Area payments (Council Regulation, 2003). In order to prevent the diminishing and degradation of turf areas, the Member States are obliged to maintain their acreage of grasslands. Poland is obliged to keep its 2005 acreage. The decline of grasslands on an agricultural farm may not exceed 8% at any time. The indicator of keeping the grasslands in good condition and hence obtaining support within the unified area payments system is grazing livestock in the vegetation period or mowing the grass at least once a year until July 31 and removing the harvested biomass.

LFA (Regulation, 1999). The less favoured areas (LFA) support scheme for agriculture in the form of compensation payments aims at ensuring the continuity of the agricultural exploitation of these areas. Pursuant to Council Regulation (EC) No. 1257/1999, the qualification for an LFA in Poland was based on its absolute height above sea level. Villages in which 50% of the farmlands are located over 500 m a.s.l. are classified as mountain areas. Submontane areas located at 350–500 m a.s.l. are classified as LFAs affected by specific handicaps. Taking into account the aforementioned criteria, in the mountain areas the support concerns 38,548 ha of grasslands (46% of their total area) and in the areas affected by specific handicaps 38,516 ha (also 46% of their total area). The remaining areas of grassland outside the LFA cover 6,748 ha.

Agri-environmental schemes (Commission Regulation, 2002). Agri-environmental schemes currently constitute the main tool of the EU Common Agricultural Policy with reference to grasslands. Their accomplishment aims at the sustainable development of rural areas and maintaining biodiversity. Moreover, their aim is to support the implementation of the European Ecological Network "Nature 2000". In all these activities grasslands play a vital role. In Poland, within the Rural Areas Development Scheme for 2007–2013, in the new agri-environmental scheme, three packages concern turf areas. They include extensive permanent grasslands, the conservation of endangered bird species and natural habitats in the areas not covered by "Nature 2000", and the conservation of endangered bird species and natural habitats in the areas covered by "Nature 2000". Three packages concern grasslands directly, i.e. sustainable agriculture, ecological agriculture and conservation of soils and waters.

"Nature 2000" (Council Directive, 1992), Pursuant to EU directives (on the conservation of birds and natural habitats), Poland is obliged to implement the European Ecological

Network "Nature 2000" within its territory. Establishing Special Conservation Areas (SCA) aiming at the conservation of precious natural habitats and species is based on Annexes I, II, and III to the EU Council Directive on the conservation of natural habitats and wild fauna and flora. Within the region researched, 24 such areas have been established and presented for approval. Within 16 of them there are natural habitats in meadows and pastures: periodically humid *Molinia* meadows, lowland and mountain hay meadows, and mountain *Polygono-Trisetion* hay meadows. The most extensive areas covered by "Nature 2000" are located in the Karkonosze Mountains, Stołowe Mountains, Orlickie Mountains, Bardzkie Mountains, Bialskie Mountains, and in the Śnieżnik Mountains. In the natural habitat cover, grasslands constitute from 1 to 6% of the area.

Forestation programmes. Excluding the grassland areas of the Sudetes from the forestation programmes is a very important element of the conservation scheme (Journal of Laws, 2007). It refers to grasslands that are productively poor and located on slopes with a gradient over 15%, on shallow skeletal soils of the V and VI valuation classes. They include an area of 12,299 ha.

The aforementioned acts and regulations have been introduced since 2004, that is, since Poland's accession to the EU. The financial support connected with them has influenced a decrease in the scale of fallows in mountain grasslands. Some previously unexploited meadows and pastures have again become included in agricultural production. Currently, the area of unexploited grasslands in the region does not exceed 15%. Resuming their exploitation is not, however, related to the headage of ruminants. In spite of a constant headage of cattle, the headage of other ruminants (sheep and goats) is decreasing further in the region. Hence the conclusion may be drawn that the aspect of the productivity of the Sudetes meadows and pastures is losing its importance. A lack of alternative measures for their exploitation and alterations in the financial support measures within the Common Agricultural Policy may pose a threat for them in the future.

Conclusions

Grasslands constitute an important part of the agricultural space in the Sudetes. The maintaining and conservation of grasslands against degradation is vital for the sustainable development of the region. CAP measures introduced in 2004, in particular financial support in the form of area and compensation payments for cultivating less favoured areas (LFAs), have slowed down the process of the land lying fallow – the area of unexploited meadows and pastures has decreased by half. Abandoning agricultural cultivation of the grasslands may pose a threat to the stabilisation of these advantageous changes.

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Protection versus production of grasslands – some remarks on the determination of socially optimal provision levels

Bergmann H. and Freese J.

Georg-August University of Göttingen, Department for Agricultural Economics and Rural Development, Environmental and Resource Economics Group, Göttingen, Germany
E-mail: holger.bergmann@agr.uni-goettingen.de

Abstract

Worldwide, grasslands are being transformed. Extensive biodiversity-rich grasslands represent a special case of renewable stocks insofar as their intensification happens suddenly, while reversal can take decades. Analysing with the economic concept of the transaction curve and employing the precautionary principle, we argue that society needs to define the social optimal thresholds of grassland conversion and develop instruments for the protection of extensive biodiversity-rich grasslands.

Keywords: grassland conversion, ecosystem services, transformation curve, social optimum

Introduction

In Central Europe grasslands provide manifold market and non-market goods and services (Sala and Peruelo, 1997; MEA, 2005). Besides market goods such as food and fibres, grasslands provide many non-market services, such as supporting nutrition and water cycles or soil erosion control. Grasslands are one of the most important European habitats that provide eco-system services and food, as well as giving protection for biodiversity. In many regions grasslands are under pressure to be transformed into arable land, afforested, or used for large infrastructure projects. Between 2003 and 2007 the area of permanent grassland in Germany declined from 5.02 mill ha to 4.87 mill ha (–3.1%).
We present an economic perspective which resolves the conflict between intensified food production and the conservation of extensive semi-natural grassland habitats in Central Europe.

Initial situation, assumptions and analysis

Deciding on the "right" balance between food production and environmental protection can be done with the instrument of a transformation curve optimising the capital stocks in question (Figure 1). To simplify, we consider the stock of biodiversity-rich grasslands (grassland stock) and sum up all the other (intensive) uses of land as 'other land uses' stock. It is important to know that the curve (e.g. point B in Figure 1a) represents all the efficient combinations between grassland stocks and other production systems. The area between the curve and the axis (e.g. point A) represents all inefficient distributions, meaning the share of one stock can be raised without having to reduce the other shares simply by increasing the efficiency of use. In such inefficient situations, win-win situa-

tions exist in which greater biodiversity, as well as more food and fibre, can be produced. If an efficient situation exists, only trade-offs are possible.
Figure 1 demonstrates the importance of defining the correct optimisation aims. If a simple indicator (e.g. hectares of different land uses) is used, it is irrelevant at which position of the curve a society is. Every change results in the same change in ratio between the stocks (Figure 1a). If more exact indicators are used – such as available farm income earned by 'other land use' (Figure 1b) – the form of the curve changes. If the labelling of the other axis is also adapted – from hectares being conserved to a conservation quality index of grassland (Figure 1c) – it becomes obvious that at different positions there are different profit maxima, depending on the demands of society. Being already situated near one axis, the gain by moving nearer to the axis is small, whereas the reduction of the other stock is relatively large.
Secondly, extensively used biodiversity-rich grasslands represent a special case of a renewable stock. Their conversion to 'other uses' e.g. by enhanced fertilisation, draining, tilling and seeding, etc. and thus the reduction of biodiversity can take place immedi-

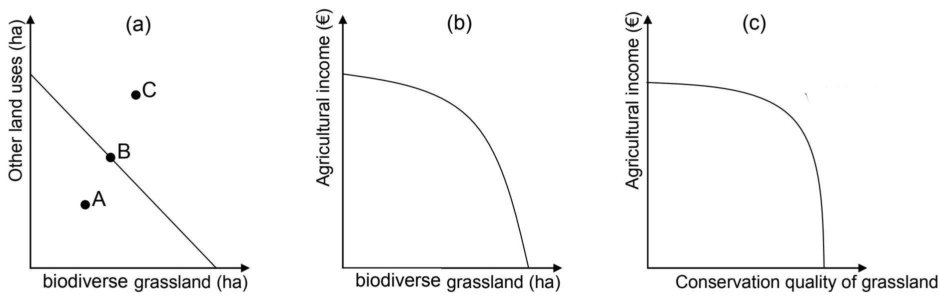

Figure 1. The transformation curves represent all efficient distributions between biodiversity conservation and intensive agricultural use of grasslands. Different axis-labelling results in different curves. Points on the curve, such as B, are efficient. A is inefficient, because not all resources are utilised. C cannot be reached with the given set of resources

ately, while the reversal (e.g. impoverishment, water logging, increasing biodiversity, etc.) normally needs decades (Spatz, 1994).
Thus the traditional economic concept of the immediate transformation and reconvention of stocks into each other in any order and without delay must be modified. The transformation curve becomes dynamic (Figure 2a). Shifting the relation towards income by converting biodiverse grasslands into arable land or into intensively used grasslands (moving from point t to t+1 in Figure 2a) results in a change in the transformation curve from M_t to M_{t+1}. To reconvert needs more investment than would be gained as additional income. Thus losing an existing patch of natural capital results in adding additional reversion (or time-lag) costs to the calculation.
Finally, taking into account philosophical considerations of coexisting individuals in a society, we have to answer two questions (cf. Kant or Rawls).
1. Can we find a theoretical justification?
2. Can we find hints to coherent behaviour?
With this procedure, we can justify the protection of a minimal natural capital stock from conversion into income. This can be justified as a majority of society benefits from the ecosystem services and goods provided by the natural capital (in our case the extensive

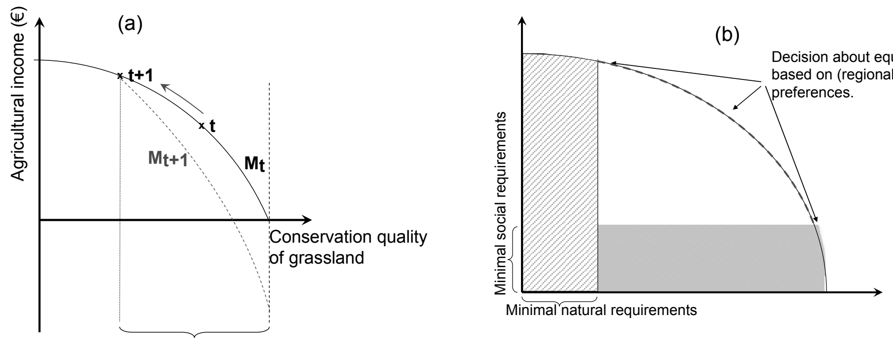

Figure 2. (a) Shifting of the transformation curve M_t to M_{t+1} as a result of the long recovery time of once-destroyed extensive grassland; (b) Using philosophical concepts economics defines taboo zones of protected minimal natural and social requirements. The social optimum has to be found as point of the transformation curve by not hurting the taboo zones and reflecting the regional preferences of the people affected

grassland and the maintained biodiversity). This is shown in Figure 2b as the minimal natural requirement which is needed to fulfil basic requirements for the survival of a society. Such a minimum requirements approach applying the precautionary principle blocks the extreme position (e.g. exhausting the resource). In the region in between (in Figure 2b the dashed part of the curve) economists are not able to make a decision based on theory; instead, economists are able to identify the equilibrium point on the basis of the will and decisions of society.

Results and discussion

Regarding the results presented in Figure 1c, there is no economic need to sacrifice the last remaining extensive grasslands for conversion into arable lands. The social costs of gaining very small additional revenues are generally higher than the expected profits. Figure 2a demonstrates that limited irreversibility of the regeneration of natural capital stocks requires additional careful evaluation by society, as well as by economists. Especially in situations in which the natural stock can become scarce, such a situation demands the analysis of public preferences so as to decide on the social optimal equilibrium.

Figure 2b demonstrates the economic representation of strong protection measures to protect the minimal natural requirements to sustain ecosystem services. Partial losses of valuable natural resources cannot be avoided. Third, there is leeway in which to socially negotiate the ‘right’ protection level, whereas we have to keep the limited irreversibility problem in mind.

As these theoretical considerations show, there is a need to protect biodiversity-rich grassland in order to:

(1) integrate the economic and social costs and benefits into future land management systems in order to find an efficient social balance between natural and material capital by e.g. the Contingent Valuation method and other stated preference methods (e.g. Bergmann, 2003; Mitchell and Carson, 1989, etc.);

(2) discuss under inclusion of the precautionary principle what the socially efficient choice of both minimal natural and material requirements is. Such discussions are

useful as in a time of highly fluctuating commodity prices the danger that biodiversity-rich grassland might be turned into arable land in the short term is increasing;

(3) advance methods and instruments such as agri-environmental schemes and implement them in projects to develop regional conflict solutions (Klimek *et al.*, 2008) as well as familiarise the broader public with analytical concepts and practical solutions (Prager and Freese, 2009).

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Evaluation of forage mixtures for environmental restoration of a clay quarry in central Italy

Staglianò N.[1], Bianchetto E.[2], Meo F.[1] and Argenti G.[1]

[1]*University of Florence, Department of Agronomy and Land Management, Florence, Italy*
[2]*Agricultural Research Council, Arezzo, Italy*
E-mail: nicolina.stagliano@unifi.it

Abstract

In areas affected by extractive activities it is important to recover the previous natural ecosystems with the aims of maintaining the biodiversity and reducing the visual impact of quarries. The objective of this work was to evaluate different plant material to restore a clay quarry site. In a randomised block design four mixtures were evaluated over two years in comparison with areas left to natural evolution. Data collection concerned periodical evaluation of ground cover and of botanical composition by means of linear analysis according to Daget and Poissonet. Ground cover was always higher in the four mixtures compared with areas left to natural evolution. Sown species dominated the swards and thus they could create some interference to the natural recolonisation of the canopy by species belonging to native flora.

Keywords: revegetation, vegetation evolution, ground cover, native species

Introduction

Human activities (such as ski runs, quarries, mines, motorways tracks, etc.) can much degrade affected areas and their biotic and abiotic components. It is important to achieve recovery of these areas. In these situations, revegetation is usually performed by means of forage mixtures which are fast in establishment and efficient in runoff prevention but, in some cases, they can lead to some environmental problems due to genetic contamination of autochthonous species or to the reduction of the recolonisation process by native flora (Scotton and Piccinin, 2004). For these reasons, the choice of the proper species to be employed in these conditions is very important and it should take into account also the intended subsequent utilisation of the area (Dinger, 1997) as the species utilised in the mixture can affect in a remarkable way the development of different plant communities on the restored surfaces (Newman and Redente, 2001). In the particular case of quarries or areas affected by extractive activities, the revegetation should be carried out with specific mixtures which are well adapted to the peculiar and difficult conditions of the soils and which are able to recover the previous natural ecosystems with the aims of maintaining the biodiversity and reducing the visual impact (Bianchetto, 2003). The paper presents some results from a revegetation trial in which different plant material was tested in a clay quarry.

Materials and methods

The trial was carried out, after the end of clay excavation, in a part of the quarry called ‘Ferrone’, about 25 km from Florence (central Italy). In a randomised block design, with three replications and plots of 125 m^2, four different mixtures and areas left to natural evolution (N) were studied. Mixture 1 (M1) comprised wastes of material coming from *Hedysarum coronarium* seed production, and for this reason it contained seeds of this species and of a large number of weeds typical of clay soils, such as *Lolium rigidum*, *Phalaris* sp., *Pichris echioides* and *P. hiearicoides*, *Rapistrum rugosum*, *Trifolium squarrosum*. The composition of the other mixtures were as follows: mixture 2 (M2) *Dactylis glomerata* (10% by weight), *Festuca ovina* (10%), *Hedysarum coronarium* (60%) and *Onobrychis viciifolia* (20%); mixture 3 (M3) *Lolium perenne* (40%) and *Hedysarum coronarium* (60%); mixture 4 (M4) *Dactylis glomerata* (19%), *Lolium rigidum* (14%), *Phalaris aquatica* (14%), *Medicago sativa* (24%), *Onobrychis viciifolia* (24%) and *Inula viscosa* (5%). Seeding was executed on spring 2002 with a seed rate of 60 kg ha^{-1} for each mixture. Data collection on seeded and natural areas was performed for two years and involved periodical estimation of ground cover and of botanical composition by means of linear analysis according to Daget and Poissonnet (1971).

Results and discussion

All tested mixtures produced efficient and rapid soil coverage (Figure 1) with reduced differences due mainly to the season of the botanical surveys. Only in a few periods the average value of ground cover was lower than 70%, which is considered the minimum level to reach to assure an effective runoff reduction (Linse *et al*., 2001). On the contrary, areas left to natural evolution produced a very low evolution with ground cover only reaching the value of about 40% after two years.

