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Grassland Farming and Land Management Systems in Mountainous Regions

Edited by

Erich M. Pötsch
Bernhard Krautzer
Alan Hopkins

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Foreword

Mountainous regions, which cover nearly half of the continent's area, are in many ways of vital importance for the European population. They supply much of the continent´s water, are centres of biological and cultural biodiversity, provide various opportunities for recreation/tourism, are home to one-fifth of the European population and provide a livelihood for many farmers. But mountainous regions are characterised by permanent natural handicaps due to topographic and climatic restrictions on economic and agricultural activity. Because of the geographical constraints to farming, work productivity is on average lower by 28% in mountain areas compared with less favoured areas, and by 40% compared with lowlands.

Agriculture in mountainous regions can therefore, in general, not compete with agriculture in advantaged lowlands and, with very few exceptions, cannot hope to become competitive in adopting intensive models in response to the growing global competition. Grassland farming plays the key role in mountain agriculture and is mainly characterized by small-scale structures and low input systems based on an efficient use of farm internal resources. Mountain farmers have to focus on quality products and niche markets like organic food and special labelling. The European Model of Agriculture affirms that specific measures are needed in mountainous and less favoured areas in order to maintain agricultural production and to keep the multi-functionality that it also provides. The compensatory allowance scheme takes into account the differences in natural conditions in the EU, but nevertheless there is a growing pressure on agriculture in mountainous regions.

The 16th Symposium of the European Grassland Federation is dealing with the challenges of grassland farming in mountainous regions. Numerous oral presentations, papers and posters contribute to the general topic and provide interesting ideas and promising approaches. All these contributions are included in the present symposium´s proceedings - at this point we want to thank all authors for submitting papers, all reviewers for their critical expertise and, by name, Alan Hopkins for the English language checking and revisions of all contributions. We also would like to thank all members of the organising committee and the scientific board for preparing and supporting this conference. Finally we express our gratitude to all sponsors, especially to the Austrian Federal Ministry of Agriculture, Forestry, Water Management and Environment at Vienna.

Enjoy the scientific programme of the 16th EGF Symposium 2011 but also enjoy the wonderful landscape, the local/regional specialities and our hospitality, which are also essential parts of a successful event.

Erich M. Pötsch
(General Secretary of EGF 2011)

Bernhard Krautzer
(Chairman of the scientific committee)

Karl Buchgraber
(Chairman of the organising committee)

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Mountainous farming in Europe

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Abstract

Mountain farming in Europe is based mainly on ruminant livestock and utilization of locally produced forage resources by grazing and hay. Farmland extends from mountains in the eastern Mediterranean to the Atlantic coast, with major areas at the highest elevations in central Europe, thus encompassing wide variation in geology, soil, altitude, slope, climate and vegetation communities. Despite this variation there are some common features, problems and opportunities. Agriculture in mountain areas seldom competes economically with lowland farming because production costs are high or labour-intensive, growing and grazing seasons are short, and annual forage production levels are low. The paper discusses the utilization of pasture resources and the need for continued management of hay meadows and grazed mountain pastures to maintain traditional landscapes and ecosystem services; these can be supported through agri-environmental support measures. Opportunities for high value niche-market products (organic, origin-based, or with food-quality attributes linked to the mountain environment) are discussed in relation to potential for improving farm incomes. Mountain grasslands include some of the most important high nature value areas in Europe, and high-biodiversity mountain farmland can increase tourism incomes and is a potential seed source for local biodiversity restoration. Challenges and uncertainties for the future of mountain farming include climate change impacts, agricultural abandonment and adapting to socio-economic changes. Improving market access and developing sustainable mountain agriculture is discussed in relation to situations lacking in technical and financial support, regulatory frameworks, supply chains and cooperative arrangements for small-scale producers.

Keywords: mountain grassland, biodiversity, food quality, ecosystem services, abandonment, climate change, market access

Introduction

Mountain farmland in Europe covers a wide range of environments in terms of soils, geology, geomorphology, ecological conditions, climate and elevation. It extends from the limestone areas of the Balkans and eastern Mediterranean zones, characterised by winter rainfall and summer drought, to the high-rainfall, volcanic and igneous mountains at high latitudes in northern Europe where the growing season is limited by day-length and temperatures and utilization often affected by heavy rainfall. Although the mountains in western coastal areas (British Isles, north-west Spain, Norway) benefit from the amelioration of the Atlantic, most of Europe's mountain areas (Alps, Carpathians) are firmly under the influence of a continental climate, further constrained by elevation. These contrasting environments have resulted in a wide range of vegetation communities, and given rise to a range of farming practices, mainly based on livestock products historically to support local needs. This paper seeks to examine some of the common issues and problems facing mountain farming in Europe today.

There is a long history of economic pressures on farming communities in marginal areas. Major changes that have taken place in European agriculture in recent decades include the intensification of agriculture on the more productive (usually lowland) areas; the liberalization of markets within the EU and elsewhere; and changes in Eastern Europe, with farming that had been under state control followed in the 1990s by privatization. In the 21st century we now have a situation in which mountain farming, based on present food prices and input costs, can seldom provide an acceptable farm income based on the market value of farm produce alone. In the absence of alternative incomes or subsidies there are increasing risks of further abandonment of mountain agriculture, especially in remoter areas. However, it is now widely recognized that farming can contribute to a number of ecosystem services, including landscape and biodiversity, which have wider societal benefits, and that the products of mountain farming have unique or distinctive characteristics valued by consumers and thus provide added value to producers. This paper considers how the future of farming in the mountain areas of Europe farming can be ensured through a combination of measures which ensure that farmers receive appropriate returns based on the value of farm outputs, biodiversity and other services, as well as examining some of the physical and socio-economic challenges.

Mountain grassland resources and their utilization

Forage systems for livestock production in different zones of Europe have been reviewed in papers presented at recent EGF meetings, including Pflimlin and Toderov (2003) and Zimkova *et al*. (2007) and therefore this section will focus on some general features of the semi-natural permanent pastures and unimproved grazings of mountain grasslands. In central European mountains *Nardion strictae* communities are widespread at higher elevations, but a wide range of phytosociological units have been mapped, especially in sub-montane zones, according to soil and humidity conditions, and past management; e.g. *Arrhenatherion* on managed hay meadows, and *Bromion erecti* on dry calacareous sites (Zimkova *et al*., 2007; Jongpierová *et al*., 2008; and references therein). These communities have their parallels in the moist montane environments of north-west Europe (*Nardus* and *Juncus* spp. on wetter sites; *Festuca* on drier sites; in all cases interspersed with dwarf-shrub communities and semi-improved hay meadows and improved grazing enclosures.

Some common features of mountain grassland vegetation and its utilization are:

(i) Relative low net primary productivity, with seasonal herbage yields of 0.5-2.0 t DM ha^{-1} being widely reported. Where soil nutrient supply is the main factor grass production, and where access and other considerations permit, applications of livestock manures and/or NPK/liming materials can enable a better matching of forage supply with demand for grazing or hay/silage crops. Importantly, fertilisation of grassland needs to be site-specific and environmentally adapted, with the livestock density adapted to the forage area, with farmyard manure and biological fixation the main source of the N supply.

(ii) Feed value is often low, notably in terms of digestible energy value, compared to the requirements for productive livestock; it is feed-value rather than available herbage dry matter production per unit area that is the limiting factor for sustainable livestock production systems. This can sometimes be overcome by integrating small areas of agriculturally improved pasture, possibly by seed introduction, to provide improved forage nutrition at critical times in the annual production cycle. Originally developed for hill sheep production in Scotland as the 'two-pasture system' (Cunningham and Russel, 1979; Maxwell *et al*., 1984) this approach has been adapted and applied elsewhere to enable livestock to utilize grazing land of nutritionally sub-optimal value (e.g. Osoro *et al*., 1999; 2000) .

(iii) There are other aspects of feed value that have links to the quality of meat and milk products and the overall sustainability of the production system, and which are of particular relevance for mountain vegetation. Meadows and pastures with a high proportion of legumes and other forbs, and a diversity of grasses, can add value to product quality and other farm and community benefits, links to agro-tourism and other ecosystem services. 'Agricultural improvement' of grassland resources needs to take these considerations into account, particularly in the context of species choice and provenance of seeds.

(iv) Grazing is to be encouraged wherever possible, but mountain grasslands are mainly characterized by a short growing (and grazing) season. Sustainable livestock systems therefore require sufficient conserved hay/silage of high quality, rather than imports of nutrients into the system via concentrate feed. Transhumance grazing has been of pivotal importance in allowing the integration of hay meadows with high mountain pasturing. In 2005 it was reported that more than 4 m ha of agricultural land in Europe depend on transhumance, though the practice is vulnerable but vital for landscapes (Herzog *et al.*, 2005).

Food and farm products from mountain farming differentiated by quality or niche markets

The environmental limitations of farmland in mountainous areas and the higher costs associated with production and utilization inevitably mean that the products of mountain farming cannot compete in a national or European market as 'commodity produce.' The solutions are: that producers receive a direct subsidy to maintain farming operations and/or payments to support ecosystem services associated with farming operations that deliver wider environmental and social benefits; or that the products of mountain farms are marketed as premium quality based on attributes of their locale, culture and method of production, eating quality and healthiness etc.

Origin-based products

Enhancing the links between people, locale, food production and agricultural products is a recognized pathway for sustainable development. At its most basic this may simply be labelling as 'local food', with items such as fresh milk and milk products or meats sold via farmers' markets or to local hotels and restaurants. Opportunities are limited by the size of the local market, consumers' willingness-to-pay, and mutual trust; but it is a system that has benefited farms in areas with a well developed tourism industry where food marketing chains can be easily established and maintained on terms advantageous to producers and consumers. The absence of a secure local market limits the opportunities for connecting with consumers unless some additional attribute of branding can be secured. Greatly increased opportunities for increased value for producers can arise when origin-based products can be linked to the geographical places where they are produced. On this basis products may attract added value through a Protected Designation of Origin (PDO) or Protected Geographical Indication (PGI), through which, and through reputation, the product's quality is recognized as attributable to its geographical area including the natural and human factors (EU: EC Regulation 510/2006; FAO, 2009). The basis of a GI product requires a 'typicity' or set of distinctive characteristics on which those tied to the 'terroir' are the most usual (defined as "*delimited geographical space, where a human community has constructed over the course of history a collective intellectual or tacit production know-how, based on s system of interactions between a physical and biological milieu, and a set of human factors, in which the social-technical trajectories are put into play, reveal an originality, confer a typicality, and engender a reputation, for a product that originates in that terroir*" (FAO, 2009, p. 193). Examples relevant in this context include the cheeses of the Savoie Alps such as Abondonce, Beaufort and Reblochon, ewe-milk cheese such as Bleu de Causses, and meat products such as Agneau de Lozère. For producers in mountain regions to benefit from a GI product status there is a requirement to identify the potential and acquire product qualification: clearly the requirements for GI limit the opportunities. But the enhanced remuneration also requires marketing (there is a global market for some products) and, importantly, reproduction of the system through measures that continue to guarantee the existence of the origin-based product (FAO, 2009). There are examples of the promotion of origin-based production for promoting sustainable development; for instance the Dinaric Arc Initiative in Serbia (Bernadoni *et al*., 2008) with its focus on reactivating sheep production and pasture management in the context of biodiversity linked to a GI status for the Livno cheese. It is likely that many further opportunities for GI status for food products remain for future development.

Organic mountain farming

Mountain farming systems are often based on low-input management and thus can be adapted to comply with organic regulations and thereby secure the additional market value associated with organic products. Additionally, producers receive the payments linked to organic farming in countries where these exist as part of agri-environmental measures. In the Alps, and notably in Austria, organic farming presents an alternative production system for many farmers because of its positive image in terms of food quality, animal welfare and environmental benefits, aspects discussed elsewhere in these proceedings (Steinwidder *et al*., 2011). Furthermore, organically farmed products need not be marketed in isolation of their locale, and further opportunities exist to embed the links with mountain pastures, biodiversity and region.

Healthiness and other indicators of food quality

A major research thrust in grassland and food science in the past decade has concerned identifying the links between the chemical composition of meat and milk products (in terms of fatty acid profile, volatile compounds, caretenoids, alpha tocopherol, etc.) as influenced by the diet of ruminants. This has implications for food quality and value in terms of shelf life, appearance, cooking and eating quality, as well as the possible healthiness of diet for consumers (Martin *et al*., 2005a,b; Wood *et al*., 2007; Wyss and Collomb, 2008; Huhtanen *et al*., 2010; Monahan *et al*., 2010). Advantages of livestock diets based on grazed grass in terms of overall quality of meat and milk products have been widely reported, with differences in fatty acid contents in milk produced from pastures at different altitudes (Collomb *et al*., 2002) which can also be related to differences in the fatty acids in forage with respect to altitude of pastures, stage of pasture maturity and plant species composition (considered elsewhere in these proceedings: Borreani *et al*., 2011; Lind and Mølmann, 2011; Revello-Chion *et al*., 2011). Thus, we can view the botanical composition of pastures as not just a consequence of the management of farming system, recognizing the continuing need for either grazing or mowing to maintain pastures and meadows, but also view sward biodiversity as an input to the farming system - enabling higher value produce (such as mountain cheeses) as an output of biodiversity.