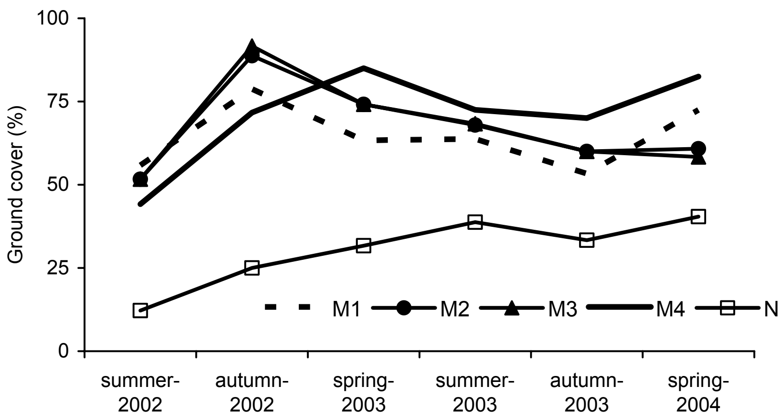

Figure 1. Average ground cover for studied mixtures and for natural areas in the years of trial

Botanical composition, grouped for families and for origin, at the end of the trial is given in Table 1. M1, M2 and M3 showed a similar pattern, with a higher proportion of grasses than M4 which was mainly composed of legumes. In sown plots, *Lolium* sp. and *Dactylis glomerata* showed the highest presence among grasses and *Hedysarum coronarium* was the dominant legume. It was also the species that mainly colonised natural areas (about 42%).

Presence of sown species was higher in M1 (more than 90%) and it was mainly due to the introduced species being particularly suitable for clay soils. Other mixtures showed

Table 1. Botanical composition for families and for origin in spring 2004

Treatment	Families			Origin	
	grasses	legumes	forbs	sown	native
Mixture 1	49.9[a]	21.7[b]	28.4[ab]	91.4[a]	8.6[b]
Mixture 2	56.4[a]	28.1[b]	15.5[b]	79.4[b]	20.6[a]
Mixture 3	50.7[a]	25.9[b]	23.4[ab]	74.1[b]	25.9[a]
Mixture 4	35.3[b]	54.1[a]	10.6[b]	75.9[b]	24.1[a]
Natural	16.2[c]	45.1[a]	38.7[a]	–	–

Values in a column with the same letter are not significantly different ($P < 0.01$, Tukey test)

a moderate presence of native species occurring on the plots. The tendency of sown species to dominate the canopies on the one hand permitted an efficient revegetation but on the other hand slowed down the recolonisation process performed by species belonging to native flora. Thus, a significant inverse relationship was found between presence of sown species and average number of native species (Figure 2).

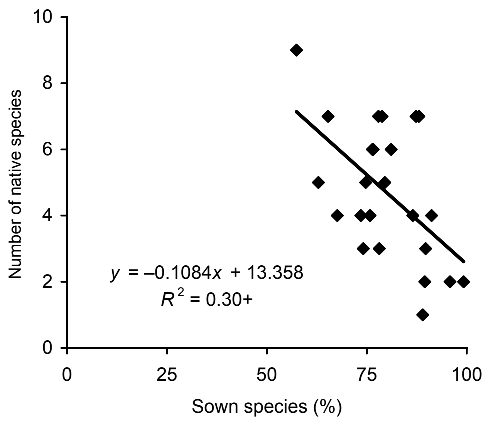

Figure 2. Relationship between presence of sown species and number of native species

Conclusions

The tested mixtures were effective, concerning growth and soil cover and thus they seem suitable for the use in these conditions. Areas that were not revegetated acted in a very different way, in terms of botanical composition and of renaturalisation. Results show that the success of a restoration, in terms of ground cover, could be achieved with very common forage species and with unconventional and cheap material (such as wastes of a previous productive process), but it is possible that some species that established in a very strong way could slow down the recolonisation carried out by the autochthonous flora, producing plant communities characterised by reduced floristic richness.

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Grassland management and nature conservation in natural grasslands of the Balaton Uplands National Park, Hungary

Penksza K.[1], Szentes S.[1], Házi J.[1], Tasi J.[2], Bartha S.[3] and Malatinszky Á.[1]

[1]*Szent István University, Faculty of Agricultural and Environmental Sciences, Department of Nature Conservation and Landscape Ecology, Gödöllő, Hungary*
[2]*Szent István University, Faculty of Agricultural and Environmental Sciences, Institute of Plant Production, Branch of Grassland Management, Gödöllő, Hungary*
[3] *Hungarian Academy of Sciences, Institute of Ecology and Botany, Vácrátót, Hungary*
E-mail: penksza@gmail.com

Abstract

Phytosociological relevés were collected in two territories of the Balaton Uplands National Park (Hungary) dominated by grassland habitats. Studied area in the Tihany Peninsula is a pasture of Hungarian Grey Cattle near the Inner Lake, where 5 phytosociological samples were taken both in the upper and in the lower third of the slope every June of 2007 and 2008. Four areas were studied in the Taplocai Basin (undergrazed and overgrazed pastures, hayfield, control area) near Badacsonytördemic. In the Taplocai Basin, a low number of species (20–30) was detected in the undergrazed pasture and the control area. The overgrazed pasture carries a low forage value and contains a high number of weed species, despite the spectacularly high total number of plant species (38–39), consequently, grazing pressure has to be decreased here.

Keywords: pasture, hayfield, grazing, species composition, nature conservation

Introduction

The domestic Hungarian Grey Cattle had originally been grazing on wet grasslands, but it has almost been extinct. Hungarian Grey Cattle can be kept on the pasture for a longer period (from April till November). Food availability depends on the quality, popularity, savouriness, nutritional value, energy concentration and digestibility of the grass, in one word the forage value of the pasture. Due to certain feeding surveys, the energy content of average grasslands is the highest in foliose status, while flowering grasslands provide only 66% in live-maintenance and 49% in body growth (Schmidt, 2003). Observations on vegetation of pastures and its changes have got a high importance (Barcsák and Kertész, 1986; Vinczeffy, 1998; Szemán, 2003). Natural grasslands were observed during the researches on botany and grassland management, and laying emphasize on the maintenance of nature conservation values as well.

Materials and methods

Phytosociological studies were prepared on grazed and non-grazed steppe grasslands near the Inner Lake (Tihany Peninsula), and wet meadows near Badacsonytördemic (Taplocai Basin), all belonging to the Balaton Uplands National Park (Hungary).

A 10 hectares grassland lying along the southern coast of the Inner Lake had been a mowed meadow before, and it has been converted into pasture for Hungarian Grey Cattle in 2002 (Penksza *et al*., 2003).
Five pieces of 2×2 m phytosociological relevés were examined on each sample area, prepared according to the Braun-Blanquet method.
Forage values of significant species occurring in the grassland were determined according to the 10-stage scale of Klapp *et al*. (1953), which gives value 8 for species with high forage value, 0 for those with the least value or not grazed by animals and –1 for poisonous species.

Results

Tihany Peninsula (Inner Lake area)

The typical association *Salvio nemorosae-Festucetum rupicolae* Zólyomi ex Soó 1964. The dominant species: *Festuca rupicola, Festuca pseudovina, Salvia nemorosa, Poa angustifolia, Cynodon dactylon*. Rate of medicinal plants has grown constantly as well (*Agrimonia eupatoria, Thymus* spp*., Hypericum perfoliatum, Achillea collina, Veronica* spp*., Cynodon dactylon, Elymus repens*). Number and covering rate of poisonous species were low (*Ranunculus bulbosus, Euphorbia cyparissias*). Amount of stinger plants, however, is high (*Carduus acanthoides, Eryngium campestre, Ononis spinosa*).
Both species number and total coverage showed a significant growth in the grassland near the Inner Lake. Among grassland management categories, rate of monocotyledonous species neutral for grassland management is the highest, showing a constant growth in coverage. Decrease in rate of grass species useful for grazing and growth in rate of narrow-leafed *Festuca* species (*Festuca rupicola, F. pseudovina., F. valesiaca*) are natural, but not disadvantageous processes in case of management by Hungarian Grey Cattle, since this breed was evolved in grasslands with similar species (Table 1).

Table 1. Characteristic data of the grassland near the Inner Lake (Tihany Peninsula)

	1994	2002	2006	2008
Species number	37	53	57	62
Total plant cover (%)	66	94.8	118	138
Protected	0	1	1	1
Medicinal herbs	20	22	24	25
Poisonous species	1	3	4	4
Forage value	2.50	2.93	4.10	3,20

Species composition, forage value of the grassland has decreased during the observed years, this is compensated by the massive growth of total cover, and therefore, the value of the grassland has grown from forage value point of view as well.
Based on data of nature conservation value categories, the rate of association composing species (E) was about 30% and the rate of weeds (GY) about 10% in every sample. Heightening nature conservation value of the grassland is showed by increasing rate of accompanying species (K) and decreasing rate of natural disturbance tolerant species (TZ).

Tapolcai Basin (areas near Badacsonytördemic)

Agostio-Deschampsietum caespitosae (Újvárosi, 1947) association was dominant on the area. The most frequent species with 10% higher *Festuca arundinacea, Poa angustifolia* and *Dactylis glomerata,* subdominant grass species: *Agrostis stolonifera* and *Deschampsia caespitosa*. Poisonous species: *Mentha aquatica, Sambucus nigra, Ranunculus repens, Ranunculus acris, R. sceleratus*.
Based on nature conservation value categories, the undergrazed area is dominated by natural disturbance tolerant species and association composing species. Rate of natural disturbance tolerant species was above 50% in the overgrazed area every time, referring to overgrazing. Association composing species have disappeared from the grassland by the end of the year. Almost 50% of the surface of sample plots on the hayfield was covered by association composing species.

Conclusions

Grassland management and forage value categories show the increase of species that are neutral for grazing, composed mainly by short, narrow-leafed *Festuca* species (belonging to the *Festuca rupicola* group), however, this is not disadvantageous for a well selected animal, in this case the Hungarian Grey Cattle. On the contrary of literature references that present species decreasing effects of grazing (Tóth *et al*., 2003) grazing activity did not cause a decrease in the number of species on the sample area of the Tihany Peninsula. The 7 to 9 cattles ensure a balance on the 10 hectares, completed by a clearing mowing once a year. This management ensures the balance of the grassland (Nagy, 1990).
In case of the sample areas lying near Badacsonytördemic changes in the vegetation are different, and they do not serve either nature conservation or economic profit in every case. Changes in vegetation of the pastures are significantly determined by grazing and there is a strict connection with the improvement of habitats (Milchunas *et al*., 1988).
A low number of species (20–30) was detected in the undergrazed pasture and the control area. About one month per year grazing time in the undergrazed area was not enough to achieve a better state for species diversity, and the amount of forage remained high.
The overgrazed pasture carries a low forage value and contains a high number of weed species, despite the spectacularly high total number of plant species (38–39), consequently, grazing pressure has to be decreased here. Although the number of species is lower in the hayfield (26–27), species composition and ability for forage supply is much better, showing that the proper management of the area is taken here.

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Influence of the thermal stress on some physiological features and survival of plants of *Lolium perenne* varieties Diament and Gagat

Borawska-Jarmułowicz B. and Mastalerczuk G.

Warsaw University of Life Sciences, Department of Agronomy, Poland,
E-mail: barbara_borawska_jarmulowicz@sggw.pl

Abstract

The aim of this paper was to estimate the freeze resistance of *Lolium perenne* varieties in controlled conditions. Two forage varieties of perennial ryegrass (*Lolium perenne* L.) – Diament and Gagat were examined in pure sowing in pot experiment at mineral soil. Plants in emergence and tillering phases were treated with low temperatures –5°C and –10°C for 24 hours. Leaf greenness index and chlorophyll fluorescence of selected varieties were measured using by standard methods and equipments. There were also recorded the number of shoots which survived after one week since thermal stress. The obtained results indicate that in analyzed plants of both *Lolium perenne* varieties exposed to low temperatures occurred significant decrease in chlorophyll content and fluorescence of chlorophyll comparing to the control. After one week since stress temperature the survival of shoots in tillering phase was clearly better than in emergence phase. It was found that the Diament variety characterized the best survival of shoots.

Keywords: chlorophyll fluorescence, freezing tolerance, chlorophyll, *Lolium perenne*, survival

Introduction

Perennial ryegrass (*Lolium perenne* L.) is the most widely grown forage grass in Poland. The increasing need for sustainable agricultural grassland requires the varieties with good winter survival to ensure sward longevity. The ability to tolerate sub-zero temperatures is integral to the survival of perennial ryegrass (Harrison *et al*., 1997). Since the development of freezing tolerance is crucial to the survival and productivity of overwintering crops, it is important to understand the basis of resistance or tolerance to low temperatures conditions (Wilson, 1981; Thomas and James, 1993). The present study investigates freeze resistance of two perennial ryegrass varieties: Diament and Gagat differing in way of utilization using some physiological features.

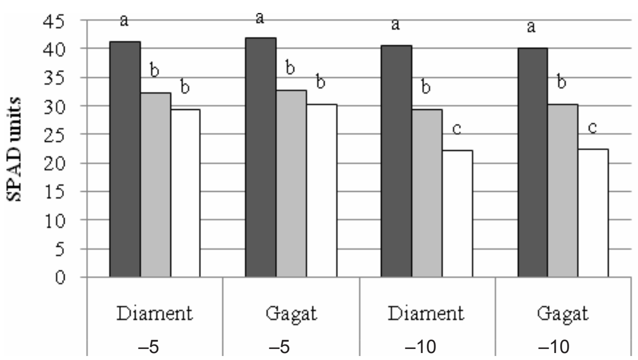
Materials and methods

Experiment was established in control conditions at the plant growth rooms (fitotron) of the Warsaw University of Life Sciences in 2008. Two forage varieties of perennial ryegrass – Diament and Gagat were sown pure in pots filled with 3 kg mineral brown soil at moisture 70% capillary water capacity (optimum moisture content). The concentration of available phosphorus, potassium and magnesium were medium and the soil pH_{KCl} was 5,1. Fifty seeds of each examined variety were sown at five pots (two stress temperature, two stages and control). Fertilization was applied once before sowing (g per pot): N – 1.039, P – 0.268, K – 0.162.

Plants in emergence and tillering phases were treated with low temperatures –5°C and –10°C for 24 h (thermal stress). Leaf greenness index with SPAD-502 chlorophyll meter (Minolta) and chlorophyll fluorescence with fluorescence meter FluorCam 800 MF Photon Systems Instruments were determined once before freezing (control) and twice after freezing (immediately and 48 h). Leaf greenness were measured in tillering phase on the fifteen youngest, fully developed leaves of randomly selected shoots of each pot. Chlorophyll fluorescence was measured in emergence and tillering phases on the single leaf in fifteen replications. There was also recorded the number of shoots survived after one week from thermal stress. The experimental data were evaluated using analysis of variance (one way ANOVA).

Result and discussion

The obtained results indicate that analySed varieties of *Lolium perenne* characterized the similar chlorophyll content of leaves expressed as leaf greenness (SPAD units) in control measurement (40.1–41.8) (Figure 1). There were also recorded that plants exposed to low temperatures (–5°C and –10°C) occurred significant decrease of chlorophyll content in the first measurement (immediately after freezing) comparing to the control. The difference was higher in plants treated with temperature –10°C independent on varieties (24.7–27.6%).
After 48 h from freezing chlorophyll content in leaves of investigated varieties was lower (especially after –10°C) in comparison to the control and first measurement.



Values on diagram followed with the same letters had no significant differences between them at the probability level of $P = 0.05$ according to Tukey's test

■ C; ■ I; □ II

Figure 1. Leaf greenness index (SPAD units) in tillering phase of *Lolium perenne* varieties (Diament, Gagat) before (control – C) and after freezing plants (I – immediately after freezing, II – 48 hours after freezing) in temperatures –5°C and –10°C

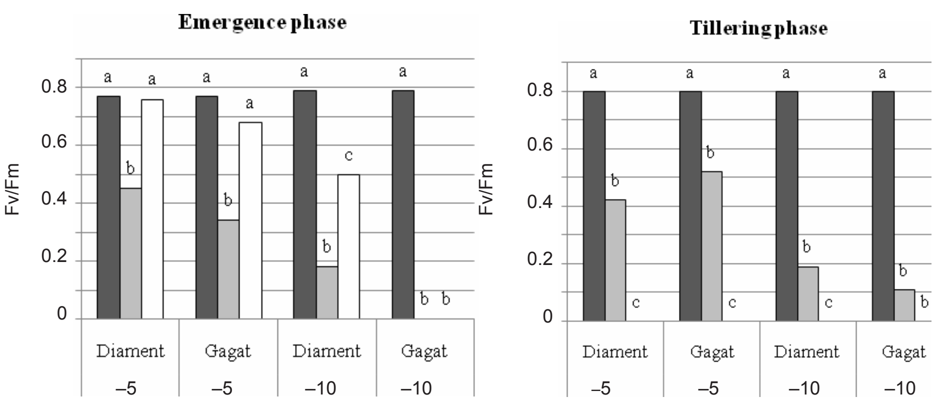
It was also found that fluorescence of chlorophyll (Fv/Fm) of plants in emergence and tillering phases of both *Lolium perenne* varieties was lower after thermal stress in comparison to the control (Figure 2). This is connected with the previous studies (Harrison *et al.,* 1997). The plants in emergence phase after exposed to freezing temperature of –5°C were recovered. The Fv/Fm values between control and 2nd measurement was nearly the same. After freezing at –10°C recovered only the plants of Diament variety.
A significant reduction in Fv/Fm values between the control and two others measurements was noted in plants in tillering phase frozen in temperatures –5°C and –10°C. There were no recovered plants.