Mountain farming as a provider of biodiversity

Biodiversity protection emerged as a key driver in environmental policy after the 1992 Convention on Biological Conservation, and has since become an issue of regional and global security. Grasslands are particularly important sources of biodiversity as hosts not only to a vast number of plant species but also to vertebrate and invertebrate fauna. Although biodiversity is one of the most important ecosystem services provided by European semi-natural grasslands, agriculture remains as a driver of biodiversity loss, either through intensification and conversion of grassland to arable cropping, or land abandonment and loss of the traditional farming practices that have often generated species-rich habitats. As the total area of grasslands has declined, particularly grasslands of high biodiversity, mountain areas now are among the last refuges of High Nature Value (HNV) grassland in Europe. Many traditionally managed mountain grasslands, which have developed under centuries of livestock grazing, are still species-rich compared with lowlands (MacDonald *et al*., 2000).

Despite the pressures from past policy agendas and from market pressures, some quite remarkable areas of HNV grasslands remain in mountain areas including, for example, the White Carpathian Mountains, the Apuseni Mountains in Romania, and the Haute Plateaux of the Vercors in France (Veen *et al*., 2009). However, changes in land use are threatening these habitats as well. At present we see increasing intensification of their use, particularly on easily accessible sites, paralleled by abandonment of mainly, but not exclusively, the less-accessible areas (Tasser and Tappeiner 2002; Mottet *et al*., 2006; Gellrich *et al*., 2007). Losses due to afforestation and development/ construction works continue, as do losses from agricultural improvement on more accessible areas, including the conversion of traditional hay meadows to pasture resulting in loss of species and biodiversity value (Fischer and Wipf., 2002; Tasser and Tappeiner, 2002). The loss of many cultural traditions and changes in farmers' workloads, particularly in the context of small land parcels, is a contributing factor (Maurer *et al*., 2006) affecting mountain grassland diversity.

Considerations of biodiversity, however, extend beyond the species-level, and issues of provenance have focused attention on the role of farmland donor-sites of seed for habitat creation or diversity enhancement based on native seed. Thus, an opportunity for biodiversity to become a 'product' of mountain grassland is through the harvesting of seed from species-rich or locally specific pastures and meadows for use in restoration work (Krautzer and Pötsch, 2009; Scotton *et al*., 2009). Restoration opportunities involving the use of locally harvested seed in mountain areas arise not only in the context of improving biodiversity on farmland, but associated with bio-engineering and restoration following erosion and construction projects associated with ski runs, power stations and road/rail infrastructure (Tamegger and Krautzer, 2006). There is an increasingly accepted aim of biodiversity protection, both within the scientific community and public institutions involved in ecological restoration, that the seed and the plants used in vegetation restoration should come from the native vegetation present in the geographically and ecologically nearest sites; for instance, same elevation belt: hill/mountain, subalpine and alpine, and soil: similar humidity, nutrient contents and pH (Scotton, 2009). In Germany, Switzerland and Austria seed propagation networks now exist and the trade in regional-specific seeds is developing. Techniques for seed harvesting exist for use on both level and steep sites (Scotton *et al*., 2009). Thus, subject to the necessary regulatory framework and compliance with seed purity standards, there is potential for farms in other areas of Europe to develop the opportunities for seed production from donor sites, both for direct sale and for propagation, as an economic 'biodiversity output' of farmland.

Management for biodiversity in the context of mountain farming requires a wider approach than just the encouragement of niche-value outputs such as premium food and regionally specific seeds. The farmland habitats may include features such as trees and shrubs, ponds and rocky outcrops, or linear habitats such as streams and tracks, which contribute to the mix of ecological niches. To counteract developments leading to biodiversity loss there is need for the protection and sustainable management of remaining areas, supported by policy measures that pay more attention to local characteristics and needs (Gellrich *et al*., 2007) including diversity of land use at the landscape level (Maurer *et al*., 2006). A farmer-centred framework, such as that proposed by Keenleyside and Opperman (2009) for HNV grasslands generally, is one way forward. It recognises the need to ensure qualification for support (in EU countries under both Pillars of the CAP), to improve social and economic initiatives, and for recognition of farmers' skills and achievements and the need for training, combined with monitoring and evaluation.

Challenges and uncertainties affecting grassland farming in mountainous areas of Europe

Climate change

The effects of climate change on European grassland agriculture has been the topic of several contributions to recent EGF meetings (e.g. Hopkins and del Prado, 2006; Mannetje, 2006; Soussana and Lüscher, 2006; Gilgen and Buchmann, 2008; Lattanzi 2010). In the context of farmland in the Alps and other mountain areas of Europe the following points are of key importance and present potential challenges for policy makers and planners, as well as for farmers and other local stakeholders. On the basis of trends, scenarios and research evidence the following are projected:

- More frequent heavy precipitation events during winter and increased storm risk, presenting increased risks of erosion of topsoil, damage to farm buildings, widespread flooding (see, Fuhrer *et al*., 2006, and references therein).
- More frequent summer droughts, leading to reduced herbage production on alpine sites and shallow soils (Gilgen and Buchmann *et al*., 2008, and references therein).
- Glacial retreat and reduced snow cover, and consequently reduced meltwater with altered river run-off regimes (Schröter *et al*., 2005; Solomon *et al*., 2007).
- Changes in vegetation in response to elevated CO_2 and to changes in temperatures and precipitation distribution, including increased net primary productivity when water is not limiting, but loss of species from vulnerable sites; changes in phenology, sward composition and in utilization under mowing and grazing; and changes in C and N partitioning and storage (Theurillat and Guisan, 2001; Soussana and Lüscher, 2006).
- Notably more severe impacts in southern Europe, e.g. with adverse effects on the drier mountainous areas of the Balkans and Iberian Peninsula, where the impacts of increased summer drought and shallow soils present increased risks of wildfires, though opportunities for species change towards more C4 species ('t Mannetje, 2006; Solomon *et al*., 2007).

The reduction in run-off from meltwater is a particularly serious impact of climate change in high mountains. Around 16 million people live in the arc of the Alps, and rain and snow from its mountains provide the Danube, Rhine, Rhone and Po rivers with up to 80 per cent of their water. Adaptations to mountain farming practices to minimize the impacts of run-off and water supply include catchment-sensitive management. For instance, the Action Plan on Climate Change in the Alps (http://www.alpconv.org/climate/index_en.htm) has an objective of improving mountain farming through measures including adaptation to climate change impacts, encouraging breeders to select resistant autochthonous species and resilient breeds, and supporting improved standards in environmental protection.

Farmland abandonment

Agricultural abandonment has been a trend in Western Europe particularly since WW2. Since the 1990s abandonment has also arisen in areas of Eastern Europe where former state-owned farmland has been privatized but where there is a now a lack of local farming skills and infrastructural support and markets (FAO, 2010). Abandonment reflects rural depopulation from isolated and poorer areas, either to urban settlements or to agriculturally more productive areas in response to technological developments, the influence of the Common Agricultural Policy in changing traditional farming practices, and changing aspirations of rural communities. But it can occur at smaller scales. A case study by MacDonald *et al*. (2000) of agricultural restructuring in European mountain areas found that a typical adjustment scenario was a mixture of abandonment and intensification on different parts of the same farm.

The problems that these trends create are particularly marked in remoter areas of Europe such as uplands in Spain and Greece (Mottet *et al*. 2006; Tzanopoulos *et al*., 2011) where distance from abandoned sites to settlements and farmsteads can be a major influencing factor. A multi-functional approach to sustainable development has often been suggested as one way to address these problems, e.g. with extensive farming linked to tourism and National Park management (Tzanopoulos *et al*., 2011) or specific nature-enhancing measures (Strijker, 2005). Multi-functionalism is a strategy that has gained favour with researchers and policy makers. The extent to which it is adopted by farmers is less certain, particularly where farming families have other social and economic objectives. In a study of mountain sheep farms in South West Ireland, an area that has many features appropriate for multi-functional agriculture linked to tourism, it was found that farmers were adapting to the problems of low farm income by taking additional off-farm part-time work and adopting a polarized management strategy on their farms by limiting farming to the more easily worked parts of their land (O'Rourke and Kramm, 2009).

Market access and other socio-economic constraints

Sustainable agriculture in mountainous areas is dependent on farmers having access to markets and to supply chains which can enable planning farm production with an acceptable degree of security and profitability. Many countries have established systems of farmer-owned cooperatives, well-managed livestock auction markets or contract arrangements with established companies in the food-supply chain, but remoteness can still present disadvantages compared with lowland farms. The problems related to market access are particularly acute in remoter areas of East European non-EU countries, including those formerly within USSR or Yugoslavia, and are often confounded by other technical, financial and regulatory issues (FAO, 2006; 2009). Some common features are: that a high proportion of farms are very small, production and farm incomes are often very low, and livestock numbers and output have fallen considerably since the 1990s. However, the security that comes with land ownership is valued by its occupiers above its economic value for agriculture, thus limiting the scope for amalgamation of land parcels. There are two main sets of issues: developing a trusted and well regulated marketing system, and overcoming the barriers that prevent small-scale farmers from developing sustainable farming practices. These include access to finance, advisory support, technical inputs and veterinary services, as well as harmonization of food safety, traceability, animal recording and veterinary standards towards those of the EU. There is a further need for improving cooperative arrangements between farmers, based on models that are trusted by farmers themselves, for instance through equipment sharing, joint sales/purchases, Young Farmers Clubs, demonstration farms and discussion groups.

Conclusions

Mountain farming in Europe faces many challenges. On the one hand, it is a provider of high quality food with attributes linked to the mountain environment and the system of production. In addition, society also recognises the benefits of sustainable mountain farming systems that respect the environment, notably in terms of biodiversity and maintaining High Nature Value grassland and related ecosystem services such as protection of soil, carbon sequestration and landscape protection. On the other hand, despite global concerns of food security and the anticipated need to increase world food production over the coming decades, it is seldom the case that mountain farms can nowadays compete economically with lowland farms in the production of dairy and meat products. Therefore, mountain farmers need to obtain a premium price for their products, or payments for providing public goods and services as a by-product of farming which have wider benefits for society, or additional off-farm income.

Forage production in mountain areas is generally low in quantity, produced over a short growing season, and its feed value may not meet the dietary needs of livestock. In addition, costs and labour inputs associated with forage utilization are high. Abandonment of farming from less accessible and least productive areas is a threat affecting many parts of Europe, within farms and at other spatial scales. There is also evidence that farming activities have been abandoned elsewhere, particularly in the mountain areas in parts of Eastern Europe after the collapse of Communism.

Climate change may present some additional challenges especially in the areas prone to summer droughts such as mountains bordering the Mediterranean and in the Balkans. Concerns about the supply of water from the Alps have focused attention on the need for land management policies that optimise environmental protection.

The continuation of sustainable farming in the mountain areas of Europe is likely to require a combination of measures including agri-environmental support to ensure protection of biodiversity and ecosystem services; marketing initiatives to raise the market profile and distinctiveness of the agricultural products of mountain farms; and, where required, the development of trusted and well regulated marketing systems with supporting infrastructure to overcome barriers to market access. The recognition of farmers' skills and their economic objectives, and the training needs of the next generations of farmers, need to be at the heart of these measures. In addition to these socio-economic issues, there are a number of scientific challenges, including the role of native livestock breeds for quality produce and environmental adaptation, the use of autochthonous plant species in land improvement and for restoration of damaged sites, and the opportunities to improve the productivity and cost-effectiveness of livestock production while minimising its environmental impacts. Farming technology can never stand still. A difficult balance exists in protecting the valued aspects of traditional mountain farming, such as transhumance grazing and flower-rich meadows, with the needs to ensure long-term competiveness and a lifestyle for farming families compatible with the 21st century.