In result of these one week after thermal stress the survival was observed only in shoots treated –5°C (Table 1). It was also found that the survival was clearly better in tillering phase and both of investigated varieties characterized similar, high survival (81% Diament, 78% Gagat). Survival of shoots in emergence phase was significantly better in Diament variety (about 26%). It was also observed that all plants treated with stress temperature –10°C died. The luck of survival of *Lolium perenne* plants after freezing for few hours in temperature –8°C was also reported by Lorenzetti *et al*. (1971).

Table 1. Survival of shoots of *Lolium perenne* varieties (Diament, Gagat) in emergence and tillering phases after one week since freezing (%)

Variety	–5°C	–10°C
Emergence phase		
Diament	25.7a	0.0a
Gagat	18.4b	0.0a
Tillering phase		
Diament	81.0a	0.0a
Gagat	78.0a	0.0a

Values in column followed with the same letters had no significant differences between them at the probability level of $P = 0.05$ according to Tukey's test



Values on diagram followed with the same letters had no significant differences between them at the probability level of $P = 0.05$ according to Tukey's test; ■ C; ■ I; □ II

Figure 2. Chlorophyll fluorescence (Fv/Fm) in emergence and tillering phases of growth of *Lolium perenne* (Diament, Gagat) varieties before (control – C) and after freezing plants (I – immediately after freezing, II – 48 h after freezing) in temperatures –5°C and –10°C

Conclusions

The obtained results indicate that in analyzed of both *Lolium perenne* varieties exposed to low temperatures occurred significant decrease in chlorophyll content comparing to the control. As a response to thermal stress –5°C and –10°C a significant reduction in

Fv/Fm values between the control and two others measurements was noted in plants in emergence and tillering phases. There was observed a recover of plants only in emergence phase after freezing in –5°C. One week after thermal stress the survival of shoots was recorded only in plants treated –5°C. It was also found that the survival was clearly better in tillering phase.
The best resistance for low temperatures characterized Diament variety.

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Effects of under-exploitation on the vegetation dynamics of permanent grassland in the vicinity of Lake Surduc (Western Romania)

Durău C.C., Moisuc A. and Tomodan I.L.

Banat University of Agricultural Sciences and Veterinary Medicine, Department of Grassland and Fodder Plants, Timisoara, Romania
E-mail: sch_carmen_1999@yahoo.com

Abstract

Wishing to meet present economic demands in a continually better way and also to develop a database for better guidance in the valorisation of the vegetal potential of a certain area or of a certain vegetal group, more and more phytocenologists and agriculturists are carrying out analyses of the different categories of plant communities. On the basis of such important factors as the share of these categories in the particular features of the species important for the different sectors of social and economic activity, on the plant organs or parts harvested for practical purposes, as well as on the evolutionary stage of the plant communities studied, specialists are increasingly capable of defining the intensity of their valorisation. In this paper, we present an assessment of the dynamics of the vegetation of grassland that was initially a *Poa pratensis* L. one, emphasising the effect of under-exploitation on the floristic composition. The inventory of the vegetal cover was made with the help of the double-meter method, while observations consisted of the analysis of 25 botanical samples over 5 years (2003-2007). Restricting occasional grazing and diminishing the number of cuttings over the 5 years mentioned above resulted in the grassland being redirected in a particular direction, in which such species as those belonging to the *Astereaceae* family are favoured (i.e. they develop extensively), while species belonging to the *Poacea* and *Fabaceae* families cover fewer and fewer areas and rank, therefore, among disadvantaged grasslands.

Keywords: dynamics, under-exploitation, specific volume, pastoral value, biodiversity

Introduction

The goal of the present paper is to point out the effects of under-exploitation on the dynamics of vegetation on a permanent pasture and, implicitly, the effects on pastoral value (PV) and biodiversity. The dynamics of vegetation are increasingly being affected by human activities. The more human society changes or the more systems that are being built, the more important it is to understand how human activities affect succession. A good example of an even more intensely managed system is agriculture, in which permanent or temporal fallows show vegetation changes (Pickett and Cadenasso, 2005). Romania's present situation concerning the continuously decreasing number of cattle (bovines, sheep, goats, and equines), together with the improper management of its privately-owned pasture patrimony, has a negative impact on the botanical composition of the permanent pastures and, implicitly, on their economic value (Durău *et al*., 2008). Thus, under-exploitation results in a decrease in the number of seeds which can induce dominance by large (competitive) species which exclude small-sized (less competitive) species and in bare land areas that are sometimes re-colonised by the seeds of new competitive plant species. Mowing, trampling, mineral or organic fertilisation, and also animal species and exploitation time are the main management variables directing the dynamics of vegetation on pastures.

Material and method

Observations of the grass cover and of the management type (mowing, grazing) were carried out between 2003 and 2007 on a pasture dominated by ass. *Poetum pratesis* L. The permanent pasture analysed is located in the Surducului Hills, close to the Fîrdea locality and to Lake Surduc (Western Romania). The pasture is 260 m above sea level, and it has a north-western exposure. The vegetation was determined through the double-meter method (Daget and Poissonet, 1971), and we observed five permanent samples (5 × 5 m). We could thus determine the average of the specific volume (SV %), of the pastoral value (PV), and of the Shannon-Weaver biodiversity index. As for the monitoring of the management with a view to the quantification of the use of this permanent pasture, we allotted points as follows: 1 point for harvesting the entire aerial parts of the plants upon mowing. In occasional grazing, we could see that they used only certain animal species, and allotted 0.5 points, while abandonment was granted 0 points. On the grounds of these considerations, the management of the pastures was quantified as follows: in 2003 the pasture was mown twice and grazed occasionally, and was granted 2.5 points; in 2004, the pasture was mown once and grazed occasionally, and was granted 1.5 points; in 2005, the pasture was grazed occasionally and was granted 0.5 points; in 2006 and 2007, the pasture was abandoned because the owner fenced it in and limited access to the pasture, which earned it 0 points for both of the years. The statistical method we used was correlation analysis.

Results and discussion

After sampling we could see that the species inventoried numbered 36 and we could group them into 15 botanical families. It is obvious that the impact of the management type of this permanent pasture had considerable repercussions for the SV (%) analysed for each botanical family. The dynamics of the SV (%) during the five years for the species belonging to the different botanical families is shown in Figure 1. Thus, most of the species we inventoried belong to the family *Asteraceae* (8 species): *Carduus*

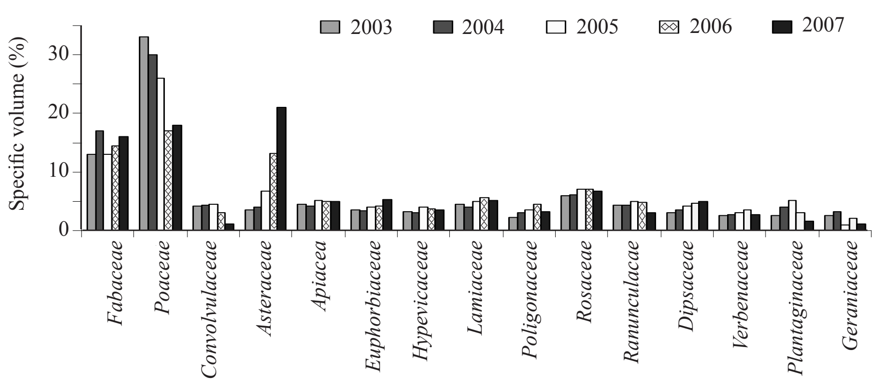

Figure 1. Dynamics of SV (%) for the species belonging to the different botanical families

acanthoides L., *Centaurea jaceae* L., *Crepis biennis* L., *Leuchanthemum vulgare* Lam., *Cychorium inthybus* L., and *Taraxacum officinale* Weber, but their SV (%) in 2003 was 3.6% and in 2007 it increased to 21.0%, compared to that of the *Poaceae*, which decreased from 33.0% to 17.4%.

Not all the species were equally influenced, for example *Fabaceae* (*Lotus corniculatus* L., *Genista tinctoria* L., *Vicia grandiflora* Scop.), *Lamiaceae* (*Mentha pulegium* L., *Salvia pratensis* L.), and *Apiaceae* (*Daucus carota* L.), which means that they have no defined trend and that the effect of under-exploitation in the years 2006 and 2007 will be felt in the years to come. The changes in the intensity and time of mowing and grazing resulted in changes in the floristic composition and, later, to the way the ecosystem functions (Backler, 1989, Milchunas and Laurenroth, 1993, Diaz *et al.,* 2007, cited by Klimešovà *et al.*, 2008). This is how we were able to explain the great interest in the monitoring of mowing and grazing of vegetal communities with a view to preserving biodiversity, economic value, and aesthetic value (Klimešovà *et al.*, 2008).The increasing or decreasing values of the specific volume are to be found in the pastoral value. Likewise, when we refer to the pastoral value of a pasture we implicitly refer to the biodiversity of the pasture because the structure of the grassy cover (i.e. the presence of some species) influences the pastoral value. This is why we correlated management and the pastoral value of the permanent pasture we analysed. The correlation coefficient $r = 0.91$ shows there is a positive correlation between the two variables we analysed and the regression straight line in Figure 2 has an ascending trend.

Analysing the biodiversity index during the five years, we can see that the pasture is characterised by a medium biodiversity (Figure 3). As for the analysis of the relation

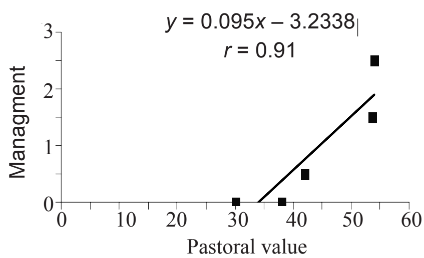

Figure 2. Relation between management and pastoral value

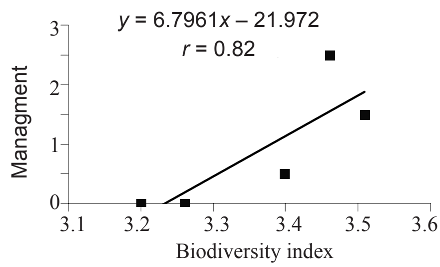

Figure 3. Relation between management and biodiversity index

between biodiversity and management, we can say that there is a positive correlation $r = 0.82$ between the two variables, which shows clearly that occasional grazing and abandonment leads to a reduction in biodiversity (Figure 3). Plant species avoided during grazing thus become competitive and this reduces biodiversity in pastures rich in species. Thus, the defoliation of competitive species is desirable when trying to manage pastures (Hessle *et al.,* 2008).

Conclusions

Restricting occasional grazing and diminishing the number of mowings until abandonment in the last two years resulted in a certain trajectory of the dynamics of vegetation. Thus, species belonging to the family *Asteraceae* are advantaged, while species belonging to the family *Poaceae* have a smaller and smaller SV (%) and are hindered. Likewise, the management type of this permanent pasture during the five years had repercussions for the PV and biodiversity.

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The reasons for degradation and methods of preserving permanent grasslands in Poland

Jankowska-Huflejt H. and Wróbel B.

Institute for Land Reclamation and Grassland Farming, Raszyn, Poland
E-mail: h.jankowska@imuz.edu.pl

Abstract

Permanent grasslands are important for their productive and economic role but also for environmental reasons. Their existence depends largely on mowing and grazing, which prevents the natural succession of trees and shrubs. Grassland in Poland constitutes 20.1% of agricultural lands, i.e. 3,217 thousand ha. This area has decreased in the last decade by 1 million ha. Pasture area decreased by 700 thousand ha, i.e. by almost 50%. Their use for animal production has weakened. Cattle numbers decreased by ca 50% and sheep numbers by 80%. C. 30% of grasslands are unused or used extensively (1–2 cuts) without harvesting the mown sward. Meadows and pastures undergo degradation and their productive and environmental potential is being lost. The development of animal breeding, mainly using low-cost systems with cattle, sheep and horses for slaughter, is a sine qua non for improving grassland use. There are also opportunities for the acknowledgement and promotion of environmental functions of grasslands. Mowing and/or grazing are an indispensable condition. Water management and the methods and systems of fodder production from grasslands with the use of modern technologies should be improved. Agro-environmental programmes or alternative biomass production for energy production might be important elements of grassland protection.

Keywords: grasslands, degradation, forage production, utilisation, ruminant breeding, biomass, environmental functions

Introduction

Permanent grasslands are the source of cheap, natural and valuable fodder irreplaceable in low-cost productive systems, e.g. ecological or extensive animal breeding (Jankowska-Huflejt *et al*., 2005). Permanent grasslands play an important role in the protection of soil, water, air, and landscape and in the maintenance of biodiversity of agricultural areas (Jankowska-Huflejt, 2006; Kopeć, 1999). The existence of meadow ecosystems depends largely on mowing and grazing, which counteract natural succession. Unfortunately, utilisation of large parts of grasslands in Poland has been limited or abandoned and mean hay yields are very low. Meadows and pastures become degraded and their productive and environmental potential is being lost. This paper aims at analysing the causes of grassland degradation in Poland and at discussing possible methods of their protection through the improved utilisation of their productive and environmental potential.

Present status of grasslands in Poland and its reasons

The total grassland area in Poland is 3,271 thousand ha – 2497.4 and 773.8 thousand ha of meadows and pastures, respectively, i.e. 20.15% of croplands (GUS, 2008). This area has decreased by ca 1 million ha in the last decade. The area of pastures decreased by 700 thousand ha, i.e. by ca 50%. This is an effect of abandoning production from part of the grasslands, particularly those situated in unfavourable and difficult habitat conditions. In the years 2000–2006, ca 20% of grasslands were not mown or were mown, but not harvested. Two cuts were harvested from 35% of meadows, one cut from 25% and three cuts from only 21% of meadows (Table 1). This provides evidence of the extensive use of grasslands; some of which were probably mown once to obtain direct subsidy and not to produce fodder. It means that productive meadows constituted slightly over 54% of their total area in 2000–2006. Poland's accession to EU and associated subsiding of agricultural production initiated some favourable changes. In the year 2007 unused meadows covered only 10%, 3-cut meadows – 51% and 2-cut meadows – 25% of the total area of meadows. Nevertheless, grassland condition is poor as evidenced by low hay yields (4.23 t ha^{-1} in 2000–2007, i.e. 30% less than in 1990 – Figure 1) and the small proportion of pastures in the total grassland area (Figure 2).

Table 1. The intensity of meadow utilisation in the years 2000–2006 (according to GUS)

Meadows	Years							
	2000	2001	2002	2003	2004	2005	2006	2007
1-cut	23.3	26.3	26.5	30.2	21.2	23.2	34.3	12.8
2-cut	33.3	36.4	38.1	39.3	34.6	37.1	33.0	25.2
3-cut	22.7	15.8	12.0	8.0	26.7	23.7	17.3	51.1
Not utilised	20.7	21.5	23.4	22.5	17.4	16.0	15.4	10.9

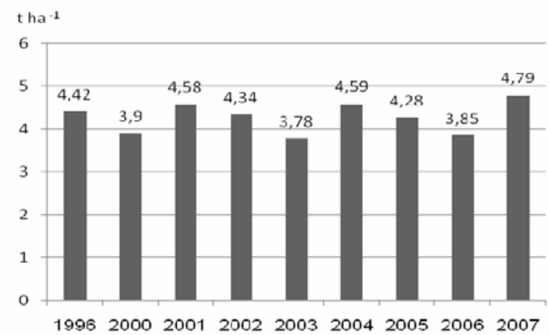

Figure 1. Yields of DM from meadow and pasture (GUS)

Such low yielding is a direct result of low fertilisation, particularly with nitrogen, which is applied usually once in spring. Extensive management of grasslands is also evident from very late first harvests, drying grasses in the swathe, grazing by tethered animals (improper care of pastures) and the production of hay (65%) instead of silage (10.9% of yields). Improperly regulated water relations due to neglected or destroyed reclamation facilities cause uncontrolled water outflow and drying out or excessive moisture of soils in river valleys (Łoś, 2005).

This low level of grassland management is caused by limited demand for fodder.The numbers of cattle and sheep in 2004 were only 50% and 20% respectively of those in 1980. There was a slight recovery in the numbers of cattle by 2007, with this recovery occurring only in cattle for slaughter (Table 2).

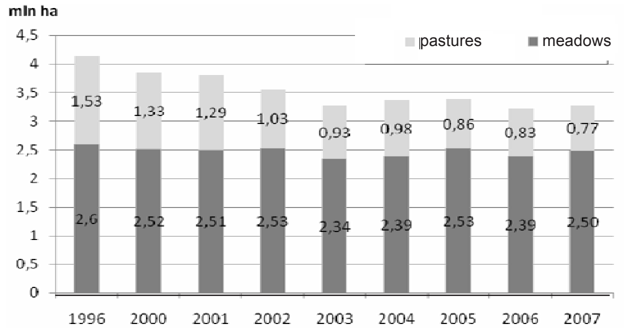

Figure 2. Area of meadows and pastures (GUS, 2008)

Table 2. Farm animal stock (head per 100 ha of croplands) (according to GUS)

Years	Cows		Sheep	Horses
	total	dairy cows		
1980	66.8	31.4	22.2	9.4
2004	32.8	17.1	1.9	2.0
2007	33.6	16.9	1.95	3.1

Excessive intensification and errors in utilisation and care are other threats to grasslands. Too frequent mowing, too high fertiliser doses, excessive grazing and intensity and type of utilisation not adjusted to the habitat and its productive potential have led to decreased sward cover and to impoverished species composition in some areas. In these circumstances, grasslands do not provide their protective environmental functions and the quality and quantity of fodder start to worsen. Changes in agrarian structure, such as the ploughing of meadows and pastures and sowing monocultures like maize, also pose a threat to grasslands.

Ways of limiting grassland degradation

A necessary condition for maintaining grasslands is their use for animal production and within agro-environmental programmes. In view of the existing milk quota (only 235 kg per capita) and less profitable milk production, the only way to improve grassland utilisation is to develop breeding of cattle, sheep and horses for slaughter. It is cheaper and simpler, especially in less accessible areas and in small farms. This approach is also favoured by increasing demand for these products in EU countries and potentially in the domestic market and by the existing farm buildings and herds. In order to do this, the herds should be restructured to select meat breeds and the approach to breeding should be adjusted to local conditions (Jankowska-Huflejt and Domański, 2008). In problem areas and on the least efficient pastures sheep breeding is the best and cheapest option to preserve plant and landscape diversity and good soil conditions.

Ecological farming – one of the fastest developing branches of agriculture worldwide – may be an alternative for neglected grasslands in Poland. Ecological farming produces fodder and animal products of better quality and favourably affects environmental quality, including water quality. In some regions (for instance with intensive water and aeolian erosion, areas of flood control, areas of recreational or ecological use) non-productive functions of grasslands might be more important from the social point of view than fodder production (Jankowska-Huflejt, 2006). The use of biomass from unexploited grasslands for energy production is another possibility. The energy value of grasses is estimated at 15 $MJ \cdot kg^{-1}$ dry weight. It is possible to obtain 1500 m^3 of biogas from 20 t of green grass . For these purposes economic calculation and implementation of modern technologies are necessary. There are also opportunities for grasslands in the implementation of agro-environmental programmes, mainly within the packages for rural development in the years 2007–2013 "Extensive permanent grasslands" and "Protection of endangered birds and natural habitats" oriented to increase biodiversity.

Conclusion

Grasslands as a source of cheap fodder are at present neglected in Poland and are being used only extensively or not at all. This brings about definite losses both economic and environmental, since such grasslands are not as effective in playing protective functions. An alternative, especially in view of the existing milk quota, is the low-cost breeding of cattle, sheep and horses for slaughter. It is advisable to improve water management and the methods and systems of fodder production, including the use of ecological farming systems. This may provide sustainable production safe for the environment and profitable for the farmer in accordance with the cross compliance instruments . Multifunctional grassland utilisation allows for various forms and levels of management intensity devoid of environmental hazards.

There are also possibilities for alternative ways of using grasslands for the production of biomass for energy production and for the accomplishment of agro-environmental programmes promoting environmental protection and sustainable development of rural areas. Ecological farming should also stimulate the use of grasslands, as the only croplands combining environmental and productive goals and the closing the nutrient cycles on the farm.

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The sowing of some wild meadow plants into grass mixture as a tool for increasing the diversity of grasslands

Marková H.[1], Pelikán J.[1], Ševčíková M.[2], Kašparová J.[2], Gottwaldová P.[3] and Vymyslický T.[3]

[1]*Research Institute for Fodder Crops, Ltd., Troubsko, Czech Republic*
[2]*Oseva PRO Ltd., Grassland Research Station, Rožnov-Zubří, Czech Republic*
[3]*Agricultural Research, Ltd., Troubsko, Czech Republic.*
E-mail: markova@vupt.cz

Abstract

The possibility of cultivating of selected wild species of the *Fabaceae* and *Poaceae* families as grassland components at two agro-ecologically different localities in the Czech Republic have been tested in 2004–2008. It can be concluded that most of the species tested are able to establish in grasslands. The climatic conditions of the locality, especially the amount of precipitation, are limiting factors for the survival of the species. A sufficient amount of seeds is necessary for the practical use of the species.

Keywords: diversity, wild species, *Fabaceae*, *Poaceae*, clover-grass mixtures

Introduction

The aim of the project called ′Increasing the diversity of forage crop communities′ is to increase the plant species diversity of grasslands with wild species of the *Fabaceae* and *Poaceae* families. During the collecting expeditions that were carried out within the framework of the ′National Programme on the Conservation and Utilization of Plant Genetic Resources and Agro-biodiversity′, attention is devoted both to wild forms of cultural species and also to other species of these two target families (Ševčíková *et al*., 2008). Vacek (1963) tested many species of the *Fabaceae* family in the fifties of the last century and some of them were recommended for cultivation. At present many wild fodder species are being collected and tested throughout the world (Jansone and Jansons, 2007). The use of these materials in field conditions is very important for increasing the species diversity of grasslands.The nomenclature of plant names in the paper was unified according to Kubát *et al*. (2002).The possibility of cultivating 22 selected species of the *Fabaceae* and *Poaceae* families as grassland components

Materials and methods

Twenty-two selected species of the *Fabaceae* and *Poaceae* families as grassland components has been tested at two localities from 2004 to 2008.
The trials were established on arable land at Troubsko (altitude 280 m a.s.1., average year temperature 8.5°C, annual precipitation 547 mm) and Zubří (altitude 350 m a.s.1., average year temperature 7.6°C, precipitation 903 mm). A grassland mixture was proposed for both localities. The grass mixture for Troubsko contained these species: *Festuca pratensis*, *Lolium perenne* , *Phleum pratense*, *Festulolium* sp. and *Poa pratense*, sowing rate was 26 kg ha^{-1}. The grass mixture for Zubří contained these species: *Festuca praten-*

sis, *Lolium perenne*, *Phleum pratense*, *Festuca rubra*, *Poa pratense*, *Trisetum flavescens* and *Cynosurum cristatum* sowing rate was 35 kg ha^{-1}.
50 seeds of species of the *Fabaceae* family (including hard seeds) and 100 seeds of the *Poaceae* species family were added to the grassland mixture. The trials were established by the method of randomised blocks in three repetitions, with a parcel size of 5 m^2. The number of surviving plants of each target species was found out at several points during the vegetation period in 3–4 growing years.

Results and discussion

Both localities differ in the number of added components found in the field plots. The species that were tested can be divided into three groups.
The first group is those species which had high coverage in the stand – *Lathyrus sylvestris*, *Trifolium alpestre*, *T. medium*, *T. rubens*, *Vicia cracca*, *Bromus erectus*, and *Phalaris arundinacea*). These species do not need special conditions for their growth and they are common species of meadow vegetation in central Europe (Slavík *et al*., 1995). Figures 1 and 2 show the increase in the number of these species during the evaluation of the trial.
The second group is those species which had low coverage in the stand (*Trifolium montanum*, *Briza media* and *Festuca rupicola*) or prospered only at one of the localities. *Lotus uliginosus* prospered in Zubří, because this species needs humid conditions for its gowth (Slavík *et al*., 1995). On the contrary *Astragalus cicer*, *Medicago falcata*, *Phleum phleoides*, and *Poa trivialis* prospered in Troubsko. These species need warmer conditions for growth (Slavík *et al*., 1995).
The third group is those species (*Galega officinalis*, *Melilotus officinalis*, *Vicia villosa*, *Brachypodium pinnatum*, *Helictotrichon pubescens*, and *Koeleria pyramidata*) which need different conditions for growth than both localities offer (for example meadow-salinated (alkaline) soils, ruderal communities, road-sides, xeric hillsides etc.). These species did not grow in the vegetation or were observed rarely.

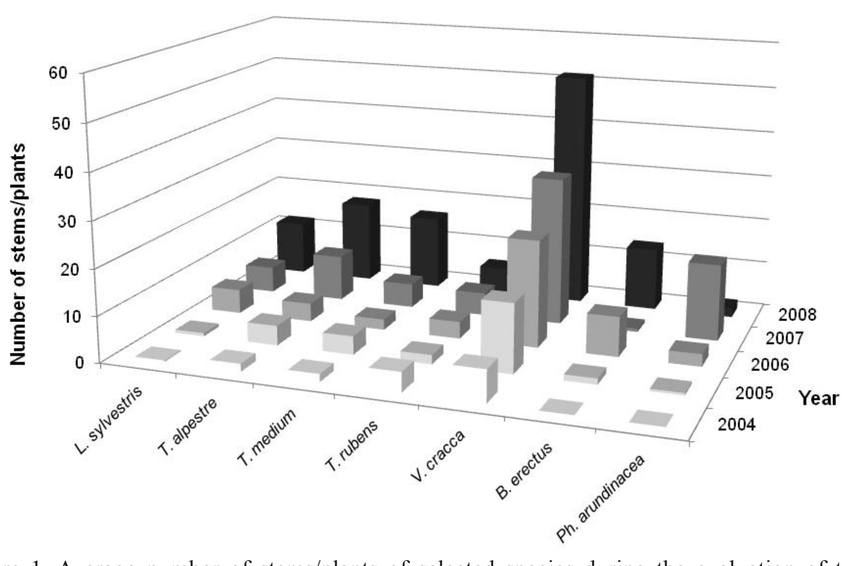

Figure 1. Average number of stems/plants of selected species during the evaluation of trial in Troubsko

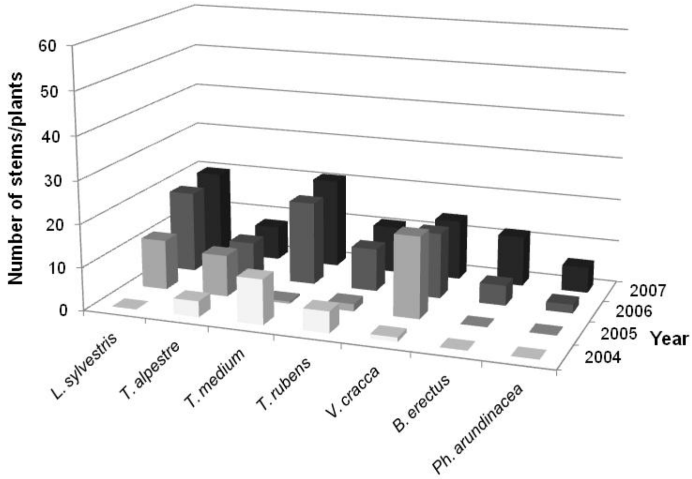

Figure 2. Average number of stems/plants of selected species during the evaluation of trial in Zubří

Conclusions

The monitoring of the species that were sown and the succession of the forage crop communities is a long-term activity. The trials are going to continue, but now we can state that many of the species of the *Fabaceae* and *Poaceae* family can be added to the mixtures for increasing the diversity of species-poor grassland communities. In favourable conditions the species of both families occur in the mixture and can keep up. We have to decide which species is suitable for the specific conditions of a given locality. The presumption of the use of the species in praxis is their good seed technology and the determination of the sowing rate of each species.

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Assessment of genetic resources of wild ecotypes and a range of cultivars of grasses and forage legumes

Martincová J.

Grassland and Mountain Agriculture Research Institute, Banska Bystrica, Slovakia
E-mail: jmartin@vutphp.sk

Abstract

Morphological, biological, and agronomic parameters, e.g. plant height, ear length, spring growth intensity, regrowth rate, and dry matter (DM) yield were assessed in wild ecotypes and cultivars of grasses and forage legumes. The research trial was carried out at a site in Banská Bystrica during 2005–2007 (1^{st}–3^{rd} harvest years). The trial involved 18 accessions (among them 13 ecotypes) of eight grasses and 14 accessions (of which 8 were ecotypes) of six forage legumes. The variability of all the traits investigated was high. The highest variability was recorded with the DM yield. The differences between the ecotypes were not significant. However, there were significant differences between the ecotypes and the cultivars. The spring growth intensity, the regrowth rate, the plant height and DM yield were higher for the cultivars than the ecotypes. The total DM yield ranged between 2.34 and 10.29 Mg ha^{-1} for grass cultivars and from 0.59 to 12.72 Mg ha^{-1} for legume cultivars.

Keywords: grass, forage legumes, dry matter yield, variability

Introduction

There are many negative effects relating to climate change. Nowadays, global warming is not to be overlooked and the issue of breeding forage crops resistant against environmental stress is very topical. Forage crop ecotypes found in permanent grassland areas are a precious source of selected traits for plant breeding. That is why attention is given to searching for and growing crops that would produce better yields and resist the negative impacts of the environment, such as drought, pests, and diseases. The objective of the research presented was to assess morphological and qualitative traits in a range of wild ecotypes, as well as in cultivars of grasses and legumes, with the aim of showing the variability of their traits.

Materials and methods

In 2004, a research trial was conducted with the aim of studying both the wild ecotypes and the cultivars of grasses and legumes at a site located within the Grassland and Mountain Agriculture Research Institute in Banská Bystrica (Central Slovakia, altitude 420 m; mean annual temperature 8.1°C; mean annual rainfall 693 mm). The research trial comprised 18 accessions of 8 grass species (*Festuca rubra, Festuca valesiaca*, *Poa pratensis*, *Trisetum flavescens*, *Phleum pratense*, *Phleum phleoides*, *Bromus erectus*, *Bromus inermis*) and 14 accessions of 6 forage legume species (*Anthyllis vulneraria*, *Coronilla varia*, *Onobrychis viciifolia*, *Lotus corniculatus*, *Medicago lupulina*, *Trifolium repens*) as given in Tables 1 and 2. Special attention was paid to selecting drought-tolerant species. The grasses were collected during missions in the Krkonoše Mountain and the Nízke Tatry Mountain ranges and also in the karst region of the Slovenský kras. The legumes were collected in the *Beskydy* Mountain range and in the Poľana and Považie regions. The trial was established by the method of randomised blocks with 2 replicates utilised for seed production or as forage crops. The pre-grown individual plants were planted in plots sized 0.5 × 2.0 m with a distance of 0.25 m between plants, with a row spacing of 0.50 m. For utilisation as forage crops, 2 rows with 14 plants per row were planted at each of the replicates. The row spacing was wider (0.80 m) when white clover (*Trifolium repens*) was planted. The soil was loamy-sandy with a high proportion of gravel and the content of available nutrients was very high. Some morphological, biological and economic traits were assessed during 2005–2007. In this paper, the basic economic traits are presented, namely plant height, spring growth intensity, after-cut regrowth rate, dry matter (DM) yield, and crude protein (CP) content. The research data were submitted for analysis of variance and the statistical significance was determined using the LSD test by the Statgraphics program.

Table 1. Morphological and agronomic traits of grasses averaged over 2005–2007

Treatment	Species	Ecotype/Cultivar	Plant height (mm)	Spring growth intensity (mm)	Regrowth rate (mm)	Dry matter yield (Mg ha^{-1})	Crude protein content (g kg^{-1})
1	*Festuca rubra*	SVKNTAT01-454	446.8	155.7	163.3	2.94	147.5
2	*Festuca rubra*	SVKNTAT01-371	487.8	180.9	157.3	2.93	166.9
3	*Festuca rubra*	SVKNTAT01-198	470.5	185.8	152.8	2.34	155.2
4	*Festuca valesiaca*	SVKGEM 02-18	455.5	202.8	160.2	3.73	153.6
5	*Festuca rubra*	Levočská	598.4	266.0	238.7	5.85	140.6
6	*Poa pratensis*	Hontianske Nemce	618.3	225.3	233.0	3.79	165.2
7	*Poa pratensis*	Čierny Balog	407.1	158.6	180.0	2.98	169.3
8	*Poa pratensis*	Lea	419.4	144.3	191.2	3.61	167.2
9	*Trisetum flavescens*	CZE KRK 01-77	674.2	334.6	374.5	3.43	128.2
10	*Trisetum flavescens*	Horal	671.8	321.9	169.5	5.06	148.2
11	*Phleum pratense*	SVKNTAT01-433	749.2	249.8	254.0	3.77	154.2
12	*Phleum pratense*	SVKNTAT01-193	562.2	213.6	229.1	3.52	144.7
13	*Phleum phleoides*	Biele Karpaty	650.9	263.1	228.1	3.86	148.5
14	*Phleum pratense*	Levočská	814.7	332.2	248.5	3,70	139.4
15	*Bromus erectus*	SVKGEM02-43	798.7	349.6	388.2	7.33	143.9
16	*Bromus erectus*	SVKGEM02-74	811.4	313.6	359.2	6.68	142.7
17	*Bromus erectus*	SVKGEM02-54	830.0	330.3	359.5	6.71	150.8
18	*Bromus inermis*	Tabrom	977.2	370.2	339.0	10.29	148.4
$\bar{x}$			637.5	255.5	245.9	4.58	150.8
$LSD_{0.05}$			130.8	66.0	74.7	1.38	26.51

Results and discussion

There were significant differences in all the traits investigated (plant height, spring growth intensity, regrowth rate, DM yield) between the wild ecotypes and the cultivars of grasses and legumes as well (Tables 1 and 2).
All the parameters were better for the cultivars than for the wild ecotypes. The differences between the species within the ecotypes were mostly not significant. High variability was recorded for the genetic resources. The plant height ranged between 419.4 and 977.2 mm (mean 637.5 mm) for the grasses and from 184.5 to 731.0 mm (mean 401.5 mm) for the legumes. Averaged over the years, the tallest plants were *Bromus inermis* cv. Tabrom (977.2 mm) from the grasses and *Onobrychis viciifolia* cv. Taja (731.0 mm) from the legumes. Among the ecotypes, the tallest plant (830.0 mm) was *Bromus erectus* (SVKGEM02-54), collected at the Soroška site. The most intensive spring growth (349.6 mm) and the highest regrowth rate (388.2 mm) were recorded for the ecotype of *Bromus erectus* (SVKGEM02-43) collected at the Bôrka site. The regrowth rate of legumes was higher for the cultivars than for the ecotypes, except for *Anthyllis vulneraria*. Drobná (2006) also reported that a comparison showed a higher regrowth rate among the bred cultivars of *Lotus corniculatus* than among the wild ecotypes. Similarly, Kelman *et al*. (1997) and also Saaren and Dev (2003) stated that the genetic variability was high among the wild populations of *Lotus corniculatus* and Martincová (2003) also reported high genetic variability in the genetic resources of tall fescue (*Festuca arundinacea*).