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Grassland Farming in Austria - status quo and future prospective

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Abstract

Austrian grassland farming is marked by very differing climatic and topographical conditions and, compared with many European countries, it is also distinctively small in structure. While in the favourable areas a definite intensification can be observed, grassland farming in the mountain regions follows traditional methods which are ecologically orientated and sustainably maintain the utilisation of the land. This is also seen in the high acceptance of the Austrian agri-environmental programme, which offers numerous specific measures for the maintenance of grassland. Austria has chosen the path of widespread agricultural utilisation of the land by farming families, who also ensure a high degree of care and product quality.
Due to the low prices paid for products, and high energy and operational costs, state compensation for production is also necessary to ensure the future survival of grassland farmers, and thus the multi-functionality of grassland. Most grassland farming is undertaken in disadvantaged alpine regions and there is only a limited number of alternatives for agricultural production. Many grassland regions today are already affected by the increasing abandonment of farms, which also leads to widespread negative consequences in the cultivated landscape, infrastructure, and the entire development of rural areas. Therefore, alternative forms of agriculture are also required in the future through simple cooperation under civil law between several farms. In this way costs can be saved and at the same time sustainable utilisation of entire valleys and regions can be assured. But appropriate general conditions are also required, as well as rethinking among the farmers who, as before, remain very ownership-orientated and conscious of tradition.
In addition, there will be a future requirement for sound agricultural research, that offers not only the solution-approaches to problems in techniques of production, but also an important interface between agriculture, teaching, consultation, practice and consumers.

Keywords: alpine farming, ecology, circuit farming, cultivated landscape, modern land management

Structure data of Austrian agriculture

Austria offers interesting and varied living spaces on a total area of 84,000 km² with all of its diverse geological and topographical forms, which extend about 500 km from the Pannonian lowlands in the east to the high mountains in the west. In this way the climatic conditions change from the Continental-Pannonian influences in the east to the Atlantic-Continental conditions in the southeast, and on to the harsh alpine conditions in the north and west. A notable altitude gradient from 200 to 2,500 metres and the often extreme, inclined locations have an additional effect on the cultivation and utilisation of varied farming and forestry cultures.

Utilisation of the agricultural land

The entire area of farming and forestry utilisation in Austria is 6.53 million hectares today. The area used for farming amounts to 3.19 million hectares, of which 1.39 million hectares are arable land and 1.73 million hectares are permanent grassland. The area used for farming in Austria has decreased in the last 50 years by 860,000 hectares. In the alpine locations in this period 566,000 hectares of grassland have become forest areas or built upon. The forested share stands at an average of 51% throughout the country, but in some regions this share has already increased to more than 90% and leads to negative developments in the landscape. Agriculture, fruit and wine production prevail in the climatically favoured east and southeast of Austria. The level of self-sufficiency is 103% for grain, 63% for fruit, 60% for vegetables, 52% for oilseeds and 118% for wine. In 2009 Austria showed a total agrarian trade deficit of € 912 million, within which the milk and dairy products sectors, and meat and meat products sectors showed a positive balance with export surpluses of € 300 million and € 182 million, respectively. The strongest import surplus was seen in vegetables, fruit, nuts, oilseeds and vegetable and animal fats (BMLFUW, 2010).

Grassland and dairy farming takes place predominantly in Austria's alpine regions, which with 2.05 million hectares comprise about 82% of the entire disadvantaged regions of 2.5 million hectares. More than a third of the Austrian population live in the mountain regions and work on about 70% of the 40,600 dairy farms, some under very difficult and extreme conditions. While for grassland farming in the favourable valley and basin locations there is the option to cultivate silage maize, field forage and grain to provide their domestic animals, most of the grassland farms in the mountain regions depend exclusively on the utilisation of permanent grassland (Graphic 1). In the western provinces of Vorarlberg, Tyrol and Salzburg, the share of grassland within the total agriculturally used area is in each case 97%. In Carinthia the grassland share is 78%, in Styria it is 64% and in Upper Austria there is still about 45% of the farming area utilised in the form of meadows and pastures (INVEKOS, 2008; BMLFUW, 2010).

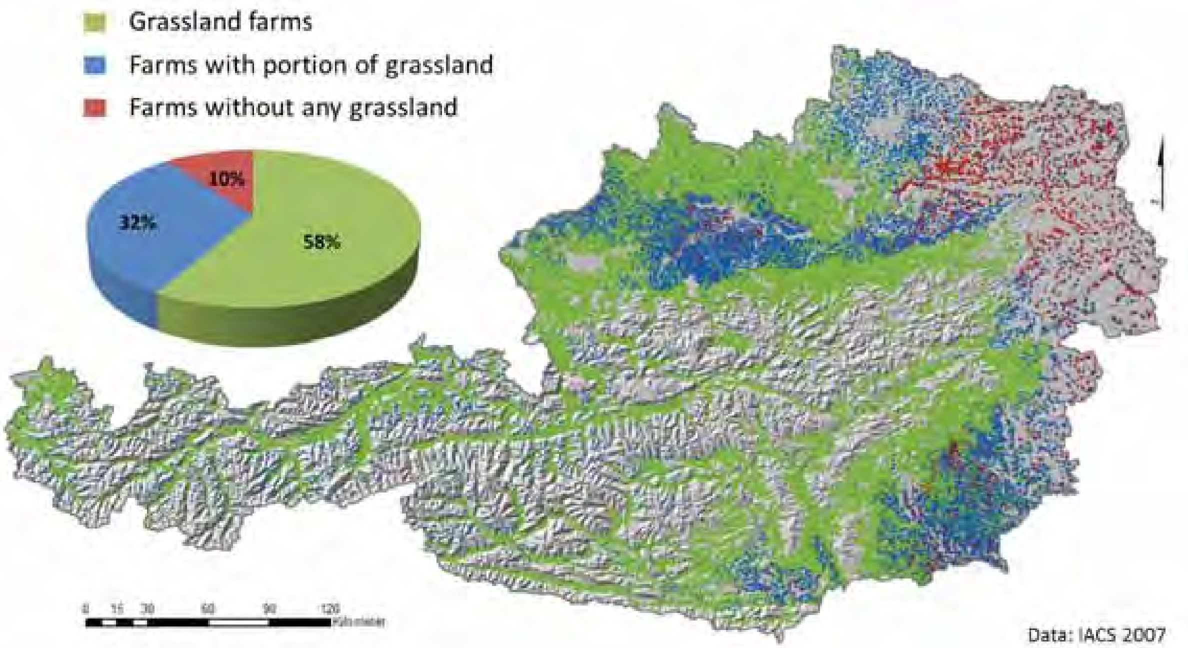

Figure 1. Spatial distribution of Austria's farms and their classification in respect of the share of grassland farmed

Two-thirds of farmed units of grassland are smaller than 0.5 hectares and in total they comprise only 12.6% of the permanent grassland area. Only 1.6% of the units are larger than five hectares, the largest mowed meadow in Austria has an area of 33 hectares (Table 1). In terms of altitude distribution, 34% of all grassland areas are at altitudes of up to 600 metres, 17% are between 600 and 800 metres and almost 50% are above 800 metres (INVEKOS, 2009). In terms of slopes: more than a third of the meadows and pastures have an inclination of more than 35% and farming them requires the use of special machines that are significantly more expensive than standard machinery (Greimel *et al*., 2003).

Table 1. Distribution in size of Austrian grassland units (ley farming, intensively and extensively used grassland) according to INVEKOS 2009

Unit area in hectares	Number	Number in %	Area in hectares	Area in %
< 0.5	1,127,854	64.74	195,479	12.60
≥ 0.5 and < 1.0	287,666	16.51	202,631	13.06
≥ 1.0 and < 2.0	196,399	11.27	271,065	17.47
≥ 2.0 and < 5.0	102,456	5.88	300,679	19.38
≥ 5.0	27,761	1.59	581,656	37.49
Total	1,742,136	100.00	1,551,510	100.00

About 60% of Austria's permanent grasslands are regarded as extensively utilised, and within this are the alpine meadows and mowed mountain meadows, extensive pastures, litter meadows and meadows that are mowed once and/or twice annually. A critical view of area development within the last five decades, however, clearly shows the dramatic decrease of extensive grassland, which is primarily caused by abandonment of utilisation and reforesting of the borderline areas, and also but to a relatively slight degree, by intensification of use (Groier, 2007). Especially affected by this decrease were the extensive pastures (-72%) and once-mown meadows (-85%), both categories of which play important roles in respect to species diversity and function as a habitat. Current statistics on alpine-meadow areas show a further intensification of this situation because the degree of alpine-meadow forage areas has also greatly decreased due to the natural increase of shrubs and bushes.

Farm and income structures

Austrian farms, compared with the EU-27, are still structured in a small way and an average area of 19.3 hectares of farming land is utilised with 27 head of cattle, including 13 dairy cows. The livestock density in 2005-2009 was at an average of 0.81 LU/ha of agricultural used area. In 2009 about two million head of cattle were kept by 73,466 cattle farmers, but in the last 30 years the number of cattle has decreased by 19.5% and the number of cattle farmers by 58.8%. The greatest structural change is to be seen in the numbers of dairy cattle: within 50 years a reduction from 1.13 million to 0.53 million dairy cows has taken place. Although the number of dairy cattle farms has decreased in the last 15 years by 48%, the remaining 40,600 farms continue to deliver the annual reference amounts for Austria of 2.7 million tons of milk to 92 processing plants with an average milk quota of 70,000 kg (Kirner, 2009). A high proportion of the milk (65%) comes from the mountain regions, within which the extreme alpine farmers have an average milk quota of only 29.3 tons per farm and year. The share of delivered organic milk in 2009 was 13.2% (9,235 dairy farmers with a total of 91,000 dairy cows), for which the price per kilogram of organic milk was, on average, 6.33 cents higher than for conventionally produced milk.

Of those employed in Austria, there are still 4.7% today in farming and forestry. Nevertheless, there are rural regions that still barely show an agrarian quota of 0.5%. The increasing abandonment of farms is of much concern in this respect in alpine regions, where in recent decades many farmers have stopped working and closed down their farms. This also leads to a loss of infrastructure, to the increased desertion of rural areas and weakening of economic power (Dax, 2007). The attractiveness of a beautiful and cared-for cultivated landscape with an intact rural life is greatly endangered in some regions of Europe's mountain areas (Tasser *et al*., 2011).

Austrian farms are run 40.1% as full-time and 59.9% as part-time operations. The share of part-time farming is up to 70% in the mountain regions, which is significantly higher than in the favourable locations. In all, individual farmers form the majority but there is a tendency shown towards an increased forming of personal associations, which in the future could play a stronger role in comprehensive farming. Agriculture in Austria is still a 'man's domain' and only 3.5% of farmers are women (+1.5% compared with 2005). The age structure of Austrian farmers can be seen as favourable because 70% are younger than 55, while the EU-27 average is only 43% below this age. Nevertheless, it is evident that farming successors are in many cases not assured and it will be increasingly more difficult to enthuse young people for a profession in farming. The basis of the small structure of farming in Austria is still family businesses, and 94% of the workers - 1.39 workers per farm - are family members, whereas only 6% of the workers are paid employees from outside.

An assessment of book-keeping farms (n = 2,250) shows that the incomes from farming and forestry (many farmers also undertake forestry in addition) from 2005 to 2009 was at an average of € 22,655 per farm. Together with the production of milk and meat, incomes were also given through holidays on farms, direct marketing, services within machinery rings and agricultural sideline jobs. To this is added about € 18,800 in incomes outside of agriculture, including social remuneration. The civil remunerations for services given during the same period are an average of € 17,183 per farm.

Rural development - agrarian environmental programme

The Austrian programme for the promotion of an environmentally compatible, extensive and natural habitat-preserving farming (ÖPUL) placed high value on the entirety of Austrian farming in its first programme period in 1995. A total of 89.2% of all the agriculturally utilised area today is farmed according to the ÖPUL criteria. The high acceptance (73.1% of all farms currently take part in ÖPUL) is proof of the great willingness of Austrian farmers to integrate environmentally-friendly and resource-sparing measures into their farming systems.

There are 28 differing measures offered in the current ÖPUL 07 programme, of which very many also have influence on the quantity and quality of forage production from grassland. Table 2 shows the connection between the current grassland-relevant ÖPUL-measures and the yield factors or quality-defining factors of grassland. The strongest of the depicted measures relate to the sphere of fertilisers, through which in many cases an additional effect on the soil is given as the most important location factor. Most of the given measures show stronger limitations in respect of the fertiliser level, which are anyway to be kept within the sphere of cross compliance (EU nitrate guideline, 1991; EU-VO 796, 2004; BGBl. II No. 457, 2005; AKTIONSPROGRAMM, 2008).

Organic farming

11.9% of all Austrian farms are run according to the criteria of organic farming (Steinwidder *et al*., 2011) and 20,800 organic farms thus work 13% of the entire area used for farming, of which about 60% are meadows and pastures with an overwhelming share that can be classified as permanent grassland. Together with organic farms, however, there are a further 38,400 farmers who voluntarily relinquish the use of yield-increasing farming measures and thus concentrate on the optimum use of their own resources. These farms also present a significant potential for the expansion of organic farming. In ÖPUL, which in 2010 was endowed with € 554 million, grassland plays a central role, which above all is also shown by relevant measures for biodiversity.

Table 2. Grassland-relevant ÖPUL-measures and their influence on yield factors and the quality-defining factors of forage production (BMLFUW, 2011)

				fertilisation			utilisation				plant stand		
ÖPUL-measures	number of farms (2010)	total area in ha (2010)	grassland therefrom in ha (2010)	intensity level	date[5]	type of fertiliser	date	frequency	type of utilisation	forage conservation	ploughing up	renewing	weed control
organic farming	20,789	414,148	231,881	×		×	×[1]	×[1]		×	×	×	×
environmental friendly use of arable land and grassland	67,305	1.286,793	468,802	×			×[1]	×[1]			×		
abdication of yield increasing	38,400	408,965	371,895[2]	×		×	×[1]	×[1]			×		×
substances on grassland abdication of silage production	9,999	113,993	111,057[3]	×		×	×[4]	×[4]		×			
mowing of steep slopes	41,703	149,731	149,702				×[1]	×[1]	×		×	×	
maintenance of field orchards	16,904	10,106	10,102								×		
use of mountain meadows	1,215	1,787	1,787			×		×	×				×
Herding on alpine pastures	7,770	409,793	409,793	×		×			×				×
nature conservation measures	23,858	84,776	60,662	×	×	×	×	×	×	×	×	×	×
ecopoint-system[6]	6,571	133,603	80,885	×		×	×	×			×		×
water protection and maintenance of grassland[7]	2,029	28,339	28,331	×		(×)[8]	×[1]	×[1]		(×)[8]	×	×	(×)[8]

[1] on at least 5 % of total grassland
[2] including 37,067 ha temporary grassland
[3] including 2,937 ha temporary grassland
[4] indirectly by hay production
[5] timely limits (ban periods) for fertilisation have to be fulfilled for all ÖPUL measures according the national „action programme nitrate"
[6] only offered in lower Austria
[7] only offered in Salzburg
[8] only available in combination with organic farming

Nature conservation

390,000 hectares of agricultural land (14% of the entire agricultural utilisation area) are within the Nature 2000 network and are thus subject to additional, specific management stipulations. At 66%, grassland represents the largest part of the 218 designated Nature 2000 regions in Austria (16% of the entire federal area). Nature conservation in Austria is the responsibility of the provinces; for this reason there exist nine, partly very differing nature conservation laws. The relationship between farming and nature conservation is unfortunately not always free from conflict, but also there are very many positive examples in which the synergies and common interests are in the foreground.

Austrian grassland farming in the area of conflict between becoming ecological or increased intensification

Around 50 years ago, all grassland- and cattle farmers in Austria still carried out a very extensive form of grassland farming. Meadows in mountain regions were mowed once or twice annually and those in the favourable locations two or three times, and together with the pasture areas they were the main providers of ruminant forage. The nutritional provision of the meadows and pastures took place as circuit farming and was based almost exclusively on the site-related use of the farm's own manure.

In the 1970s and 1980s, together with enhanced mechanisation (particularly in the techniques of mowing, harvesting and conservation) there was also increased intensification of the utilisation and fertilisation of grassland. In accordance with the practices in Germany, Netherlands and Denmark, the frequency of utilisation was increased, especially in the more favourable areas (utilisation to as many as six times annually), and the use of concentrates from outside of the farms and mineral fertilisers was clearly increased. In the highly favourable areas of Austrian grassland farming (Rhine Valley, Inn Valley, foothills of the Alps), the yield potential of the meadows and pastures could be better utilised and, initially, the quality of forage significantly raised. Higher frequency of cutting, however, often led to the loss of utilisation-sensitive species of grass and many open-patch areas were created, which according to the demands of today in respect of yield and quality could no longer be sufficiently fulfilled. The open patches were colonised more and more by broad-leaved dock (*Rumex obtusifolius*), common dandelion (*Taraxacum officinale*) and rough-stalked meadow-grass (*Poa trivialis*), which are of less feed value and no longer fulfil the ration demands of dairy cows in the middle- and higher performance spheres.
In the mountain locations, on the other hand, traditional farming has only been changed slightly so that the meadows there today are mowed twice or a maximum of three times annually. According to ÖPUL-stipulations, mineral nitrogen is hardly used in the mountain locations and, moreover, with two to four kilograms per dairy cow the daily amounts of concentrates are at a comparatively low level. This site-adapted farming system takes ecological contexts into account to a high degree and guarantees sustainable, resource-sparing farming of the land. An essential contribution for making farming ecologically viable in Austria is also undoubtedly the numerous existing general legal conditions in respect of the utilisation of water, soil, nature- and animal conservation. Among other things clearly defined limits are fixed within the legal framework, the maintenance of which is also severely controlled in the course of cross compliance.

How ecologically do Austrian farmers utilise grassland?

The proof of ecologically orientated, sustainable farming of the land can take place by different ways and means. At a European and national level, the evaluation of the programme for rural development makes an essential contribution (Pötsch and Schwaiger, 2009). The Austrian agri-environmental programme is very critically controlled within the sphere of this evaluation in respect of its effect on the protected resources of soil, water, climate and biodiversity and, based on the results achieved, is improved and further developed. The current evaluation results offer an excellent testimony as a whole to Austrian grassland farming, but also shows a certain potential for improvement (BMLFUW, 2010; Pötsch and Schwaiger, 2011).
Recommendations were laid down as early as 1991 in the “Guidelines for Appropriate Fertilisation” for the fertilisation of grassland with nitrogen, phosphorous and potassium. In addition, together with the yield situation and the type of utilisation and frequency, the subsequent delivery of the nutrients from soil was also taken into account. These recommendations are not targeted on the maximisation of yield but on sustainable utilisation of grassland as a circuit farming system (BMLFUW, 2006). The farm’s own fertiliser and its appropriate use plays an increasingly important role for grassland farms, not least due to the high energy and fertiliser prices. Nutrition balances are an important means for the depiction and assessment of material flows and enable concrete statements from various points of view (international, national, regional, and for individual farms and areas). What is decisive, however, is that the method of nutrient balancing is clearly defined and thus also open to comparison (Taube and

Pötsch, 2001). Farm gate balances for differing grassland regions in Austria showed average nitrogen balances of -7 kg to +10 kg per hectare and year, although significant deviation appears (Pötsch, 2000). With an average of +17 kg N per hectare and year, farms in the valley regions show a higher surplus than farms in mountain locations, which are almost equally balanced. A tendentious difference was also seen in the farming method with an average of +9 kg N per hectare and year among conventional farms and +2 kg N per hectare and year among organic farms. Balance results from Steinwender *et al*. (2001) show a strongly marked difference between mountain farmers using organic farming methods and the most intensive conventional grassland farmers in the favourable locations, with nitrogen balances of -1.2 kg N per hectare and 115.6 kg N per hectare and year. According to Guggenberger (2006), Austrian grassland areas show an average nitrogen balance of +11.4 kg N per hectare. If a balance surplus of 50 kg N per hectare and year is accepted as a tolerable upper limit, according to Guggenberger (2006) 93% of Austrian grassland areas can be considered to be sustainably farmed.

Site-adapted utilisation and fertilisation of grassland guarantees a high floristic diversity on both levels of species and plant associations. According to Bohner (2007), on average, between 36 and 70 species of vascular plants are to be found among the permanent-meadow and permanent-pasture plant communities in Austria. The intensively utilised meadows and pastures in the favourable locations still show at least 20 to 30 species. In the alpine-valley meadows and mountain meadows, according to Buchgraber and Sobotik (1995) up to 72 species can be assessed in regional transects. According to Bohner *et al*. (2010), 910 species of vascular plants were found in a single quadrant of 35 km². By far the most species-rich grassland types identified were alpine-meadows, extensive pastures (with up to 115 species) and mountain meadows, followed by once- and twice-cut areas and cultivated pastures (Pötsch *et al*., 2005). Together with floristic diversity, the diversity of the types of grassland utilisation and their significance for the habitat- and landscape structure were recorded by Pötsch and Blaschka (2003). Austrian grassland farming thus makes an indispensable contribution to a positive image of a cultivated landscape that, year after year, attracts many tourists and holidaymakers to the mountain regions of Austria.

Protecting and maintaining an open cultivated landscape

In the past 60 years the number of farms in Austria has decreased from 400,000 to about 180,000. The loss of many small farms has meant that particularly in areas in the mountains, and steep locations that are difficult to work, farming has been given up. This also means the ecologically valuable but very sensitive alpine-meadow areas that are increasingly threatened by the growth of shrubs and forests are becoming fully overgrown. Of the currently existing alpine-meadow areas (about 720,000 hectares), for example, only 63% are now designated as forage areas. Many grassland areas become overgrown within a few years after no longer being utilised, and thus no longer fulfil their original function for production.

The problem of giving up utilisation and the loss of function can be seen over the entire region of the European Alpine Bow and, together with farming, also affects numerous other sectors and stakeholders (Tasser *et al*., 2011). In Austria this development also increasingly affects those regions in which tourism plays a significant economic role. Tourists come mainly because of the cared-for and open cultivated landscape that still shows a high agricultural identity (Buchgraber, 1995). To keep open the regions with an agrarian quota of less than 3%, and which are endangered from being overgrown, new forms of organisation and production alternatives must also be implemented for comprehensive farming in the future together with full- and part-time farmers. Under the title of "Modern Land Management", models for cross-farm cooperation in endangered regions were considered and their practical realisation capacity discussed. In a specific living area (e.g. side valley, region) all of the resources that are still available (land areas, buildings, animals, machines, workers) should be voluntarily bundled on the basis of private legal cooperation, and the cared-for cultivated landscape maintained in its diversity (Buchgraber, 2004; Buchgraber, 2007). With the preservation of the cultivated landscapes in the mountain regions, according to Pötsch (2010) their multi-functionality can be guaranteed, so that together with production, such aspects as protection, wellbeing and recuperation can also be contained. Giving up the utilisation of these often steep grassland areas can trigger extensive natural dangers in mountain locations, above all due to extreme precipitation. Sustainable farming, on the other hand, fosters the turf and root penetration of the soil and thus protects the steep locations against erosion and mudflows. If these mountain meadows and mountain pastures become overgrown with forest, much of the biodiversity and the popular image of this delightful living area will be lost (Ahrens and Kantelhardt, 2007). The mountain regions of Europe must therefore assume an important role in the future as a living-and-recuperation area, as well as for the production of foodstuffs.

Specialised theme focuses in theory and practice

The number of experts responsible in Austria for grassland and animal farming may be limited but their efficiency is very high. Science, consultation, training and further education work together effectively in practice. In recent years the following focal themes have been dealt with and put forward.

Soil - fertilizer - plant stands

Protection of the soil and maintenance of the soil fertility must also be given increasing attention (Starz, 2007). The use of increasingly larger and heavier machines also leads in the mountain regions to heavy loads and compaction of grassland soil, as well damage to the swards. The environmentally friendly use of farm manure is given the highest regard. The national guidelines for appropriate fertilisation (BMLFUW, 2006) take into account the differing site characteristics and in practice they are very well implemented. Together with liquid manure, slurry and farmyard manure, organic compost (Buchgraber, 2000) is also used on Austrian grassland and controlled in respect of effects on yield, forage quality and soil. The carrying out of soil sampling and soil analysis is recommended at intervals of 5-6 years and their results taken into account in the planning of fertilisation.

Great attention is given to research, consultation as well as teaching of the composition and improvement of plant stands. Knowledge of the most important plant species in grassland and knowledge of their feed value must be further improved, above all by the farmers to ensure that problems are recognised on time and appropriate regulating measures can be undertaken. This is all the more important because, due to the raising of the cutting frequency in recent years, especially so in the favourable regions, a certain loosening of the swards has been shown. This open patchiness often leads to unfavourable development of the plant stands and thus to a reduction of forage quality. Together with the classic dock problem (*Rumex obtusifolius*, *Rumex crispus*, *Rumex alpinus*), the current increased appearance of rough-stalked meadow-grass (*Poa trivialis*) presents great challenges in practice. Mechanical weed control moves into the foreground due to the increasing renunciation of chemical-synthetic farming methods (Pötsch and Griesebner, 2007). A majority of the Austrian grassland is old and permanent, the improvement and renewal of which, due to climatic and topographical conditions, presents a special challenge. While in many European regions that are favourable for grassland farming a regular ploughing up of grassland swards takes place, often combined with the use of herbicides such as glyphosate, in Austria grassland renewal without ploughing is increasingly implemented as a modern grassland standard procedure. In this respect site-specific seed mixtures of very high quality are used (ÖAG quality), which in their spectrum of species and varieties differ very greatly from the mixtures containing a predominance of ryegrass and white clover that are used in the favourable locations (Krautzer *et al*., 2010). The ÖAG seed mixtures, which compared with the general European norms clearly fulfil stricter quality criteria, have been checked for more than 15 years in field trials, and further developed and utilised in practice with the greatest success.