Table 2. Morphological and agronomic traits of legumes averaged over 2005–2007

Treatment	Species	Ecotype/Cultivar	Plant height (mm)	Spring growth intensity (mm)	Regrowth rate (mm)	Dry matter yield (Mg ha^{-1})	Crude protein content (g kg^{-1})
1	*Anthyllis vulneraria*	SVKBES99-515	334.7	98.6	180.9	1.40	168.5
2	*Anthyllis vulneraria*	Třebíčský	389.5	87.1	110.1	2.08	177.5
3	*Coronilla varia*	SVKZAH98-112	552.3	129.1	163.5	2.34	219.8
4	*Coronilla varia*	Eroza	710.1	153.7	175.3	5.86	218.5
5	*Onobrychis viciifolia*	SVNPIR01-86	682.6	189.6	159.6	5.16	189.8
6	*Onobrychis viciifolia*	Taja	731.0	241.4	275.6	12.72	198.0
7	*Lotus corniculatus*	SVKPOL96-132	250.0	69.6	124.0	2.85	186.4
8	*Lotus corniculatus*	SVKPOL96-112	448.1	80.4	148.0	0.60	208.0
9	*Lotus corniculatus*	Polom	360.8	120.0	172.7	5.92	184.5
10	*Medicago lupulina*	POLBES99-772	242.7	44.7	82.8	1.37	174.3
11	*Medicago lupulina*	Ekola	184.5	56.9	125.8	0.59	174.2
12	*Trifolium repens*	SVKPOV96-042	200.1	73.1	121.0	3.64	187.6
13	*Trifolium repens*	SVKPOV99-415	240.1	78.0	137.8	3.69	203.9
14	*Trifolium repens*	Dúbrava	294.7	108.0	156.3	6.73	208.3
$\bar{x}$			401.5	109.3	152.4	3.88	192.8
$LSD_{0.05}$			166.0	46.9	146.9	6.68	21.10

The research presented here showed the highest variability in DM production. The total DM yield was 2.34–10.29 Mg ha^{-1} for the grasses and 0.59–12.72 Mg ha^{-1} for the legumes. Averaged over the research years, the highest DM yield was recorded for *Bromus inermis* cv. Tabrom (10.29 Mg ha^{-1}) among the grasses and *Lotus corniculatus* cv. Taja (12.72 Mg ha^{-1}) among the legumes. There were significant differences between the cultivars and the ecotypes. The effects of the weather during the growing season on DM yield were very significant. In 2006 especially, the long period of drought and rainfall deficiency during the growing season resulted in a major reduction of the legume proportion and only the most drought-tolerant and persistent species – such as *Onobrychis viciifolia* and *Coronilla varia* – remained in the sward. On average, the crude protein content was higher in the ecotypes than in the cultivars, but the variability between them was low. However, the differences between the botanical groups were significant and CP content was higher for the legumes than for the grasses (192.8–150.8 g kg^{-1} DM), thus confirming that the CP content is richer in legumes than in grasses.

Conclusions

Grass and legume ecotypes and cultivars were compared within the research project "Measures considering adaptation of grassland and crop growing to climate change" during 2005–2007. Spring growth intensity, after-cut regrowth rate, plant height, and DM yield were better for the cultivars than for the ecotypes. The highest DM yields were recorded for the tallest cultivars of *Bromus inermis* (cv. Tabrom, 10.29 Mg ha^{-1}) and *Onobrychis viciifolia* (cv. Taja, 12.72 Mg ha^{-1}). The content of CP (as g kg^{-1} DM) was higher for the legumes (192.8 g kg^{-1} DM) than the grasses (150.8 g kg^{-1} DM).

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Transformation of arable land into wet grassland on a degraded low peat soil

Müller J.[1] and Kayser M.[2]

[1]*University of Rostock, Faculty of Agricultural and Environmental Sciences, Rostock, Germany*
[2]*University of Göttingen, Department of Crop Sciences, Göttingen, Germany*
E-mail: juergen.mueller3@uni-rostock.de

Abstract

Transformation of arable land into permanent grassland adapted to extensive use according to nature conservation guidelines is a special problem on eutrophic low peat soils. On these sites common restoration measures have often failed because of unfavourable soil conditions and ruderalization processes. The aim of our investigations was to compare the success of different treatments at producing a sward, well adapted to the goals of meadow bird conservation, by common agricultural measures. We tested the effects of different seed mixtures and utilization patterns in a field experiment. The different seed mixtures induced special vegetation characteristics in the first 4 years after sowing. The consistency of the artificially created diverse botanical compositions depended on the main grass component in the mixture. These findings reveal options for a more targeted restoration of grasslands depending on the site characteristics and on the specific renovation goals.

Keywords: restoration, peat soil, seed mixtures, cutting frequency

Introduction

Transformation of maize land into permanent grassland for extensive use according to nature conservation guidelines is a problem on eutrophic low peat soils. Common restoration measures, like fallowing or the introduction of diaspores from areas with the target vegetation (Manchester *et al*., 1999), often fail due to unfavourable soil conditions and invasion of ruderal species. To establish species-rich grassland on former arable land with high nutrient contents, the sowing of grass dominated seed mixtures could be a more successful way (Lawson *et al*., 2004). Sowing has advantages compared to fallowing: less danger of soil erosion, a reduced risk of nutrient leaching into the aquifer, prevention of invasion of ruderal species, better utilization of biomass, and reduced costs for habitat maintenance. The ideal seed mixture for this purpose would be able to dominate the ruderal flora and to realise high nutrient uptake during the phase of sward establishment, but would also allow a change in botanical composition towards the desired species-rich sward in due time (Müller, 2001).
The aim of our investigations was to assess the effect of different seed mixtures and cutting regimes at producing a sward that is favourable for meadow bird conservation on former arable land. We tested parameters of plant diversity, the proportion of ruderal flora and the quality of biomass for agricultural use.

Materials and methods

The field experiment was established at a low peat site in northwest Germany in 1998 and lasted until 2003. The field had previously been used as silage maize. No manure or mineral fertiliser was applied after transformation to grassland. The soil can be described as a degraded low peat fen rich in macro nutrients (P, K, Ca, Mg). The two-factorial experiment had 4 replications (Table 1).

Table 1. Experimental design of the transformation experiment

Factors	Level
1. Seed mixture	1.1–1.7 (7 seed mixtures with different main species)
2. Cutting regime	2.1 intensive – aiming at forage quality (3 cuts)
	2.2 extensive – aiming at nature conservation (2 cuts)[1]

[1] not before 21 of June

Plot size was 50 m^2 and biomass yield was determined at subplots of 10 m^2. Plant samples were dried at 60°C, ground to 1 mm and analyzed for crude nutrient contents by near-infrared spectroscopy (NIRS) using the validated calibrations 'FAL-EQA 99-02'. Calculations of the net energy value were made according to Weissbach *et al*. (1999). While the plots for nature conservation aims were cut only 2 times and not before June 21, the conventional plots had no restrictions (3 cuts), but harvesting had to take account of weather conditions and trafficability. Details of seed composition and seed rates are given in Table 2.

Table 2. Composition and seed rate (kg ha^{-1}) of grassland mixtures (main species in bold letters)

Species	Varieties	Seed mixture						
		I	II	III	IV	V	VI	VII
Lolium perenne	Barmaco/Limes	19.0				1.0	3.0	**14.0**
Festuca pratensis	Predix/Lifara		19.0			6.0	**14.0**	6.0
Phleum pratense	Liganta/Thibet			19.0		6.0	5.0	5.0
Festuca arundinacea	Feline/Elfine				**19.0**	6.0		
Festuca rubra	Tridano/Gondolin	3.0	3.0	3.0	3.0	3.0	3.0	
Poa pratensis	Oxford/Lato	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Trifolium repens	Milkanova/Rivendel	2.0	2.0	2.0	2.0	2.0	2.2	2.2
Seed rate (kg ha^{-1})		27.0	27.0	27.0	27.0	27.0	30.2	30.2

Results

The 7 different seed mixtures developed into differently composed swards with different biodiversity indices and varying proportion of ruderal species (Table 3).
Biodiversity was significantly reduced in mixtures with *Festuca arundinacea* as thee main species (Table 3), while the invasion of *Juncus effusus* was succesfully limited; obviously tall fescue was a strong competitor. Grasses with a fast initial growth like

Table 3. Some sward characteristics 5 years after sowing

Seed mixture	Main species 2003	*Rumex obtusifolius* (%)[1]	*Juncus effusus*	Taxa (S)[2]	Shannon (Hs)	Eveness (E)
1	*Glyceria fluitans, Alopecurus geniculatus*	1.4	1.0	15[a]	1.96[a]	0.72[a]
2	*Glyceria fluitans, Ranunculus repens*	0.8	2.3	14[a]	1.92[a]	0.73[a]
3	*Glyceria fluitans, Phleum pratense*	1.1	1.6	14[a]	1.80[a]	0.68[a]
4	*Festuca arundinacea*	2.0	0.0	7[b]	0.44[b]	0.23[b]
5	*Festuca arundinacea*	1.4	0.5	10[c]	0.60[b]	0.26[b]
6	*Glyceria fluitans, Ranunculus repens*	2.0	1.0	14[a]	2.01[a]	0.76[a]
7	*Glyceria fluitans, Alopecurus geniculatus*	0.4	1.0	15[a]	2.04[a]	0.75[a]

[1]Percentage of ground cover
[2]Values in columns with different letters are significantly different at the $P < 0.05$ level (SNK-Test)

Festuca pratensis and *Lolium perenne* seemed to curtail the spread of *Rumex obtusifolius*. However, this did not result in a lower degree of biodiversity, probably because of the limited persistence of the ray grasses.

In order to assess the possible utilisation in animal nutrition, harvested biomass was classified into four categories (UC) according to their net energy. UC1: > 6.0 MJ NEL kg^{-1} DM; UC2: 5.6–6.0 MJ NEL; UC3: 5.0–5.6 MJ NEL; UC4: < 5.0 MJ NEL kg^{-1} DM. Forages with a net energy < 5.0 MJ NEL can hardly be used for feeding cattle. Seed mixtures II, IV and V had reduced forage qualities under the extensive cutting regime. With seed mixtures I, II, and to a lesser extent VI, forage quality even under the extensive cutting regime was in a range, that would allow an economic grassland utilisation.

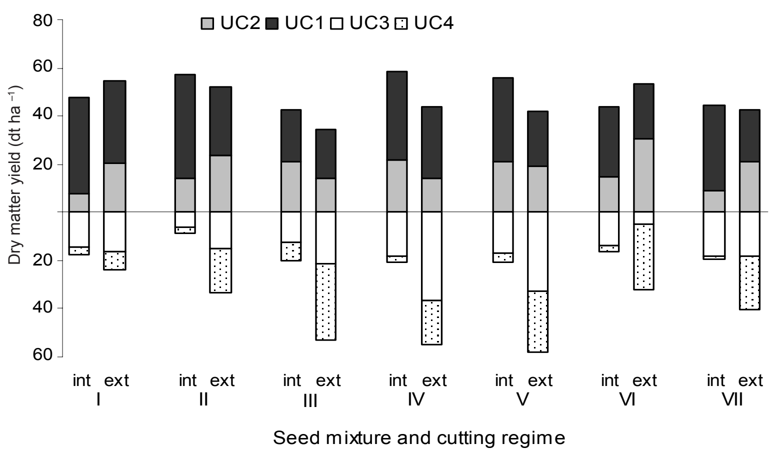

Figure 1. The effect of seed mixture and cutting regime on the proportion of 4 utilisation categories of the total dry matter yields (UC1–UC4 = utilisation categories based on the net energy value of the growth; int = intensive, ext = extensive cutting regime)

Discussion and conclusions

The consistency of the new swards and the development towards a diverse botanical composition depended on the choice of the main grass species in the seed mixture. This finding is in agreement with those of Müller (2001) and offers options for a well planned development of grass swards according to site characteristics and the aims of the restoration. Swards from seed mixtures with a higher proportion of grasses with a rapid development had significantly less weed species than *Rumex obtusifolius; Festuca arundinacea* dominated mixtures led to lower biodiversity, but realised high yields and nutrient uptake. Under extensive cutting regimes, often demanded for nature conservation, mixtures with *Festuca pratensis* are a good choice. Late ripening varieties of *Lolium perenne* seem to cope well with initial invasion of ruderal arable weeds and due to their limited persistence on peat soil will successively make room for autochthonous plants. We have shown, in line with Lawson *et al*. (2004), that by the sowing of a grass-based seed mixture on former arable land it is possible to create a vegetation which meets the functional demands of nature conservation, especially meadow bird breeding. The effect of the cutting regime, however, on the restoration of grassland on peat soil was not clear and depends to a large degree on the composition of the seed mixture and on the time passed since sowing.

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Biological properties of soil below seminatural grassland with the application of mineral and organic fertilisers

Ondrášek Ľ. and Čunderlík J.

Slovak Agricultural Research Centre, Grassland and Mountain Agriculture Research Institute, Banská Bystrica, Slovakia
E-mail: ondrasek@vutphp.sk

Abstract

The effects of mineral fertilisers (30 P + 60 K kg ha^{-1}; 60 N + 30 P + 60 K kg ha^{-1}or 120 N + 30 P + 60 K kg ha^{-1}) and farmyard manure (12 or 24 Mg ha^{-1}) on the biological and agrochemical properties of soil were investigated in seminatural grassland during the years 2004–2007. The following parameters were investigated: the intensity of total N mineralisation (TMN), the rate of nitrification (NIT), the total C content in microbial biomass (MB-C), NH_4^+-N, NO_3^--N, C_{ox}, N_t, P, K, Ca, Mg, pH, and the ratio of humic acids to fulvic acids (HA : FA). The research trial was established at the Radvaň site (near Banská Bystrica, central Slovakia, altitude 480 m, loamy to sandy-loamy Cambisol). The application of manure showed the strongest effect on the research parameters. The increase in TMN and NIT was significant. The soil pH, MB-C, N_t, Mg. P and C_{ox} also increased.

Keywords: grassland soil, mineral fertilisers, manure, nitrogen mineralisation, microbial biomass, agrochemical properties of soil

Introduction

The application of inorganic and organic fertiliser is a part of grassland management practices. These fertilisers have a great impact on a complex of physical, chemical, and, especially, biological properties of soil; great attention has been paid to this theme (Lovell and Jarvis, 1996; Parham *et al*., 2003; Bittman *et al*., 2005; Gondek and Filipek-Mazur, 2005). Data recorded in a four-year trial are presented here with the aim of comparing the effects of the application of farmyard manure and inorganic fertiliser on some biological and chemical properties of soil below seminatural grassland.

Materials and methods

A field trial was established on seminatural grassland utilised by three cuts at the Radvaň site (near Banská Bystrica; altitude 480 m; mild climatic region; long-term mean annual temperature 7.0–8.0°C; mean annual rainfall 852 mm; loamy to sandy-loamy Cambisol). In the autumn of 2003 and also 2005, farmyard manure (12 and 24 Mg ha^{-1}, i.e. rates of 60 and 120 kg N ha^{-1} as net nutrients, respectively) was applied to Treatments 5 and 6. During the period 2004–2007, inorganic fertilisers were applied to three more treatments at the following rates (as net nutrients kg ha^{-1}): 30 P + 60 K (Treatment 2); 60 N + 30 P + 60K (Treatment 3); 2× 60 N + 30 P + 60 K (Treatment 4). Treatment 1 was the non-fertilised control. The fertilisers were applied as ammonium nitrate (N), superphosphate (P), and potassium chloride (K).Throughout the trial, fresh soil was sampled (using a system of mean sampling) at 20–100 mm (the top 20-mm layer of the sward was cut off) on the dates of the 1st, 2nd, and 3rd cuts, as well as in the spring and in the autumn. The soil samples with natural moisture content were passed through a 2-mm sieve and the following parameters were determined: (a) the instantaneous content of NH_4^+-N and NO_3^--N (spectrophotometry, SKALAR); (b) the intensity of total mineralisation of nitrogen (TMN) after 14-day aerobic incubation of the soil samples at 25 °C and based on the difference in the content of NH_4^+-N and NO_3^--N between and after the incubation; (c) the rate of nitrification (NIT) after 14-day aerobic incubation at 25°C and based on the difference in NO_3^--N content between and after the incubation; (d) the C content in total microbial biomass (MB-C) of the autumn-sampled soil by the fumigation method (Šantrůčková, 1992), and (e) the soil sampled in the year 2006 was dried at laboratory temperature and the following parameters were measured: C_{ox} content (Tjurin); Nt (Kjeldahl); P, K, Ca, Mg (according to the Mehlich III method); pH (*n*KCl) and the ratio of humic acids to fulvic acids (HA:FA) by the spectrophotometry method. The data were analysed by the method of multiple and simple analysis of diffusion with a statistical software package (Stratgraphics).

Results and discussion

The intensity of total N mineralisation was markedly influenced by the application of fertiliser to grassland. The rate of 2× 60 N + 30 P + 60 K kg ha^{-1} (Treatment 4) significantly increased the TMN in 2004, 2005, and, especially, in 2007 – in this year, the TMN was twice as high as that recorded for the control. However, the application of manure showed the greatest effect on the TMN. In 2004, in comparison with the control, the TMN was three times higher with the manure rate of 12 Mg ha^{-1} (Treatment 5) and twice as high with one of 24 Mg ha^{-1} (Treatment 6), as shown by the mean values given in Table 1. The stimulating effects decreased during the following two years. In 2007, again, the TMN was notably stimulated and increased by 70% and 80% at Treatments 5 and 6 in comparison with the control, respectively. A strong relationship was found between the TMN and NIT (r = 0.92^{++}) in the trial. This indicates that nearly all the nitrogen coming from ammonification was oxidised to the nitrate N, and also that it was not the low pH (Table 3) but the NH_4^+-N content that was the limiting factor for the nitrification bacteria.

Table 1. Means ($\bar{x}$ = soil sampling 1–5) of total N mineralisation (mg NH_4^+-N kg^{-1} 14 day^{-1}) over the growing seasons of the research years

Years	Index	Treatments					
		1	2	3	4	5	6
2004	TMN	9.0^{a}	11.2^{ab}	13.1^{abc}	15.6^{bc}	26.3^{d}	18.1^{c}
	NIT	9.6^{a}	11.4^{ab}	14.9^{bc}	16.0^{cd}	23.7e	19.8^{de}
2005	TMN	13.9^{ab}	17.6^{cd}	13.2^{a}	21.6^{d}	20.5^{cd}	19.0^{cd}
	NIT	14.3^{a}	17.5^{b}	13.9^{a}	20.7^{c}	20.8^{c}	20.3^{bc}
2006	TMN	18.3^{ab}	16.3^{a}	23.1^{c}	21.0^{bc}	23.5^{c}	20.9^{bc}
	NIT	15.5^{a}	15.1^{a}	19.2^{ab}	20.7^{b}	23.3^{b}	21.3^{b}
2007	TMN	11.1^{a}	11.7^{a}	14.7^{a}	23.7^{c}	18.8^{b}	20.5^{bc}
	NIT	9.4^{a}	11.0^{a}	13.3^{a}	24.7^{c}	20.1^{b}	21.2^{bc}

Mean values not sharing a common letter are significantly different (LSD test, P = 95.0%)

The determined instantaneous NH_4^+-N and NO_3^--N content in the soil was mostly low throughout the growing seasons of the research years, indicating the ability of the sward to utilise sufficiently the nitrogen supplied as manure or fertiliser. Increased amounts of both the forms of nitrogen were found at Treatment 4, especially during the second spring sampling in 2004 (34.4 mg kg^{-1}), in 2006 (22.4 mg kg^{-1}), and in 2007 (21.8 mg kg^{-1}), as well as at the third sampling in 2007 (33.0 mg kg^{-1}); here, the nitrate N dominated.
The effects of the application of fertiliser and manure on the total C content in the microbial biomass in the soil (MB-C) were not uniform, but were mostly positive during the research years (Table 2). The highest rates of fertiliser and manure resulted in a somewhat increased C_{ox} and N_t content. Additionally, there was a tendency towards an improvement in the HA:FA ratio, especially at Treatments 2 and 4. Moreover, the application of manure in particular resulted in an increased content of Mg and P, and the acidity of the soil was reduced at all the treatments with nitrogen applied (Table 3). The increased values of the agrochemical and microbiological parameters of grassland soil resulting from organic

Table 2. The total C content in soil microbial biomass (mg C kg^{-1}) at sampling in the autumn of 2004–2007

Years	Treatments					
	1	2	3	4	5	6
2004	1,026.9^a	1,013.1^a	1,093.8^a	1,391.6^b	1,355.5^b	1,584.8^b
2005	789.9^a	769.0^a	889.0^b	901.3^b	792.0^a	1,069.4^c
2006	1,335.6^b	1,397.9^{bc}	1,569.5^e	1,337.8^{bc}	1,449.7^c	1,198.5^a
2007	914.9^a	974.0^a	906.1^a	1,140.0^b	1,193.5^b	973.5^a

Mean values not sharing a common letter are significantly different (LSD test, *P* = 95.0%)

Table 3. Mean values of agrochemical analysis of soil sampled in 2007 ($\bar{x}$ = soil sampling 1–5)

Treatments	C_{ox}	N_t	HK:FK	P	K	Ca	Mg	pH
1	28.4^{ab}	2.35^a	0.46^b	20.8^b	110.3^a	0.91^{ab}	231.1^a	3.83^a
2	25.1^a	2.50^a	0.50^d	8.2^a	114.3^a	0.90^{ab}	263.3^{ab}	3.96^{ab}
3	28.6^{ab}	2.84^a	0.43^a	6.6^a	130.9^b	0.85^{ab}	280.0^b	3.99^b
4	29.9^b	2.65^a	0.48c	7.6^a	116.4^{ab}	0.99^b	273.1^b	4.18^c
5	30.1^b	2.55^a	0.47^{bc}	56.0c	112.9^a	0.82^a	314.8c	3.96^{ab}
6	28.6^{ab}	2.68^a	0.45^b	21.0^b	110.1^a	0.99^b	281.4^b	4.15^c

C_{ox}, N_t (g kg^{-1}); P, K, Ca, Mg (mg kg^{-1})
Mean values not sharing a common letter are significantly different (LSD test, *P* = 95.0%)

fertilisers applied in various forms or through the excreta of grazing animals had been reported earlier (Lovell and Jarvis, 1996; Parham *et al*., 2003; Bittman *et al*., 2005; Gondek and Filipek-Mazur, 2005).

Conclusions

The application of the highest rate of inorganic fertiliser and both the rates of farmyard manure resulted in a notable increase in the intensity of the total mineralisation of nitrogen, as well as in the rate of nitrification in the soil. In spite of the increased TMN and NIT, the level of mineral forms of nitrogen was rather low in the soil during the period of the research. The impact of the inorganic and organic fertilisers on the total C content in the microbial biomass in the soil was mostly positive. The application of farmyard manure increased the C_{ox} and N_t content and reduced the soil acidity. Moreover, a farmyard manure application rate of 12 Mg ha^{-1} increased the content of P and Mg in the soil.

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Semi-natural grassland use in the Apuseni Mountains in the context of cultural landscape maintenance

Păcurar F., Rotar I., Vidican R. and Gârda N.

University of Agricultural Sciences and Veterinary Medicine,.Cluj-Napoca, Romania
E-mail: fpacurar@gmail.com

Abstract

On the Gheţari-Poiana Călineasa Plateau in the Apuseni Mountains (Romania) there are still important landscape elements that give a specific character to the region. The management that is being applied to semi-natural grasslands has generated a specific mountain landscape with a rich plant biodiversity and with a special tourism potential. The management continues to show numerous specific and traditional elements. The main inputs in grassland systems are: organic fertilisation, fighting against wooden vegetation, gathering rocks etc. The grasslands of the hamlets and their surroundings are exploited through a mixed system, grazing and mowing, and those situated at greater distances are used through grazing.

Keywords: cultural landscape, landscape elements, traditional management

Introduction

In Romania, the Apuseni Mountains are well known as being inhabited at high altitudes and the human influence is considerable. The actual landscape in the Gârda de Sus community is the consequence of traditional land use. In time, it generated some specific landscape elements which make it different from other mountain areas in the country. The individualisation process of the landscape elements is still unfolding. The application of traditional management to the grasslands contributes to the maintenance of some specific elements which define the original cultural landscape. Any modification that appears in the techniques used for the grasslands brings about the disappearance of some landscape elements or, perhaps, the appearance of others which can determine a significant alteration of the cultural landscape in the region being studied, with repercussions on the economic, ecological, and social levels (Reif *et al*., 2008). The objectives of our paper were to identify the main landscape elements which resulted after grassland use and to describe the traditional management that has been applied to the grasslands in the village of Gârda de Sus.

Material and methods

The research activity unfolded on the Gheţari-Poiana Călineasa Plateau, in the communnity of Gârda de Sus in the Apuseni Mountains (Romania). The area corresponds to a boreal floor and it is characterised by an average annual temperature of 4.9° C and average annual rainfall of 1,177 mm. The dominant grassland species are *Agrostis capillaris*, *Festuca rubra*, and *Nardus stricta*. The identification of the main landscape elements was performed through a satellite image, on which their spread on the plateau was marked. The traditional management of the grasslands was studied through a questionnaire with 79 questions being administered to 83 grassland owners. The questionnaire contained questions concerning the manner in which maintenance work on the grasslands was performed and how the grasslands were used.

Results and discussion

The landscape elements which characterise the Gheţari-Poiana Călineasa Plateau are permanent human settlements, seasonal constructions on grasslands, traditional building techniques, traditional roads, specific wells and watering places, the way in which grassland surfaces are delimited, solitary trees and piles of rocks in the grasslands, grasslands with plum trees, green terraces, arable land, and forest grazing. Permanent human settlements are specific to mountain areas, with diffuse precincts of the village organised in family hamlets called "crânguri" (groves). Among the groves, traditional roads appear which are narrow, with numerous rocks on the surface and accessible only to carts and, sometimes, to off-road cars. Other specific landscape elements are traditional wells and watering places. Each property is delimited by a small fence built out of the waste material resulting from the processing of fir and spruce fir trees. Within a farmstead, fences are used to delimit pastures, hay meadows and arable land. Solitary trees are remarkable elements for landscape aesthetics on the Gheţari-Poiana Călineasa Plateau. They appear in many forms: spruces with barren trunks, spruces with scarred-over holes, and solitary beeches with a short thick bole. Spruces with barren trunks show just a few branches at the top, because the lower ones are harvested by the locals for their fresh branches, which are fed to animals as supplementary fodder in winter time. The spruces with scarred-over holes are the result of resin collecting, and the *Fagus* with the bark removed appear as an effect of their sweet sap – a delicacy for locals, especially for children – being scraped away. Solitary beech trees with short, thick, and contorted boles can be seen on families' hay meadows and at the forest edge. Their unusual aspect is due to the periodical cutting of their branches, the leaves being used as fodder in very dry summers, which are frequent on this limestone plateau. The rock piles were formed as the result of rock-gathering activity on grasslands and arable land in order to facilitate the application of maintenance and exploitation works. Once gathered, the rocks are placed in piles at the plot's margins, or used in road repairs or for construction purposes in farmsteads. Another important element on the plateau is meadows with plum trees, which are located near the houses and whose trees serve as a source of fruit for family consumption. The yield is very low and the trees bear fruit only in favourable years. Fallow terraces are rather frequent elements on the plateau and they were formed over a period of time after agriculture with fallow ground practicing. Small land plots (2–5 ares) were cultivated for a few years and then naturally fallowed and are being further exploited as hay meadows. The assortment of plants that are cultivated is very restricted and consists of a few species of vegetables and potatoes. Forest grazing is an important landscape element in the region. It is practised not only on the plateau, but also on the communal pasture with cattle and horses during the summer.

All these landscape elements are the result of the application of traditional management for a long time. The exploitation system of pastures and hay meadows is rather complex because it involves, in addition to exploitation and maintenance works, the seasonal movement of the locals towards the Călineasa communal pasture. The system of exploitation of the grasslands begins early in the spring with extensive grazing around farmsteads. Then, at the end of May, the locals move with their animals to the Călineasa communal pasture, where they stay until the beginning of July. In July, they return to the village to mow the grasslands on their property. This activity lasts for approximately one month, and at the beginning of August, the locals, along with their animals, return to the communal pasture, where they remain until the conditions become suitable for grazing. The majority of the landowners questioned have plots of land for over 20 years (60 positive answers out of 83) (to save space we will further express ourselves more simply in our interpretation of their answers, e.g. 60 out of 83). The maintenance tasks carried out on the grasslands are the following: gathering rocks, destroying anthills, fighting against wooden vegetation and weeds, fertilisation, and others (Table 1). The most frequent maintenance tasks are gathering rocks (85.5%) and fertilisation (80.3%). All maintenance work is manually performed with different tools, and for the application of fertiliser animal-drawn carts are used (horses). Grassland fertilisation is organic only (60 out of 60), generally with stable manure that is 6 months old (57 out of 60) and comes from cattle and horses (59 out of 60).

Table 1. Status of performance of maintenance tasks

Question	Possible answers	Answers (number)	Answers (%)
What kind of maintenance tasks do you perform on grasslands?	gathering rocks	65	85.5
	destroying anthills	52	68.4
	fighting wooden vegetation	46	60.5
	fighting weeds	21	27.6
	fertilisation	61	80.3
	others	11	14.5
Total		76	100.0

Information regarding the quantity of manure applied was obtained, but it is not real, because the locals never weigh the manure and neither can they estimate it. After spreading, the manure is broken up by a “harrow”. This harrow is a fir tree with rocks on it and it is drawn by a horse. The unbroken manure is gathered by means of a rake and placed in piles (47 out of 60). Grasslands are mostly used in a mixed way (mowing + grazing) or only through grazing (Table 2). The mowing is generally performed manually (62 out of 63), and the starting moment is established according to the calendar date (60 out of 63). The mowing height is 2–3 cm (25 out of 63) or the grass is rasped (22 out of 63). In general, the grasslands are mown manually (44 out of 63) and there is one yield per year (58 out of 63). The grass is dried on the soil (62 out of 63), and the dry matter yield could never be estimated by the landowners. Regarding the grazing, the moment to begin is established randomly (57 out of 81) and rarely depending on the height of the

Table 2. How grasslands are used

Question	Possible answers	Answers (number)	Answers (%)
How do you use the meadow?	grazing	20	24
	mowing	2	2
	mixed	61	74
Total		83	100.0

grass (17 out of 81). The grazing stops with the onset of winter (54 out of 81). Grazing is generally practised with cattle and horses (75 out of 81).

Conclusions

On the Gheţari Poiana Călineasa Plateau there are still traditional landscape elements of great importance for landscape aesthetics.
The management applied to the grasslands still has numerous traditional elements of major importance for the maintenance of the cultural landscape on the plateau.

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Temporal variability in the forage production of a protected area with heterogeneous vegetation types

Peratoner G.[1], Figl U. [1], Gottardi S. [1], Bodner A.[1], Werth E.[1] and Kasal A.[2]

[1]*Research Centre for Forestry and Agriculture Laimburg, Auer/Ora, Italy*
[2]*Forest Department, Autonomous Province of Bozen, Bozen, Italy*
E-mail: Giovanni.Peratoner@provinz.bz.it

Abstract

Besides the site conditions, human intervention is often decisive for the development and the conservation of grassland areas of great ecological relevance, such as pastures on dry grassland. In this case, the conservation of protected areas can only be achieved if the animal load is adjusted according to the quantity of forage on offer. However, measuring forage production is sometimes difficult, because of yield fluctuations over time and the occurrence of different vegetation types. A two-year survey was conducted at the Natura 2000-site of Castelfeder (220–408 m a.s.l., South Tyrol, Italy). The changes over time of the growth rate of the three main grassland types (dry and semi-dry grassland, nutrient-rich pastures and extensively managed pastures) were monitored with the Corrall-Fenlon method. Forage production was found to differ greatly between different vegetation types and both within and between growing seasons. Precipitation was the factor that mostly affected the growth rate.

Keywords: protected areas, pasture, forage yield, precipitation, management plan

Introduction

The nature of pasture vegetation is the result of traditional agricultural activities with livestock farming. In protected areas, it is necessary to balance forage on offer and animal load, in order to avoid undesirable succession. However, a quantification of the forage on offer is often difficult to accomplish, because of high structural diversity of the vegetation and variation of forage production from year to year depending on environmental factors. For the formulation of precise management tools for protected areas including pastures, scientific studies focusing on yield productivity are required.

Material and methods

The study was carried out in the biotope Castelfeder, a protected area of 108.2 ha in the valley of the River Etsch. The investigated pastures belong to the township of Montan/Montagna (South Tyrol, Italy) and have an area of about 50 ha. The area is characterized by a mean yearly temperature of 12.4°C and a precipitation sum of 821 mm, with two peaks in June and October, respectively. The Castelfeder area belongs geologically to the Athesian Volcanic Group, mainly leading to shallow, acidic soils. The protected area of Castelfeder exhibits great species richness, due to the proximity of the Mediterranean and the Central European floristic regions. Within the protected area, three main pasture types can be found: dry and semi-dry grassland (DG), extensively managed pastures with *Festuca*

rubra (EP) and nutrient-rich pastures with *Festuca rubra* and *Agrostis tenuis* (RP) (Ruffini *et al.*, 2005). The grazing season starts in mid-April and ends in mid-November.
Starting in 2007, the forage growth rate was determined over time with the Corrall-Fenlon method (Corrall and Fenlon, 1978). In each of the main pasture types, an area of about 6 m² was fenced to prevent animal grazing. The location of the three sampling areas is given in Table 1. Six series of plots of 0.25 m² each were harvested in rotation, spaced a week apart. Data on growth rate and cumulative yield were obtained from the beginning of May until mid October. The experiment was laid out as a randomized complete design with four replications. In the second year, a different area in the immediate surroundings of the previous one was used for the assessments. The plots were harvested with electric scissors. The harvested forage was dried at 60°C for four days and then weighed.