Forage quality and feed conservation

Grassland in the mountain regions presents other plant stands than those in the favourable locations and due to the difficult conditions (climate, area size, steepness, etc.) it also presents great challenges to the farmers in respect of forage conservation. Forage quality is at the centre of attention of numerous, specific research projects, as well as field studies, which offer an excellent insight into the situation in-practice on farms and, at the same time, indicate the unrealized potential (Pötsch, 2009). A specific forage-value table for the forage from alpine regions was created at LFZ Raumberg-Gumpenstein (Resch *et al*., 2006). This is complementary to the additional sensory assessment of silage and hay on farms (Buchgraber, 1998) that is increasingly being used. In forage conservation in recent decades the production of silage has increased significantly, while traditional hay making has decreased, especially in the favourable locations. The production of haylage is increasingly more popular in several areas. In respect of silage systems, high silos are also being increasingly replaced in the mountain regions by baled silage and bunker silo systems. But in recent years the production of hay again acquired importance after "hay milk" and "hay cheese" were exceedingly well accepted by consumers. Within the sphere of the Austrian agri-environmental programme, hay is produced exclusively and the production of silage voluntarily renounced on about 10,000 farms on about 115,000 hectares in selected areas.

Alpine-meadow farming

28,600 Austrian farms utilise a total of 8,855 alpine meadows. However, in recent decades many alpine meadows have no longer been farmed and have already become overgrown. There are many initiatives today for the re-cultivation of these ecologically valuable but also very sensitive areas (Aigner *et al*., 2003), which, due to especially difficult farming conditions, require financial support. The re-cultivation of extreme mountain locations, within the sphere of farming as well as following diverse construction measures (ski runs) or occurrences of damage (avalanches, mudflows) were intensively processed and successfully realised with the use of site-specific seed and special techniques (Krautzer *et al*., 2006).

Transfer of expertise in practice

The research applied at the AREC Raumberg-Gumpenstein is used in its projects to deal with numerous practice-relevant and future-orientated themes. The results are communicated in professional and scientific journals, and through lectures, professional events, seminars and on field days, to pupils, students, teachers, consultants and above all to farmers. The close cooperation between all participants enables the necessary efficiency in the individual regions. The Austrian Grassland Association (ÖAG) also offers an ideal platform for all participating stakeholders, and by means of practically edited brochures and leaflets it informs continuously on current problem areas and approaches to solutions.

Perspectives of Austrian grassland farming

With the predicted expiry of the European milk quota system and the advancing liberalisation of the markets, the pressure on small farms in the disadvantaged regions will be further increased. The giving up of farms will lead to a noticeable change in the cultivated landscape and its appearance. In the more favourable regions, on the other hand, an intensification of farming and enlargement of farms will take place, and also at the same time there will be increasing competition for utilisation of the available areas for the production of energy and for infrastructure use.

These extremely contrasting developments in the mountain regions, and especially in the regions of the Alps, will take place parallel in time with each other, and within locations of close proximity. But a minimum of farming in the mountain regions, as well as an upper limit of cattle stock in the favourable locations, is also required for the maintenance of the diverse economic and ecological functions of the grassland. On the one hand there is the danger of giving up utilisation, and of excessive intensification on the other; and both developments finally lead to a further reduction of the agrarian quota. New, cooperative forms of land utilisation could counteract this, and, together with maintaining the preparedness to produce, should also continue to guarantee the qualitatively high-value production of healthy and nutritious foodstuffs. An indirect contribution to maintaining the farming of meadows and pastures could be provided by the rising costs for energy and concentrates (above all protein components), which brings the farm's own forage more into the foreground. Grassland and dairy farming can take place to a medium level of performance based on the farm's own resources - forage and farm manure - and thus show a high degree of self-sufficiency. But this also demands an improvement in the future of plant stands, further development of the quality of silage, hay and aftermath, optimisation of grazing and the efficient use of environmentally compatible farm's manure.

The attractive but difficult-to-farm living space in the mountains requires coordinated farming in unison with nature. But the mountain farmers must be offered the appropriate incentive in the rural development programmes to ensure that they are also able to undertake their valuable tasks in the future for the benefit of all of society!

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Session 1

Meeting the challenge of grassland management in disadvantaged areas

Agricultural changes in the European Alpine Bow and their impact on other policies

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Abstract

The socio-economic frame-conditions of land-use change in the Alps are diverse, as is the adaptation of agriculture. Generally, the Alpine space is a land of meadows and pastures. This is a result of developments on the European agricultural market and a better economic context for the production of milk and meat. This specialisation in cattle farming comes along with an intensified fodder production in the favourable valley floors. The slope regions and subalpine zone are dominated by land abandonment, which is a result of the need for lower production costs. Against the background of global change, intensification of land use, and land degradation throughout the Alps, increasing attention has been paid on ecosystem services and the underlying ecosystem functions, regarding, e.g., the production of natural goods, habitat and resource protection, preservation of biological diversity, and the supply of space and environment for recreation.

Keywords: agricultural market, ecosystem services, production of milk and meat, valley-specialisation, slope-abandonment scheme

Introduction

In recent decades, many regions all over the world have experienced massive changes in agriculture and forestry (Pan *et al*., 1999; Nusser, 2001; Lütz and Bastian, 2002; Tappeiner *et al*., 2008). This is mainly due to the increased use of machinery, new production techniques, improved breeds, different national and regional subsidizing instruments or even just the public standing of the respective sectors. The most decisive break occurred in the second half of the last century, when production for self-sufficiency changed towards production for the market. Suddenly, farmers were faced with a problem that they had not previously encountered in such a severity, i.e. global competition (Lambin *et al*., 1999; MacDonald *et al*., 2000; Veldkamp *et al*., 2001). A rethinking and reorientation was necessary. However, in many cases these profound socio-economic changes resulted in a complete abandonment of farming, which particularly affected farmers in the Alps. As recently as 60 years ago, farmers in the Alps were using the few favoured valley areas to grow cereal and field crops. Hay was made on steep slopes and high-altitude mountain meadows and the animals were driven up to the mountain pastures for the summer. Today, everything has changed: in favoured areas, many fields are farmed more intensively; marginal areas, however, are farmed less intensively or have been abandoned altogether. As a result of such developments, nearly 36% of the farmers have given up farming within the last 20 years (1980-2000), with a decidedly heterogeneous picture emerging across the Alps. According to Streifeneder *et al*. (2007), around one-quarter of all farms in Germany and Austria have closed down within the last 20 years, while in Slovenia the figure is more than half of all farms. Of the remaining farms around 40% are run as a sideline. Today, on average about 20% of agricultural land lies fallow, with figures in some regions approaching 70% (Tappeiner *et al*., 2006; Tasser, 2007).

In recent decades we have come to know a lot more about the ecological effects of changes in land use, but this knowledge still stems mainly from ecosystems research, i.e. from selective surveys (Cernusca *et al*., 1999; Tenhuhnen *et al*., 2008). Such studies provide detailed findings on the processes taking place on a specific site but do not lend themselves to generalizations (Meentemeyer, 1978; O'Neill *et al*., 1991). Today, society expects researchers to give answers to regional and global issues, such as the future impact of changes in land use or climate on various spheres of living. Since Rio de Janeiro 1992, the concept of sustainable development has also played an important role in discussions. Sustainable development largely depends on the political, economic and environmental contexts which are defined at international and national but also at regional and local level. Nevertheless, regional development is particularly steered by the local stakeholders who operate mainly in regional and local spheres. Consequently, it is of fundamental importance to be conscious of the actual situation at local level and to work on an adequate interdisciplinary approach in order to understand how a sustainable regional development can be supported. Therefore, research findings must be valid on these topics on the spatial and temporal scale of emotional, social and economic life, the level where decisions may be made. At the same time they have to map trends for assessing and evaluating future developments. Applied ecological research is increasingly moving into this direction (Ludwig *et al*., 2003; Del Barrio *et al*., 2006; Seidl *et al*., 2007).

The situation of the regional development in the Alps

The Alps are not only the highest inner-European mountain chain, crossing eight different countries; they also contain a large variety of landscapes, species and cultures. Usually, one thinks of mountains as sparsely populated areas. In relation to the amount of land that is actually available for settlement or agriculture, however, they are among the most densely populated (Tasser *et al*., 2008), and the cultural heritage they preserve runs the whole gamut from ancient to modern times. The Alps are a hot spot of biodiversity and a complex ecosystem. Altitudinal climate-gradients and topography influence the natural dynamics of many processes (e.g. soil development, hydrology), and thus the typology of land use and habitat variety. The dominating environmental factors also expose the hillsides and valleys to various dangers (e.g. erosion, floods).

Today, also the socio-economic frame conditions of development in the Alps are highly diverse, as is the adaptation of agriculture (Tappeiner *et al*., 2003; 2008). We identified nine different developments in the Alps (Figure 1, Tappeiner *et al*., 2008):

- Residential municipalities: Typical residential and dormitory municipalities are found in the vicinity of large employment hubs. Transport infrastructure is better than average, daily commuting into the employment hubs is possible without great loss of time. Due to the great appeal of pleasant surroundings and lower land prices, these municipalities are attractive as places of residence and they draw residents. Their inhabitants commute daily to work in the larger centres. Like in the employment hubs, agriculture is retreating and there are a lot of artificial areas.
- Employment hubs: Employment hubs show a high positive commuter balance, i.e. many employed persons commute into such a hub on a daily basis while the number of out-commuters is relatively small compared to the in-commuters. These centres have a very good transport infrastructure and are built up on a large scale. Business parks, industrial facilities and shopping centres offer a good supply of jobs. Thanks to the abundance of jobs, the employment rates are high, especially for women and older people. The local economy is characterized by a domination of the tertiary sector, while the primary sector is in sharp

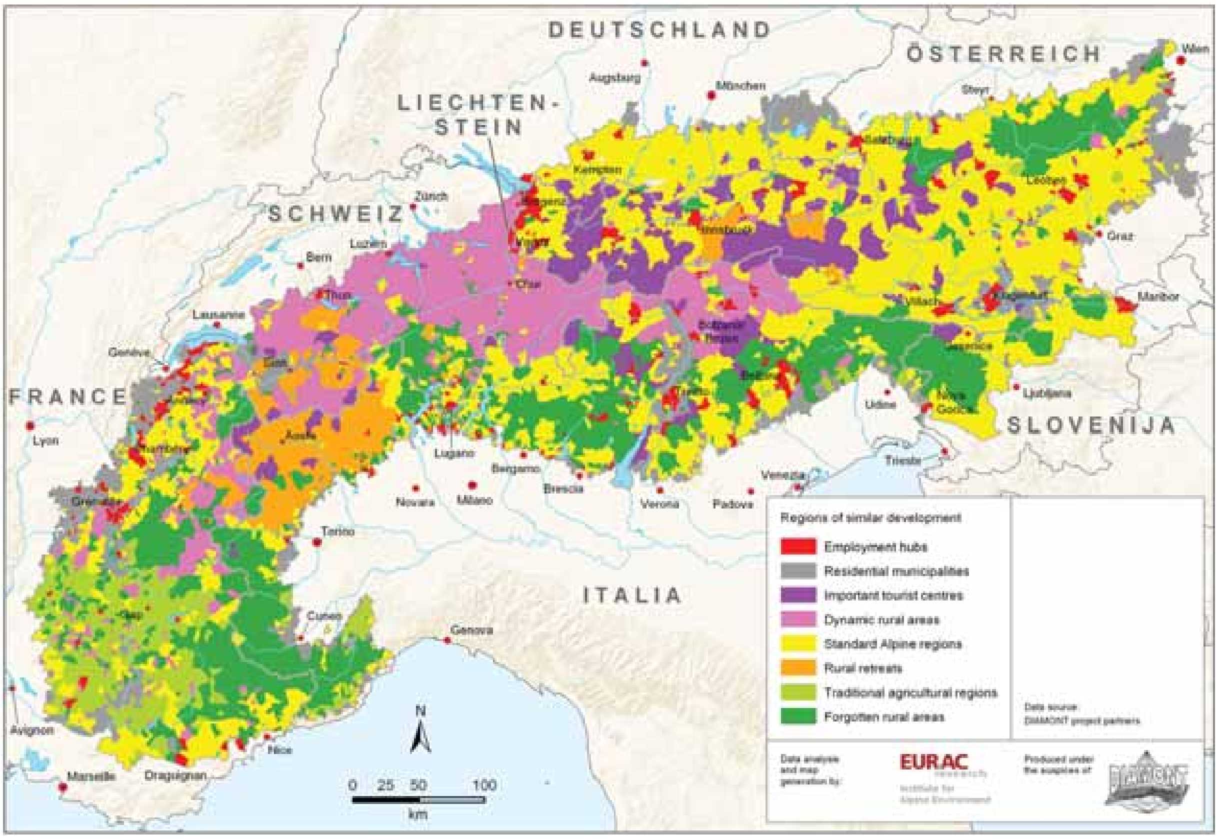

Figure 1. Typology of the Alps, based on economic, environmental and social aspects (Tappeiner *et al*., 2008)

decline. As the cluster incorporates urban imprinted municipalities, there are many artificial areas.