Table 1. Location and topographic features of the sampling areas

Pasture type	Location	Altitude (m a.s.l.)	Exposition
DG	11°17'38"E 46°20'19"N	350	SW
EP	11°17'20"E 46°20'5"N	320	NW
RP	11°17'13"E 46°20'2"N	300	W

Meteorological data were obtained from the meteorological station of the Research Centre for Agriculture and Forestry Laimburg (11°17'18"E, 46°22'59"N, 222 m a.s.l.), about 5 km away from the experimental site. Growing degree days and precipitation sums were calculated for each regrowth period. Potential evapotranspiration was calculated according to Penman-Monteith (Allen *et al.*, 1998). A simple soil water balance was calculated for each regrowth period as the difference between the cumulative precipitation and the cumulative potential evapotranspiration.

Results and discussion

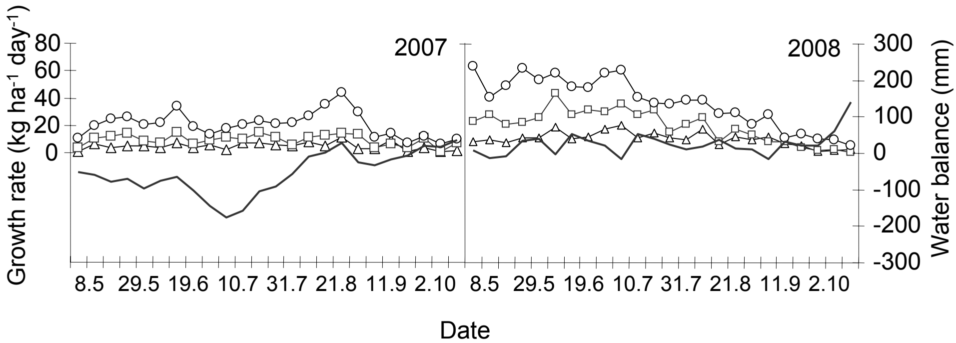
The cumulative forage yield showed great variability depending on the growing season and on the pasture type (Table 2).

Table 2. Effect of year and vegetation type on the cumulative forage yield (kg ha^{-1})

Pasture type	Year	
	2007	2008
DG	804^{c}	1,959^{c}
EP	1,556^{b}	4,671^{b}
RP	3,438^{a}	7,333^{a}

Mean separation by Tukey HSD at α = 0.05 with log-transformed data. Back-transformed means are shown. Within each year, means without a common letter significantly differ one from another

All pastures yielded more than twice as much in the second growing season as in the previous year. Growth seemed to be mainly constrained by lack of precipitation. In comparison to the long-term average for precipitation between April and October, a deficit of 169 mm was recorded in 2007, while this average was exceeded in 2008 by 256 mm.



Growth rate: △ DG; ○ EP; □ RP; — Water balance

Figure 1. Changes over time in the growth rate of different pasture types and in the water balance of the respective regrowth period (6 weeks)

While in 2007 the water balance exhibited negative values during a large part of the growth season, water deficits were only intermittent in 2008 (Figure 1).

Great yield differences were also found between different vegetation types, the dry grassland yielding about one fourth of the nutrient-rich pastures. The extensively managed pastures seemed to take particular advantage from the increased water availability, as their yield was three times higher in the second than the previous year.

None of the investigated climatic traits was able to explain variations of growth rate over time to a large extent and the correlation never exceeded 0.75. Growth rates were found to be mainly correlated in both the growing seasons with the precipitation sums recorded during the whole regrowth period (Table 3). Correlation with growing degree days was found to be consistent for all vegetation types only in the second growing season, in which rainfall did not represent a limiting factor. The correlation with the water balance was particularly poor in both years.

Table 3. Relationship between the mean growth rate in each regrowth period and growing degree days, precipitation sums and water balance

Vegetation type	2007			2008		
	growing degree days (°C)	precipitation sum (mm)	water balance (mm)	growing degree days (°C)	precipitation sum (mm)	water balance (mm)
DG	0.382**	0.441**	n.s.	0.670**	0.503**	–0.322*
EP	n.s.	0.201*	n.s.	0.527**	0.634**	n.s.
RP	0.545**	0.745**	-0.235*	0.398**	0.531**	n.s.

Correlation was calculated according to Spearman. Correlation coefficients (R) of significant correlations are shown (n.s. = not significant, **P* < 0.05, ***P* < 0.01)

Conclusions

Assessments of the forage production in protected areas with different vegetation types, whose growth is limited by water availability, should be made over more years, in order to gain information about average yield and the range in yields. The great seasonal yield fluctuations and the non-uniform response to change in water availability suggest that flexible management plans should be adopted in order to meet changes in forage production.

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Effects of seed rate and mixture composition on the revegetation of a landslide in an Apennine area

Staglianò N.[1], Argenti G.[1] and Albertosi A.[2]

[1]University of Florence, Department of Agronomy and Land Management, Florence, Italy
[2]Agricultural and Forest Service, Massa-Carrara Province, Firenze, Italy
E-mail: nicolina.stagliano@unifi.it

Abstract

The revegetation of landslides is an important technique to reduce soil erosion, to enhance the recolonisation of native vegetation, and to improve the visual impact of the area. To provide technical information on this topic, a two-year trial was carried out in an Apennine area of central Italy where two different seed rates (100 and 200 kg ha^{-1}) and four mixtures, differing in their composition and number of species, were compared in a factorial experiment, which also took into account areas left to natural evolution. The data collection concerned the ground cover and botanical composition. The seed rate had no effect on the soil cover or botanical composition. Three different mixtures permitted the attainment of values of ground cover that were adequate for erosion control, but differed in a remarkable way regarding their vegetal composition.

Keywords: runoff ,environmental restoration, native species, vegetal evolution

Introduction

Areas characterised by hydrological instability are restored by means of bioengineering techniques that also include revegetation in order to reduce soil erosion and to improve the visual impact of the bare surface (Argenti *et al*., 2006). Some lacks in this context concern the herbaceous species to be used, the seed rate, and the vegetal evolution of the restored areas (Albertosi, 2004). The aim of the present work was to test different seed rates and vegetal materials, in some cases represented by unconventional mixtures, to verify their utilisation in the environmental restoration of an area subjected to a landslide.

Materials and methods

The experimentation was conducted on a landslide located at 450 m a.s.l. in Tuscany (Italy), characterised by an annual rainfall of 865 mm and an average temperature of 14.0°C. The following four mixtures were compared: M1, composed of natural seeds harvested in mountain areas (*Festuca* gr. *rubra* 84% by weight, *Avenella flexuosa* 11%, *Poa trivialis* 4%, and minimal quantities of *Briza media*, *Luzula campestris*, and *Taraxacum officinale*); M2, a commercial mixture (*Festuca* gr. *rubra* 30%, *Festuca pratensis* 15%, *Dactylis glomerata* 15%, *Festuca* gr. *ovina* 10%, *Lolium perenne* 10%, *Medicago lupolina* 5%, *Onobrychis viciifolia* 5%, *Lotus corniculatus* 4%, *Trifolium repens* 3%, *Sanguisorba minor* 3%); M3, consisting of M2 to which the waste from the production of *Hedysarum coronarium* seeds had been added and which, for this reason, included a lot of autochthonous species; M4, a commercial mixture heavily dominated by red fescue (*Festuca* gr. *rubra* 58%, *Lolium perenne* 5%, *Phleum pratense* 5%, *Poa nemoralis* 5%, *Deschampsia caespitosa* 3%, *Agrostis tenuis* 3%, *Avenella flexuosa* 2%, *Trifolium repens* 10%, *Trifolium hybridum* 3%, *Trifolium pratense* 2%, *Lotus corniculatus* 2%, *Onobrychis viciifolia* 2%). The sowing was performed in March 2002 with seeding rates of 100 kg ha^{-1} and 200 kg ha^{-1} for each mixture. In comparison to the sown plots, bare areas left to natural evolution (N) were also assessed. The trial was arranged as a randomised blocks design with three replications and each plot was 50 m^2 wide. The data collection from spring 2002 until autumn 2003 concerned ground cover by means of visual estimation and botanical composition on each plot according to Daget and Poissonnet (1971).

Results and discussion

The seed rate produced significant effects only at the beginning of the trial and for this reason the results here presented concern only a comparison among the mixtures. The ground cover in the first phases of the trial (Figure 1) was rather low, especially in M1 (23%) and N (15%). Afterwards, all the mixtures studied produced growing soil coverage and in November 2002 M3 and M4 showed ground cover that exceeded the value of 70%, which is considered efficient in reducing soil erosion in a significant way (Linse *et al.*, 2001). M1 performed the worst, and M2 showed intermediate behaviour. The vegetation established in the areas that were not seeded reached its maximum value (about 50%) only at the end of the summer.

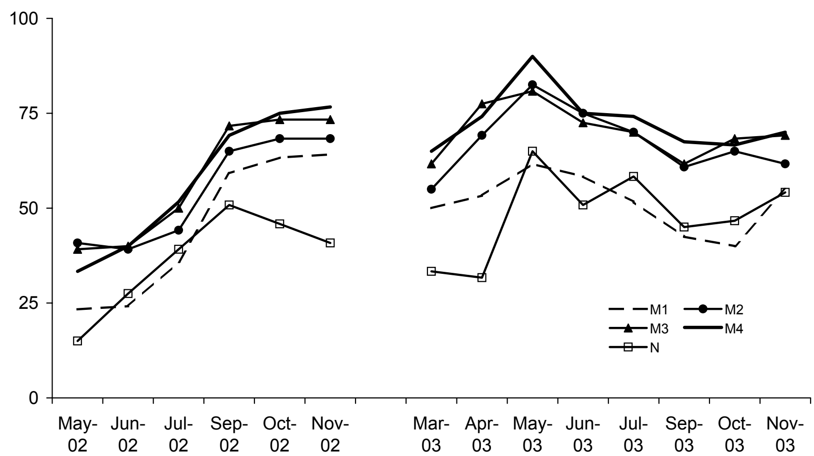

Figure 1. Ground cover for mixtures tested and for natural areas during the trial period

During the second year the performances of the mixtures were remarkably affected by the summer of 2003, which was particularly dry. In this year M2, M3, and M4 showed superiority in terms of ground cover, mainly because of the high presence in their composition of legumes, which tolerated the arid weather in a better way thanks to the depth of their taproots. On the contrary, M1 showed a very low capacity for facing the dry conditions and its ground cover values were similar to those observed in areas left to natural evolution. The average values of the total amount of specific contributions of sown species for each mixture and for the two years of the trial are given in Table 1.

Table 1. Specific contributions for sown species in each mixture for the years of the trial. Values in a column with the same letter are not significantly different ($P < 0.01$, Duncan test)

Treatments	2002	2003
Mixture 1	39.8[c]	31.4[c]
Mixture 2	81.1[a]	87.1[a]
Mixture 3	75.7[a]	85.5[a]
Mixture 4	66.1[b]	75.1[b]

The contributions of the sown species presented the same behaviour in both years of the experiment. It was very low in M1 (about 35% in the two years average) and, on the contrary, palpably higher in the other mixtures, with better performances for M3 and M4 (more than 80% on average), and, as before, M2 showed intermediate behaviour, even if it was closer to the better mixtures for this parameter.
The analysis of specific contributions (Table 2) showed that grasses were represented mainly by sown species, with a reduced percentage ranging from about 26% to 35%, probably as a result of the limited tolerance to drought of the species present in the mixtures. Moreover, the occurrence of grasses was higher in M1 than the other mixtures, even if the performance of this mixture is inferior than expected on the basis of its composition, which consisted of more than 80% grasses. This can be explained by the difficult adaptability of *Festuca* gr. *rubra* coming from high mountains to this environment. Legumes were generally more suited to the site area and the specific contribution of the sown species was not significantly different among the mixtures (around 40%). Species belonging to other families showed a reduced presence in the mixtures in which they were utilised, even if in M2 and M3 the sown species performed in a better way than in M1. *Sanguisorba minor* in M2 and *Pichris hieracioides* in M3 were the species that behaved in the best way among this category. The recolonisation of natural areas was performed mainly by legumes and forbs, as grasses confirmed their reduced adaptability to recover a herbaceous cover in this environment.

Table 2. Specific contributions for sown species and in total grouped for grasses, legumes, and other families. Values in a column with the same letter are not significantly different

Treatments	Sown species			Total		
	grasses	legumes	other families	grasses	legumes	other families
Mixture 1	34.5[a]	–	1.1[b]	41.6[a]	38.8[c]	19.6[b]
Mixture 2	29.8[ab]	44.5[ns]	9.8[a]	33.2[ab]	53.9[ab]	12.9[bc]
Mixture 3	29.5[ab]	38.9[ns]	12.2[a]	32.0[ab]	50.8[b]	17.2[b]
Mixture 4	25.7[b]	44.9[ns]	–	29.0[b]	61.8[a]	9.2[c]
N	–	–	–	12.6[c]	46.6[b]	40.8[a]

$P < 0.01$, ns = not significant, Duncan test

Conclusions

The experiment showed that even with seed rates that are not high it is possible to obtain efficient results during landslide restoration in terms of ground cover. Among the mixtures tested, Numbers 3 and 4 were those that performed in a better manner to reduce soil erosion and these good results were mainly due to the significant presence of productive species belonging to the grass or legume families. In this particular and dry environment legumes behaved in a very strong way, testifying to the possible use of this botanical family even in unconventional contexts such as this. In some cases species belonging to other families could also produce remarkable soil coverage and deeper investigations into this topic should be carried out. It is of extreme importance, in degraded areas from the hydrological point of view, to use in the mixtures for revegetation species that are surely suited to the peculiar environmental conditions in order to reduce failure in establishment.

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The influence of organic fertilisers on *Nardus stricta* L. grasslands in the Carpathian Mountains of Romania

Vintu V.[1], Samuil C.[1], Iacob T.[1], Saghin Gh.[2], Popovici I.C.[1] and Trofin A.[1]

[1]*University of Agricultural Sciences and Veterinary Medicine, Iasi, Romania*
[2]*Agricultural Research and Development Station of Suceava, Suceava, Romania*
E-mail: vvintu@univagro-iasi.ro

Abstract

The grassland patrimony of Romania is represented by over 4.9 million ha, of which more than half is found in mountainous areas. We have studied, in the intra-mountainous Depression of Vatra Dornei from the north-eastern Carpathian Mountains of Romania, the influence of organic fertilisation, at rates of 20–50 Mg ha^{-1}, applied each year or every two years, on the productivity, vegetal canopy, and content of crude protein, crude fibre, phosphorus, and crude ash. The goal of this paper was to emphasise the dynamics of the productivity and the phytocenosis biodiversity, resulting from the application of some technical and practical measures meant to improve fodder yield and quality on the *Nardus stricta* permanent grasslands with minimal effects on the environment. The organic fertiliser rates determined changes in the dominant species of *Nardus stricta* grasslands by increasing the percentage of *Festuca rubra* and *Agrostis capillaris*, from 10% to 11–35%, and by increasing the productivity and the CP content, by 25–115% and 16.2–31.9% respectively, compared with the unfertilised control. An increase in the phosphorus content of the fodder was also found.

Keywords: permanent grassland, organic fertilisation, productivity, quality, *Nardus stricta*

Introduction

In Romania, the grassland area, dominated by *Nardus stricta,* is over 100,000 ha. In this context, the main aim of our study was to improve the productivity of natural grasslands by finding economically efficient solutions which respect their sustainable utilisation and the conservation of biodiversity (Peeters and Kopec, 1996). An important factor in getting high-quality animal production is the quality of fodder, which is determined by its chemical composition. The fodder quality is influenced by the floristic composition, morphological characteristics of plants, vegetation stage at harvest, and level of fertilisation (Todorova and Kirilov, 2002; Pozdisek *et al*., 2008; Vintu *et al*., 2008).

Materials and methods

In order to reach our objectives, we carried out an experience in the Coşna region, on a *Nardus stricta* grassland, situated at an altitude of 840 m, on a soil with 13.6 ppm P_{AL} (extracted phosphorus in ammonium lactate-acetate) and 381 ppm K_{AL} (flame-photometer method, in ammonium lactate-acetate). The forage obtained from these grasslands is mainly used for feeding dairy cows. The trial was of the monofactorial type, in randomised block design with four replicates. It followed the influence of unfermented manure, applied each year or every two years at rates of 20–50 Mg ha^{-1} (Table 1).

Unfermented manure with a content of 0.42% total N, 0.19% P_2O_5, and 0.27% K_2O was applied by hand early in the spring, at the beginning of the grass growth. The high manure rates were used to reduce the percentage of *Nardus stricta* species in the vegetal canopy. For crude protein determination, we used the Kjeldahl method, for crude fibres, the Weende method, and for the total phosphorus, the photometrical method, and the raw ash was determined by ignition. The analyses of the fodder were performed on samples taken from the first harvest cycle, the average of the years 2007–2008.

Results and discussion

The fertilisation of mountainous grasslands with organic fertilisers leads to their improvement as regards productivity and quality. The use of 20–50 Mg ha^{-1} manure resulted, together with the climatic factors, in getting significant yield increases, especially when using 40–50 Mg ha^{-1}. At these rates, the DM yield recorded significant increases, compared with the control, having values comprising between 72% and 115% with annual fertiliser application, and 42–78% in the event of its application once every 2 years. As a 3-year average, we obtained 2.60 Mg ha^{-1} DM for the control, and with fertilisation, we got yields of 4.48–5.58 Mg ha^{-1} DM with rates of 40–50 Mg ha^{-1} applied every year, and 3.69–4.63 Mg ha^{-1} DM with the same rates applied once every 2 years.

Table 1. Influence of organic fertilisation on DM yield on *Nardus stricta* grassland in the Carpathian Mountains of Romania (Mg ha^{-1} DM)

Fertilisation rate	2006	2007	2008	Average for 2006–2008	
		(Mg ha^{-1})		(Mg ha^{-1})	(%)
Unfertilised control	1.17	2.77	3.85	2.60	100
20 Mg ha^{-1} manure, every year	1.28	3.69*	5.38**	3.45	133
30 Mg ha^{-1} manure, every year	1.61	4.44***	6.23***	4.09**	157
40 Mg ha^{-1} manure, every year	1.49	5.45***	6.49***	4.48***	172
50 Mg ha^{-1} manure, every year	2.21*	6.77***	7.77***	5.58***	215
20 Mg ha^{-1} manure, every 2 years	1.38	3,87*	4.50	3.25	125
30 Mg ha^{-1} manure, every 2 years	1.72	4.21**	5.11*	3.68*	142
40 Mg ha^{-1} manure, every 2 years	1.64	4.25**	5.18*	3.69*	142
50 Mg ha^{-1} manure, every 2 years	2.03*	5.18***	6.67***	4.63***	178
*$P \leq 0.05$	0.82	0.87	0.95	0.96	
**$P \leq 0.01$	1.27	1.20	1.35	1.32	
***$P \leq 0.001$	1.75	1.65	1.83	1.82	

The organic fertilisation of *Nardus stricta* grassland, with moderate rates of 20–30 Mg ha^{-1} manure, determined the increase in the CP content by 22 g kg^{-1} DM, compared with the unfertilised control. The rates of 40–50 Mg ha^{-1} did not result in high increases in the CP content of the fodder, but greatly diminished the percentage of the dominant species and determined the increase in the DM yield and CP content by 72–115% and 112–259%, respectively, compared with the control. The content of raw ash (RA) increased with an increase in the rate of organic fertiliser applied, varying between 69.6 and 82.4 g kg^{-1} DM with the annual application of organic fertilisers, compared to only 60.1 g kg^{-1}

DM for the control. The content of crude fibre (CF) was highest in the control (282.4 g kg^{-1} DM) and lowest in the variant fertilised with 40 Mg ha^{-1} applied once in 2 years (219.5 g kg^{-1} DM). Phosphorus, an important element of animal feed, recorded an increase from 1.4 g kg^{-1} DM in the control to 2.2 g kg^{-1} DM in the case of a 50 Mg ha^{-1} manure applied once in 2 years (Table 2).

Table 2. Influence of organic fertilisation on yield (Mg ha^{-1} DM) and CP quantity (kg ha^{-1}) and on the chemical composition of the fodder obtained from *Nardus stricta* grassland (g kg^{-1} DM)

Fertilisation rate	(Mg ha^{-1}DM)	CP	RA	CF	RF	P_{total}	(kg ha^{-1} CP)
Unfertilised control	2.60	80.8	60.1	282.4	18.7	1.4	210.1
20 Mg ha^{-1} manure, every year	3.45	93.9***	69.6	265.1	20.1	1.9*	323.9
30 Mg ha^{-1} manure, every year	4.09	102.8***	82.3	271.7	17.5	2.0*	420.5
40 Mg ha^{-1} manure, every year	4.48	99.5***	77.2	255.2	19.8	2.1**	445.8
50 Mg ha^{-1} manure, every year	5.58	97.7***	82.4	250.6	17.9	2.0*	545.2
20 Mg ha^{-1} manure, every 2 years	3.25	96.8***	78.1	242.2	19.3	1.8*	314.6
30 Mg ha^{-1} manure, every 2 years	3.68	106.6***	76.7	238.7	21.1	2.1*	392.3
40 Mg ha^{-1} manure, every 2 years	3.69	102.1***	80.2	219.5	18.4	1.9*	376.7
50 Mg ha^{-1} manure, every 2 years	4.63	105.8***	78.9	225.3	17.7	2.2**	489.9

*$P \leq 0.05$; **$P \leq 0.01$; ***$P \leq 0.001$; NS = not significant
CP = crude protein, RA = raw ash, CF = crude fibre, RF = raw fats, P_{total} = total phosphorus

The organic fertilisation of permanent grasslands resulted in some changes in the canopy structure, both as regards the number of species and the percentage of species in the vegetal canopy. Thus, the number of species increased as a result of the annual application of organic fertilisers, varying between 24 and 27 species, while with the application of manure once in 2 years their number was between 25 and 31 species. The percentage of dominant species was significantly changed. The percentage of *Nardus stricta* species decreased from 73% in the control to 7% in the case of fertilisation with 50 Mg ha^{-1}, while the *Festuca rubra* species increased from 10% in the control to 35% in the case of fertilisation with 20 Mg ha^{-1} (Table 3).

Conclusions

The fertilisation of *Nardus stricta* grasslands with 20–50 Mg ha^{-1} manure causes the yield to increase by 25–115% and leads to important changes in the chemical composition of the fodder, improving its quality significantly, by increasing the CP content from 80.8 g kg^{-1} DM (control) to 106.6 (30 Mg ha^{-1} manure, applied once in 2 years), the total phosphorus from 1.4 to 2.2 g kg^{-1} DM, and raw ash from 60.1 to 82.4 g kg^{-1}, and by diminishing the CF content from 282.4 to 219.5 g kg^{-1} DM , thus increasing the digestibility of the fodder.
The application of 20–50 Mg ha^{-1} manure led to important changes in the flower composition, by diminishing the percentage of the *Nardus stricta* species from 73% to 3–12% and increasing the percentage of the *Festuca rubra* species and of legumes (*Lotus corniculatus, Trifolium pratense*, and *Trifolium repens*).

Table 3. Influence of organic fertilisation on the evolution of the vegetal canopy, 2008

Species	Plant abundance – covering degree (%)								
	Unfertilised control	20 t ha^{-1} manure every year	30 t ha^{-1} manure every year	40 t ha^{-1} manure every year	50 t ha^{-1} manure every year	20 t ha^{-1} manure every 2 years	30 t ha^{-1} manure every 2 years	40 t ha^{-1} manure every 2 years	50 t ha^{-1} manure every 2 years
Agrostis capillaris	+	4	4	–	–	6	6	5	4
Festuca rubra	10	35	18	24	17	13	20	11	25
Nardus stricta	73	7	3	12	7	12	12	8	5
Other species	1	12	12	16	25	6	7	8	2
Grasses	84	58	37	52	49	35	45	32	36
Lotus corniculatus	–	10	5	5	4	4	4	4	6
Trifolium pratense	–	8	15	10	19	10	18	20	20
Trifolium repens	1	12	35	15	12	39	18	36	20
Legumes	1	30	55	30	35	53	40	60	46
Achillea millefolium	–	2	+	4	12	6	5	2	4
Campanula serata	–	+	+	2	+	–	–	–	–
Plantago lanceolata	4	+	2	–	2	+	10	–	–
Other species	11	10	6	12	2	6	0	6	14
Various species	15	12	8	18	16	12	15	8	18
Total %	100		100	100	100	100	100	100	100
Number of species	24	25	27	24	27	25	29	27	31

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Regulation of *Urtica dioica* L. on grasslands

Vozár Ľ., Jančovič J. and Bačová S.

Slovak Agricultural University in Nitra, Faculty of Agrobiology and Food Resources, Department of Grassland Ecosystems and Forage Crops, Nitra, Slovakia
E-mail: lubos.vozar@uniag.sk

Abstract

We studied some possibilities for the biological and mechanical control of the ground cover of *Galio-Urticetea* Passarge ex Kopecký 1969, with the association of *Urtica dioica* L., in a place which belongs to the village of Chvojnica in the Strážov Hills in the middle of Slovakia. The place was used as a corral for cattle in the past. Cattle had a great influence on the eutrophication of the soil. The floristic composition changed there. We examined 4 variants in our experiment: 1st – control, without cutting; 2nd – cutting every 5th week with biomass being taken away; 3rd – cutting every 5th week with mulching; 4th –*Dactylis glomerata* L. and *Trifolium repens* L. reseeding, cutting four times a year. According to the five-year results of the different types of regulation it seems that the best way of regulation is reseeding with the strong competitive species *Dactylis glomerata* L. and *Trifolium repens* L.

Keywords: regulation of weed infestation, *Urtica dioica* L., stand eutrophication, corral for cattle

Introduction

Livestock numbers have decreased to 1/3 of their original level in Slovakia since the year 1989 (Green Report, 2007). The area of grassland utilisation has been reduced. Inaccessible areas have been abandoned and degraded and have become covered by weeds. These stands have low or toxic forage value and these weeds also have negative influences on the environment and formation of the countryside.

One way to destroy undesirable species in grasslands is mechanical treatment. The ground cover is removed when it is at the maximum expansion of the leaves and the root and rhizome carbohydrate reserve matter is depleted (Vozár *et al.,* 2007). Frame (1992) has a similar opinion. He writes that many weeds can be effectively controlled by cultural or mechanical measures, especially when dealt with at the correct stage in their life cycle.

Another possibility for the biological control of weeds is reseeding with strong competitive species. Vozár *et al.* (2006) found out a way through the biyearly monitoring of different types of regulation. They state that the best treatments were reseeding with powerful competitive species and tillage with the subsequent sowing of the powerful competitive species.

The aim of this study was to investigate some possibilities for the biological and mechanical control of *Urtica dioica* L. in grasslands overgrown with weeds.

Materials and methods

The site is situated at an altitude of 640 m a.s.l. in the locality of Chvojnica in the Strážov Hills (48°53'N, 18°33'E). Climatically it is a mildly temperate region, a mildly dry region with prevailing cold winters. According to year-long measurements, the average year temperature is 7.5 °C and that within the growing season is 11.1°C. The long-term average of the whole year sum of precipitation is 848 mm and that of the growing season 431 mm. The soil-forming substrate is formed by crystalline rocks with a predominance of granite and crystalline slates on which a brown, acidic, sandy-loam soil (Cambisol) has developed.

The original grassland is represented by the *Lolio-Cynosuretum* Tx. 1937 association. The place was used as a corral for cattle in the past. Cattle have had a great influence on the soil eutrophication in the corral, which changed the floristic composition. An association of *Galio-Urticetea* Passarge ex Kopecký 1969 was created there, within an *Urtica dioica* L. association.

We monitored four variants in our experiment:

1st – control, without cutting;

2nd – cutting every 5th week, harvesting of above-ground phytomass;

3rd – cutting every 5th week, mulching with above-ground phytomass;

4th – *Dactylis glomerata* L. and *Trifolium repens* L. reseeding, cutting every 5th weeks.

The first cut of the 2nd, 3rd, and 4th variants took place when the ground cover was 250–300 mm high.

The dominance of the botanical groups and individual species was determined in accordance with Regal (1956). This was done each spring and autumn.

Results and discussion

The botanical composition of the association *Galio-Urticetea* Passarge ex Kopecký 1969 over the period investigated (2004–2008) is given in Table 3. The community consisted mainly of nettles (*Urtica dioica* L., from 90.0 to 95.3%) before the regulative interventions were applied. The changes came after their application.

We found only a minimal change in the portion of *Urtica dioica* L. in variant 1, which represented the original association *Galio-Urticetea* Passarge ex Kopecký 1969. Its proportion did not drop to less than 83.3%.

Table 1. Agrochemical soil properties of the original site.

Depth (mm)	pH/KCl	N_{tot} (mg.kg^{-1})	P (mg.kg^{-1})	K (mg.kg^{-1})	C_{ox} (g kg^{-1})
100	5.4	1,735.0	28.0	717.0	21.0
200	5.6	4,080.0	84.0	590.0	34.0
600	3.7	2,512.0	6.0	150.0	22.0

Table 2. Dates of reseeding and cutting in the first year of the investigation (2004).

Variants	Reseeding	1st cut	2nd cut	3rd cut	4th cut
1st	–	–	–	–	–
2nd	–	12.5.	16.6.	21.7.	25.8.
3rd	20.4.	12.5.	16.6.	21.7.	25.8.
4th	-	12.5.	16.6.	21.7.	25.8.

Table 3. Botanical composition of the association *Galio-Urticetea* Passarge ex Kopecký 1969 impacted by different management (%) (average of replicates)

Botanical groups	Year	Variants							
		1st		2nd		3rd		4th	
		spring	autumn	spring	autumn	spring	autumn	spring	autumn
Grasses	2004	–	–	–	1.3	0.7	15.0	-	21.7
	2005	–	–	5.0	3.3	17.0	23.3	13.3	84.0
	2006	0.3	-	9. 7	3.7	24.0	10.0	68.3	89.3
	2007	4.3	0.3	13.0	16.0	23.3	22.7	79.7	91.7
	2008	6.0	-	41.7	42.7	43.0	21.0	88.7	89.0
	s^2	8.00	0.0	265.7	301.7	231.5	32.8	1639.1	901.1
Legumes	2004	–	–	–	1.7	–	–	–	51.7
	2005	–	–	0.7	0.0	+	+	48.0	9.3
	2006	–	–	1.7	1.7	1	+	12.3	0.3
	2007	–	–	3.7	6.7	2.3	2.0	+	-
	2008	–	–	4.0	10.3	1.0	11.7	0.3	2.3
	s^2	–	–	3.2	18.5	0.9	38.9	512.1	488.0
Herbs	2004	97.7	100.0	91.7	64.3	95.3	48.3	91.7	13.3
	2005	100.0	100.0	60.0	95.0	44.7	58.7	21.0	5.7
	2006	96.3	100.0	88.7	94.7	66.7	90.0	17.7	6.0
	2007	95.7	99. 7	81.0	75.0	68.7	75.3	17.0	8.3
	2008	91.0	100.0	51.7	47.0	55.3	65.7	10.3	7.7
	s^2	11.0	0.0	317.3	421.1	359.1	254.1	1145.1	9.5
Urtica dioica L.	2004	90.0	100.0	91.7	45.0	95.3	29.0	91.0	8.3
	2005	96.0	91.7	15.0	8.3	23.0	4.7	8.7	0.3
	2006	90.7	94.7	2.7	1.3	22.3	7.3	1.3	+
	2007	88.0	97.0	1.7	0.7	10.7	6.3	0.3	0.3
	2008	83.3	92.7	1.3	1.7	6.0	1.3	+	+
	s^2	21.0	11.4	1529.0	362.4	1328.7	121.2	1930.4	21.3
Blank places	2004	2.3	–	8.3	32.7	4.0	36.7	8.3	13.3
	2005	–	–	34.3	1.7	38.3	18.0	16.7	1.0
	2006	3.3	–	+	–	8.3	–	1.7	4.3
	2007	–	–	2.3	2.3	5.7	–	3.3	–
	2008	3.0	–	2.7	+	0.7	1.7	0.7	1.0
	s^2	2.6	–	230.9	246.6	234.4	259.2	43.7	30.3

s^2 – variance, + rarely, – without presence

The share of grasses rose to 42.7% (autumn 2008) with cutting every fifth week with phytomass harvesting (variant 2). It was attended by the dominance of *Poa trivialis* L. (34.3%). The portion of *Urtica dioica* L. fell to approximately 1%. The negative effect was the substitution of *Urtica dioica* L. by *Rumex obtusifolius* L. (44.3%, autumn 2008). The positive effect was the increasing of the leguminous part (to 10.3%, autumn 2008). A similar tendency to that in variant 2 was observed in variant 3 (cutting + mulching). There *Urtica dioica* L. was also replaced by *Rumex obtusifoilius* L. Its portion increased to 54.3% (autumn 2008).

The most positive effect in the botanical composition from the animal feeding viewpoint was found in variant 4. There *Urtica dioica* L. was substituted by reseeded *Dactylis glomerata* L. Its share of the ground cover stabilised at a level around 80.0% from the 3rd year of the investigation. The development of the reseeded *Trifolium repens* L. was also very interesting. Its portion increased from 0.0% to 51.7% in the 1st year of the observation. However, a rapid reduction in its ground cover, to 9.3% (autumn 2005), was found the next year.

The portion of blank places of the exploitation variants (variant 2–4) rose noticeably from the beginning of our observation. Its share then declined to a level of 0.0-2.7%. It may have been caused by the rearrangement of the cover. Our results are in accordance with the previous research of Vozár *et al*.(2006).

Conclusions

The dominance of *Urtica dioica* L. was evidently smaller in all variants at the end of the monitoring period. According to the five-year experiment it appears that the best variant was reseeding with *Dactylis glomerata* L. However, an important problem was the subsequent increase in the dominance of *Rumex obtusifolius* L.

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Index of Authors