- Important tourist centres: A typical tourist centre has very well developed accommodation facilities; the labour market is better developed than average because of an abundance of jobs in the service sector. An established tourist sector allows for a functioning agricultural sector: agricultural areas can be maintained or even increased although the number of farms is slightly decreasing. This results in an intact cultural landscape with little landscape dissection.
- Dynamic rural areas: Such an area is characterized by a rural location and a dynamic labour market. Employment, particularly for women and older people, is very high and has improved significantly, not least as a result of positive developments in tourism. The commuter balance is negative, but rather low compared to the other regions because the local economy provides more jobs than average. Moreover, agriculture is still intact in such areas, with few farms or pieces of land being abandoned.
- Standard Alpine regions: This region has no outstanding features and in all aspects returns average values for the Alps. Typical characteristics include low tourist intensity, a decline of agriculture and a negative commuter balance. Balanced migration and birth rates, however, prevent excessive over-aging in these areas.
- Rural retreats: Characteristics for this cluster are good transport links, which the residents use to commute even further to work while retaining the centre of their life in the rural hinterland. In recent decades, agriculture has largely retreated from such areas, resulting in large natural spaces with little fragmentation and a highly diverse landscape.

- Traditional agricultural regions: Typical for such a region are a severe over-aging and a poor transport *infrastructure*. Unlike in the cluster "Rural retreat", agriculture is not retreating to any great extent from these areas but farms are run extensively. Overall, this results in a rich traditional landscape. The poor employment situation in the service and tourist sectors in this region might also contribute to the lower rate of abandoned farms.
- Forgotten rural areas:This cluster is dominated by distinct over-aging and a particularly sharp decline in farming. A major reason for this could be the poor transport infrastructure in such an area. These areas are real passive spaces: employment is low for all population groups and jobs are scarce; both the service sector in general and tourism in particular are small-sized; many old people are living alone.

The distribution of the development clusters is, among other things, a consequence of industrialization and globalization. The general trend in all industrialized countries is even a shift in employment from the primary and secondary to the tertiary sectors. In Europe, less than 5% of the labour force is employed in agriculture (Eurostat, 2005). In the Alps, the situation is different: on average 12% of the jobs in a municipality are provided by the primary sector. Generally, the share is higher in more rural and remote areas than in more urban-oriented ones.

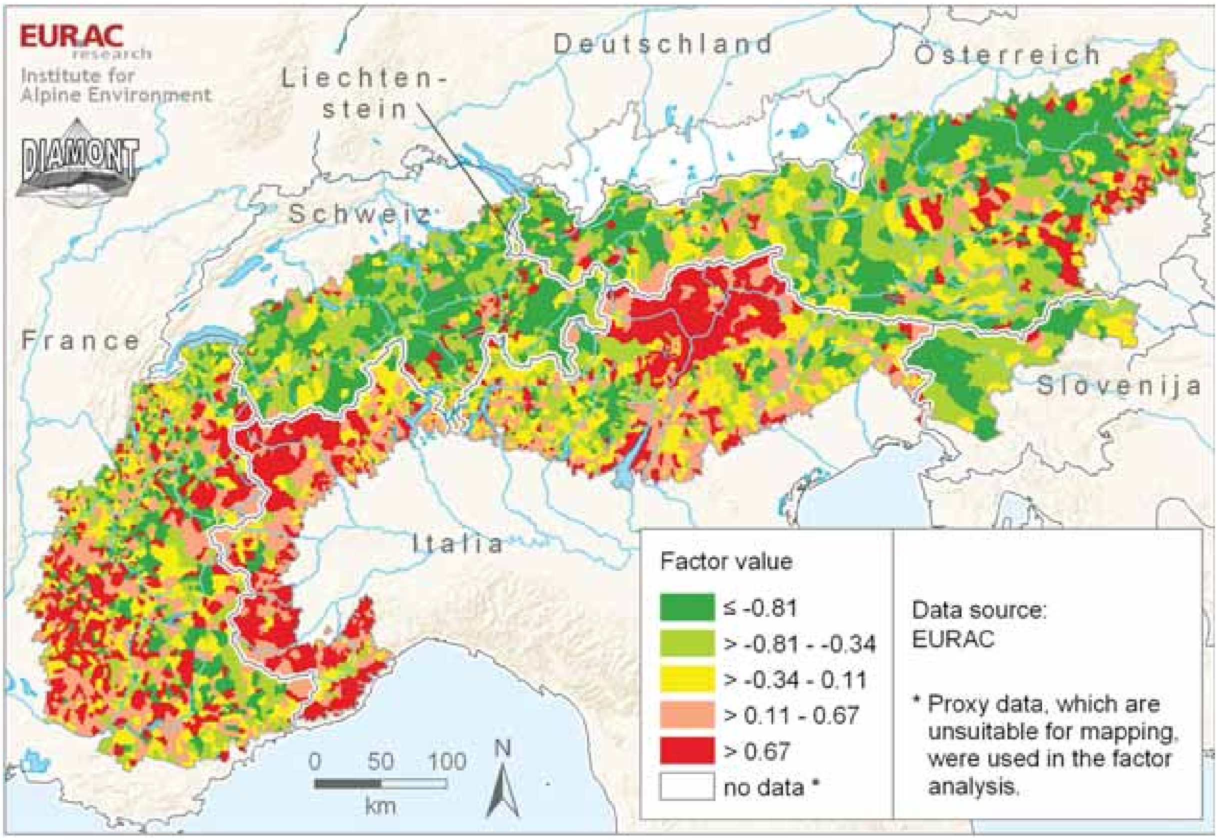

Figure 2. The factor "agriculture" summarizes an aspect of the economic structure, namely the size of the primary sector and the extent to which the local economy depends on it (after Tappeiner *et al*., 2008).

The factor "agriculture" (Figure 2) measures the extent of the primary sector in terms of jobs. A high share of jobs in the primary sector signals a rather unbalanced economic structure in terms of sectoral breakdown of jobs, defined as the sum of squared differences from the Alpine mean of the proportion of jobs in the three economic sectors. The average enterprise size in the secondary and tertiary sector correlates negatively with the factor agriculture: in municipalities with a large agricultural sector, the businesses in the other two sectors are rather small.

Furthermore, the percentage of the self-employed correlates positively with the number of jobs in the primary sector, because the probability of being self-employed is higher in agriculture than in other sectors (Blanchflower, 2004). With the shift of employment from the primary to secondary and tertiary sectors, the proportion of self-employed persons decreases, as many of them were previously employed in agriculture. In sum, the phenomenon of agriculture is most pronounced in municipalities with a large proportion of jobs in the primary sector as well as an unbalanced economic structure. These municipalities are further characterized by a high share of self-employed persons and small businesses in the other sectors.

The role of the agriculture

Before the mid-19th century, the economy of the Alps was predominantly based on agriculture in form of farming and grazing (MacDonald *et al*., 2000; Zimmermann *et al*., 2010). The landscape represented the form that man had consciously and systematically imposed on the natural landscape in the course of history. Most of the values represented by this cultural landscape today are connected to traditional techniques and practices that have shaped this territory for several centuries (Tasser *et al*., 2009). However, during the last 60 years traditional Alpine farming has undergone a radical change. There has been a widespread abandonment of unfavourable farming locations, while at the same time agriculture has been intensified in favourable areas (MacDonald *et al*., 2000).

The phenomenon of “agrarization” (Figure 3) combines two perspectives: agriculture viewed in terms of jobs as well as in terms of farms and how they change. High values indicate an above-average status of agriculture, i.e. hardly any abandonment of farms, a large number of agricultural enterprises and with it lots of primary sector employment. Regions with high values are mainly found in Austria, in the German Alps and in some parts of Italy. Particularly

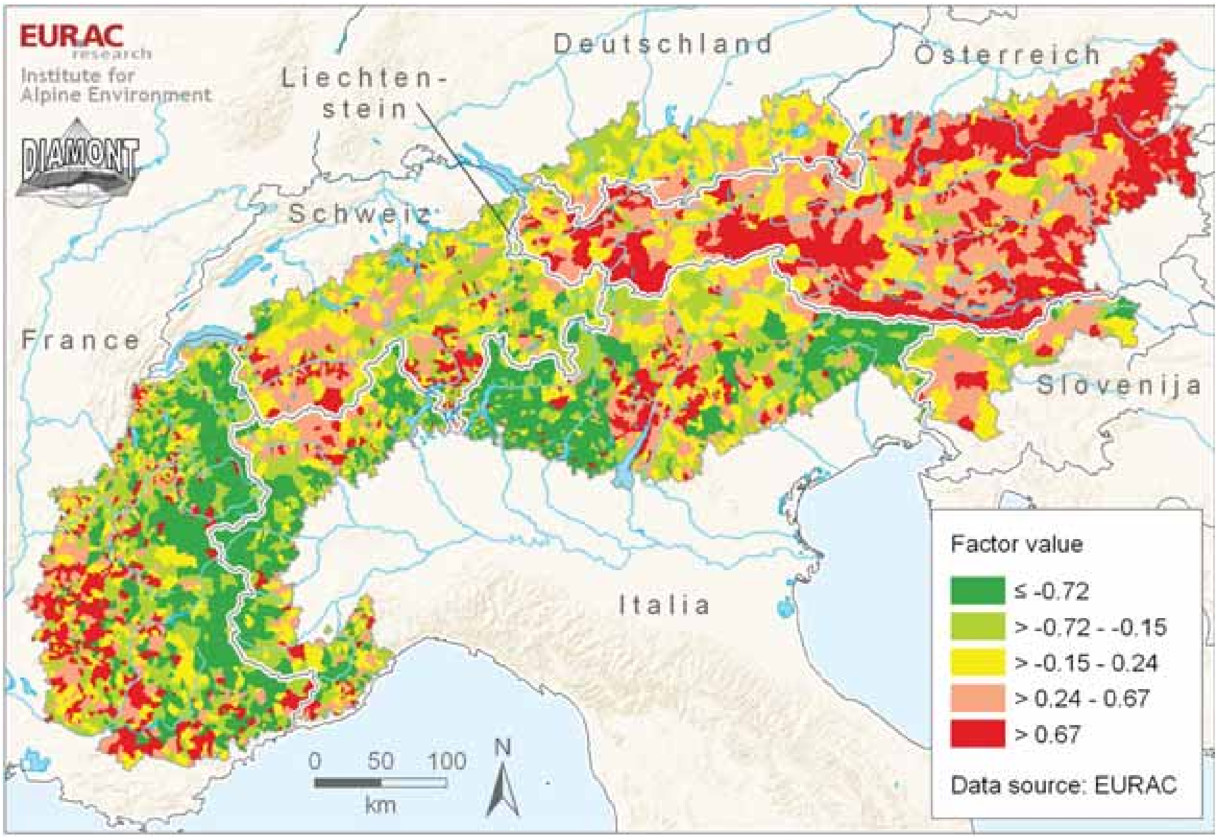

Figure 3. The phenomenon of “agrarization” shows the vitality of agriculture in the Alps (after Tappeiner *et al*., 2008).

striking in Italy are the Autonomous Province of Bozen/Bolzano - South Tyrol and the Autonomous Region of the Aosta valley. As a result of their autonomous status, these regions have the authority to pass laws and they have profited from this capacity in order to better support farming by creating appropriate conditions for agriculture in a mountain area. High values are also found in the south-western French Alps, an extensive arable-farming area with additional sheep and goat keeping. Such extensive forms of agriculture receive high subsidies, which give farmers a positive outlook (Tappeiner *et al*., 2003). In large parts of the Italian, French, and Slovene Alps, but also in the Swiss Alps, the significance of the agricultural sector is in sharp decline. Even if the economic effects of this development might not be too grave, it must be remembered that agriculture provides a number of important services to the society, such as the preservation of landscape elements and structures that are part of the cultural heritage (Barthelemy and Vidal, 1995-2007).

Today, the Alpine space is characterized by two major types of agriculture. The first one prevails in the drier and warmer Alpine areas (e.g. inner-Alpine dry areas, Southern and south-western Alps) with predominantly arable farming or permanent cultures, small farm sizes, high parcelling of agricultural areas and partible inheritance. The second type prevails in the humid and cooler Alpine areas (north-western and northern Alpine rim, eastern part of the Eastern Alps) dominated by animal husbandry, relatively large farms, little parcelling of agricultural areas and primogeniture (Bätzing, 1996). Especially the property-structure is a consequence of the history: in the east of the Alps, the Baiuvarii implemented a law which allowed the transfer of an entire farm estate to only one heir (Anerbenrecht). In contrast to this, the land in the west was divided by the Alemannen equally among all heirs (Realteilung). But also the dominance of these two recent major types of agriculture is a consequence of the history, but of the younger history. In the Alps, the European agricultural market favoured the production of milk and meat (Isermeyer, 2005). And also the natural site factors, in particular the unfavourable climatic conditions and steepness of many areas, limit agricultural productivity. Generally, the Alpine space is therefore a land of meadows and pastures (Zimmermann *et al*., 2010); hardly anywhere else does grassland farming dominate as much as in the Alps today. In most regions the non-grassland use does not exceed 5% of the area in agricultural use (Figure 4). In only 25% of the municipalities arable farming and permanent crops take up more than 15% of the agricultural land. Arable farming is mainly found in the French departments Isère, Drôme, Hautes-Alpes, Alpes-de-Haute-Provence, in the eastern provinces of the Italian Alps, particularly in the province of Udine, in Slovenia and at the eastern rim of the Austrian Alps. In favoured locations of inner-Alpine dry valleys, e.g. the valleys of Adige and Rhône, and in the Mediterranean climate of Liguria and southern France, specialized permanent crops are common. These two forms of farming also indicate the environmental impact (Matson *et al*. 1997), because in principle they necessitate a high degree of mechanization, far-reaching melioration measures as well as intensive use of fertilizers and pesticides.

On the other hand, two developments in grassland use exist, which are adaptation strategies to the agricultural market (Giupponi *et al*., 2006). Specialisation in grassland use is dominant in the valley floors and less frequent in the slopes and higher regions. The main reasons for this are unfavourable conditions such as a shortened vegetation period and difficult terrain with steep slopes and small arable plots, which incur higher production costs. Mountain agriculture can therefore not compete in national and international markets. Thus, from the 1950s onwards, marginal land with low yields has successively been taken out of agricultural use. However, this development greatly varies in intensity between regions (cf. Tasser, 2007): in the South Tyrolean Oltradige, one of the most productive regions of the Alps, only about 6% of farming

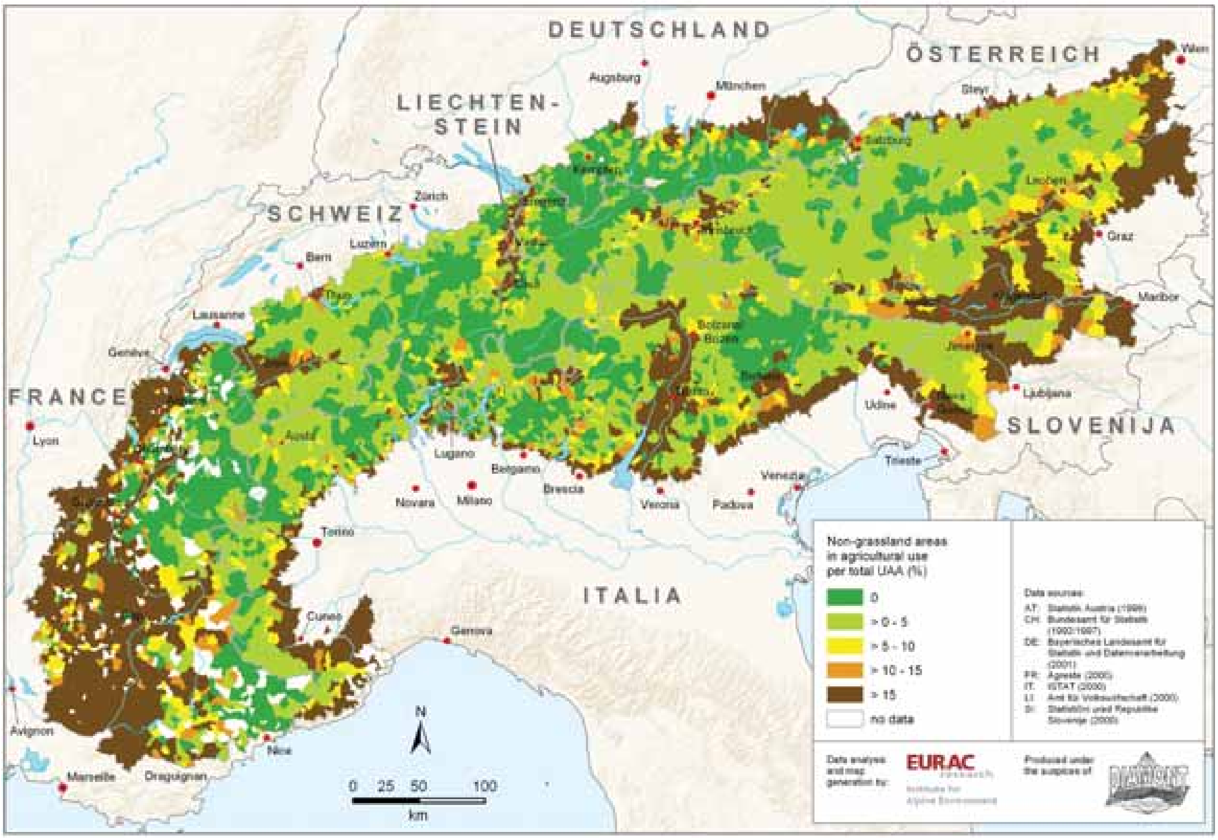

Figure 4. The map shows the areas used for non-grassland farming as a proportion of the total area used for agriculture (after Tappeiner *et al*., 2008).

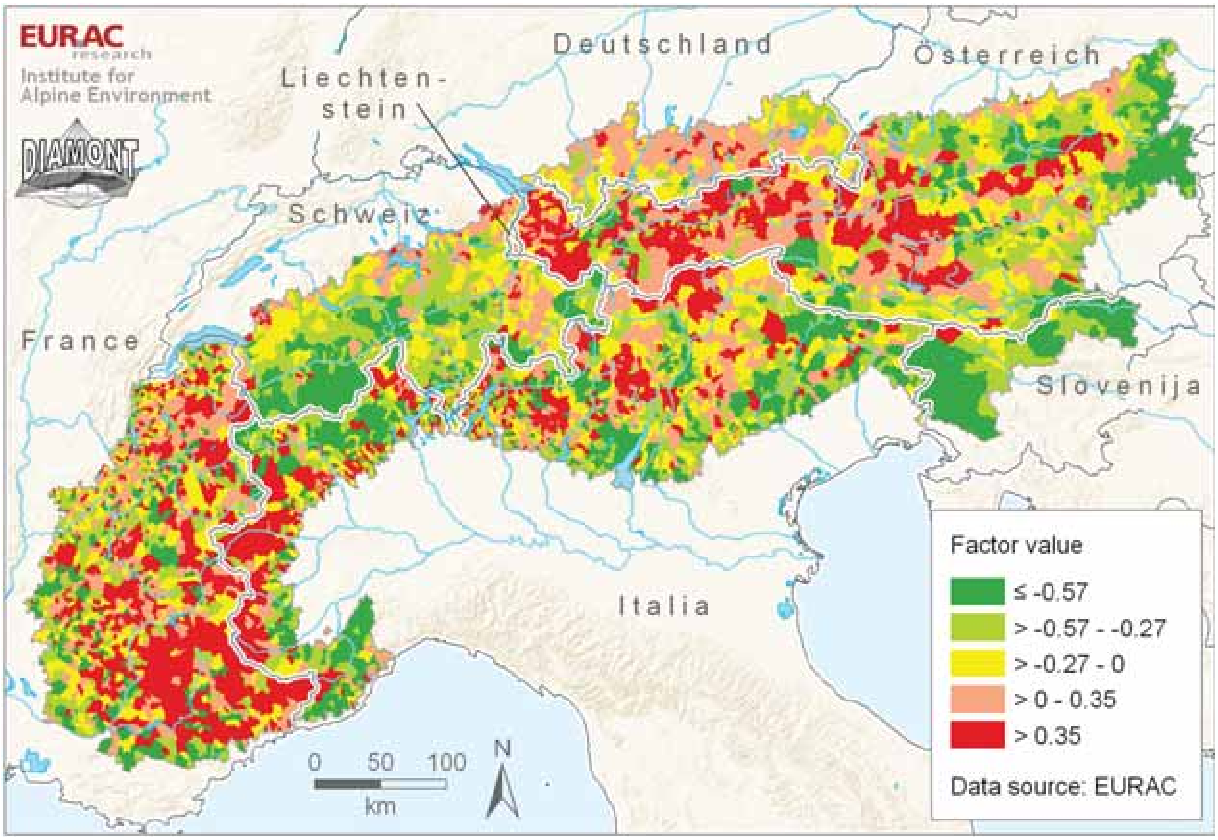

Figure 5. The phenomenon “Changes in agricultural area” depicts the actual used agricultural area per farm and its changes between 1990 and 2000 (after Tappeiner *et al*., 2008).

land has been abandoned within the last 150 years, whereas the figure stands at 33% for the Tyrolean uphill areas, 37% in the region around Innsbruck and reaches 67% in the Carnia region. The most intensive push for giving up agricultural use occurred in the 1950s and 60s. These differences stem to a large degree from differences in agricultural policies (Tappeiner *et al*., 2003); Streifeneder *et al*., 2007). In Austria, Bavaria, Switzerland and South Tyrol, for instance, subsidizing mountain agriculture started early on (Penz, 2005), while France and most of the Italian regions have supported mountain agriculture only hesitantly (Bätzing, 1996).
However, the younger developments depict, in some parts of the Alps, an about-face in agricultural use (Figure 5). Slovenia, Italy, and Germany show particularly severe reductions. Only small reductions in agricultural land have occurred in the last 10 years in Austria and Switzerland, where the proportion of used agricultural areas is still high. Some regions, however, show a trend reversal: there, the amount of agricultural land has stabilized or even increased. A slight increase can be noted mainly in western Austria and in the French Maritime Alps.

The consequences

The land-use changes consequently also result in considerable ecological effects on each single individual, on ecosystems and hence also on landscape. The manifold consequences affect population biology, on vegetation (Ellenberg, 2010), on soil (Gamper *et al*., 2007) but also on processes of the ecosystem, such as hydrological cycles and ecological stability (Schauer, 1975; Leitinger *et al*., 2010). The effects may hence also be of socio-economic relevance, such as the resulting costs and the safety risks (Cernusca *et al*., 1999).
The significance of anthropogenic influence in the form of land use becomes especially clear in landscape diversity (Ellenberg, 2010; Zimmermann *et al*., 2010). Depending on the type of land-use (mowing, grazing), as well as on the land-use history, on intensity of land-use (frequency of annual mowing, fertilisation, irrigation, number of grazing animals) and site conditions, characteristic stands of vegetation develop (Stampfli and Zeiter, 1999; Tasser and Tappeiner, 2002). Even human activities have had a strong impact on the natural landscape in the Alps, resulting in a diversified cultural landscape that is continuously influenced by natural forces, especially in higher altitude sites. Great disparities within the Alpine space become immediately obvious from the map (see Figure 6). As a rule, municipalities along the Alpine rim and in the main Alpine valleys show higher diversity than municipalities at higher altitudes within the Central Alps, thus reflecting the more favourable conditions for agricultural land use. In these areas, arable farming, market gardening, wine and fruit growing are generally possible in addition to grassland farming. Indeed, it is particularly in those parts of the Alps with a Romance tradition, especially in the Provence and in the southern parts of the Eastern Alps that one still finds such a traditional small-scale farming. In many other areas, however, landscape has changed enormously. In the southern Italian Alps, in particular, large-scale abandonment of farming has resulted in forest regrowth across large areas along with a severe decline in diversity. In Austria and Switzerland, agriculture has mainly specialized in grassland farming, but here too, melioration measures, consolidation of plots and increasing mechanization have reduced the diversity of the cultural landscape in many places.
A high patchwork of natural, semi-natural and cultural landscape fragments is also a major factor for supporting biodiversity in the Alps by creating complex spatial pattern of ecosystems and habitats (Olsson *et al*., 2000). The Alps are, therefore, a hotspot of biodiversity in Europe. About one-quarter of the plant-community diversity is man-made or depends on particular forms of agriculture. This is especially true for the many types of mountain meadows (Tasser and Tappeiner, 2002): species-poor communities occur in flat areas and with high anthropoge-

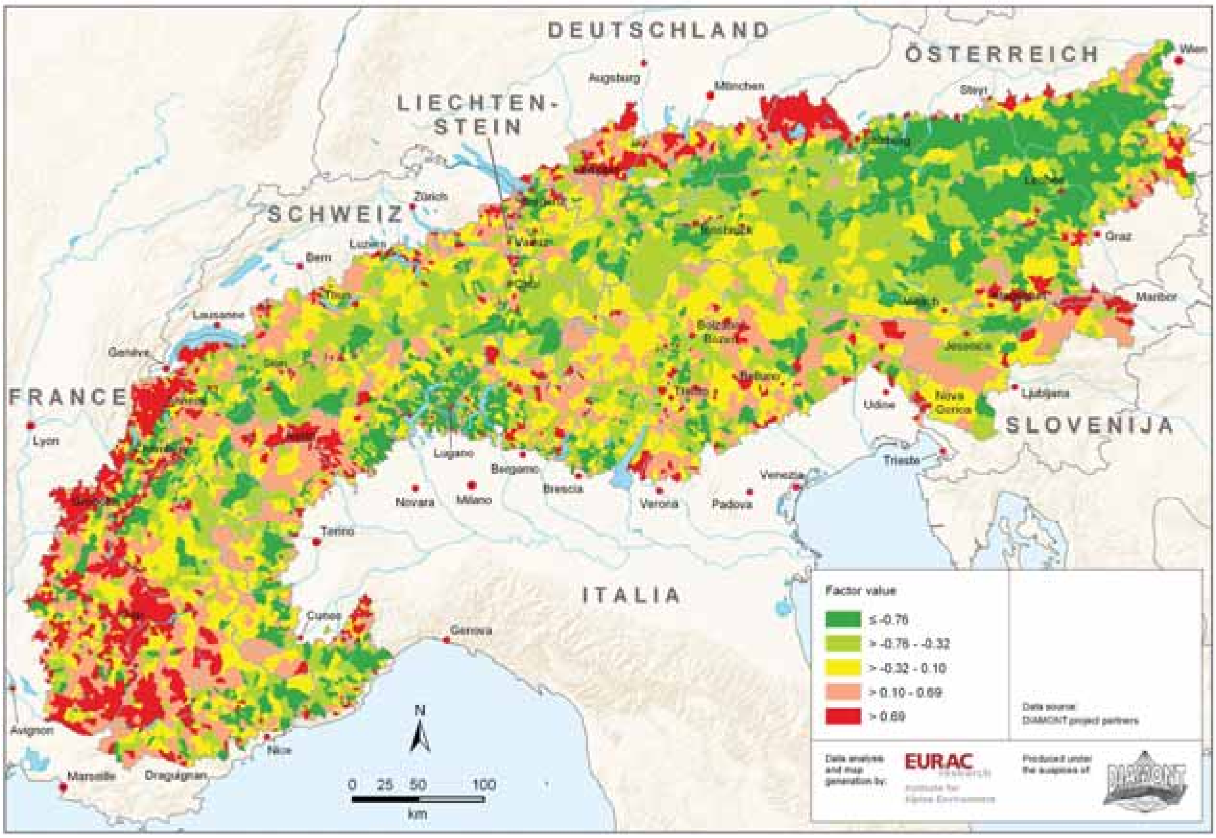

Figure 6. The phenomenon "Cultural landscape diversity" measures the diversity of the mountain landscape (after Tappeiner *et al.*, 2008).

nic influence, whereas on steep sites land-use intensity is low and communities provide high vascular-plant biodiversity (Niedrist *et al.*, 2008; Lüth *et al.*, 2011).

Not surprisingly, the hemeroby-distribution map for the Alpine space shows a rise in values from the Central Alps to the Alpine rim (see Figure 7). Hemeroby indicates the degree of anthropogenic influence on the environment. It takes all human activities into account and is thus an integrative unit (Steinhardt *et al.*, 1999). Types that are unaffected by anthropogenic influences were given a value of 1, non-natural systems a value of 7. Systems without anthropogenic influences include glaciers and virgin rocky areas; a hemeroby value of 7 was applied to industrial areas and densely built-up settlement areas. Within the Central Alps, anthropogenic impact is significantly lower. Here, large areas of the alpine and the nival zones remain natural. On the Alpine rim, but also in the larger Alpine valleys, human pressure on land is much higher. At second glance, hemeroby values also show the current state of agriculture. Many Swiss municipalities return an above average hemeroby-value. This is the result of a very high degree of land use. The opposite is true for the French and the Italian southern Alps. Here agriculture has been abandoned on large tracts of land resulting in low hemeroby values.

A highly diverse landscape is also one of the most valuable ecosystem services in terms of the provision of leisure and recreational activities of a mountain environment. In some parts of the Alps tourism is the main source of income for the local population. Beautiful scenery constitutes a competitive advantage, particularly for summer tourism, and the aesthetic qualities of a region are to a great extent linked to its range of biological diversity. Due to topographic characteristics and large differences in elevation, mountain areas are characterized by a high variety of climatic life zones with small-scale habitats and a wide range of species diversity (Schirpke *et al.*, in preparation). Sustainable agricultural land use contributes to landscape

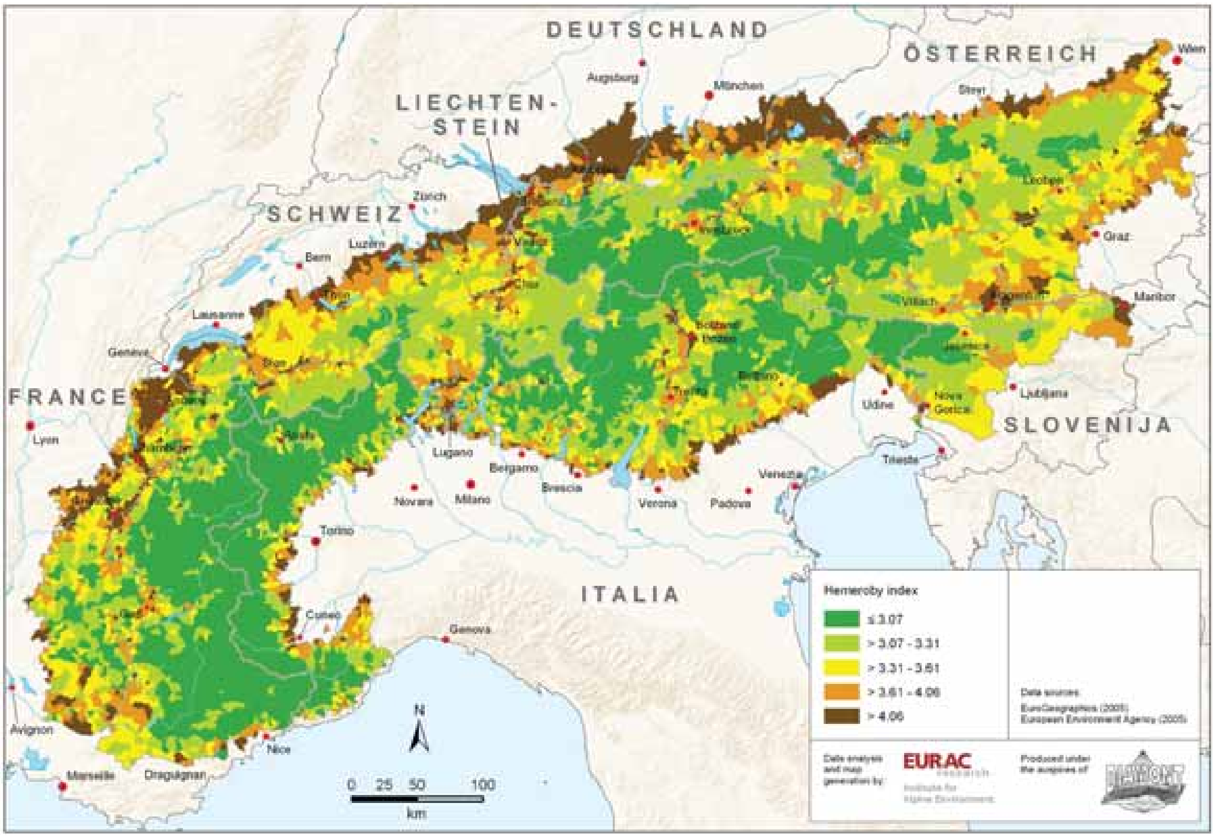

Figure 7. Hemeroby in the Alps: A low hemeroby-value means that natural types of the environment dominate in that municipality, high values point to a municipal area that is mainly shaped by human impact (further details in Tasser *et al*., 2008).

diversity and represents a vital aspect for the cultural heritage of a specific region. However, changes in land use result in altered biodiversity, landscape patterns and functions. Land abandonment leads to natural reforestation and towards more homogeneous scenery. Especially the loss of viewpoints implicates a decrease in the recreational value of the region, and as a consequence, the local economy is subject to changes. Therefore, sustainable management solutions for agriculture and touristic activities are needed to preserve biodiversity assuring the provision of ecosystem services in mountain regions.

Outlook

It has become very important to provide a scientifically based foundation for the decision-making and evaluation of the future development of alpine farming on a local, national and European scale. It is to be expected that special funding for future mountain farmers will be firmly based on the provision of services of social relevance - and then only if society recognises and approves their effort. The non-farming part of the population - especially those from urban regions, though intermediately also increasingly those from the periphery, - no longer acknowledges the mountain agriculture as a benefit for the society. This possibly results in a loss of sympathy for the financial situation of Alpine farmers. For the future, it is important to focus on conveying a broad and sustainable image of the ecological services provided by agriculture, in the hope of improving social cohesion and solidarity among the population. On the other hand, it will also be necessary to help the farmers to recognise and understand the wishes of the society. This would be a great contribution to a sustainable development of the Alpine region.

Acknowledgments

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Climate change and impact on European grasslands

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Abstract

This paper analyses the likely impact of climate change on European grasslands in relation to their present agro-climatic conditions. Such an analysis is an essential part of any assessment of climate change impacts on agriculture given that grasslands are of high importance for agriculture in temperate and humid regions of Europe and they occupy a large proportion of the landscape area (13.2% of total area, or 568 042 km² within the EU27). This paper analyses agro-climatic limitations of grassland production over 12 Environmental zones and then analyses impacts of climate change on grasslands through: i) changes in grassland phenology; ii) changes in grassland yield; iii) changes in botanical composition, and iv) potential effects of extreme events (mainly drought). The projections indicate that grassland production on the European scale is likely to be enhanced rather than hampered by the ongoing climate change. This is mainly because of the improving (or at least not worsening) agro-climatic conditions in northern and north-western Europe. On the other hand, the productivity of grasslands in southern Europe (including higher elevations) is likely to decrease. This can be shown in the case of the southern part of the so-called southern alpine zone (ALS) as this will change its character towards the climate presently experienced in the Mediterranean areas. At the regional scale, the impacts could be much more pronounced as some traditional grassland areas will either become unsuitable for grassland production (unless irrigation is provided) as is likely to be the case in more southern areas, or they will compete less favourably with other more profitable cropping systems.

Introduction

Grasslands are of high importance for agriculture in temperate and humid regions of Europe and occupy a large proportion of the landscape, covering 13.2% of the total area or 568 042 km² within the EU27 (EUROSTAT, 2010). Permanent grasslands are defined in the EU as agricultural surfaces that are under land use for several, usually more than five, consecutive years and are covered by herbaceous forage crops, either naturally (through self-seeding) or through cultivation (sowing). They are not included in the crop rotation scheme of the arable land on the agricultural holding, and can be managed either as pastures with grazing livestock or by mowing for hay and silage. Such grasslands are dominated usually by only a few key species (Beierkuhnlein *et al.*, 2011). The proportion and acreage of agricultural land used as grasslands varies greatly over the EU, depending on topography as well as on climate and soil conditions (Table 1). The distribution of grassland areas over various climates in Table 1 is based on a subdivision of Europe into 12 distinct Environmental zones (Figure 1a) (Metzger *et al*., 2005). Table 1 shows that grasslands tend to dominate the landscape in those regions where they are most productive.

It is obvious that the effect of climate change on grasslands will be region specific, and it will vary greatly with the character of climate change. While increased precipitation and temperature (and thus growing season length) together with higher atmospheric CO_2 concentration are likely to lead to higher yields, the opposite will occur where changes in climate lead to an increased risk of prolonged droughts, as are expected for the Mediterranean area (and according to some estimates also to most of France), Panonian region and Central Europe.

This paper first analyses agro-climatic limitations of grassland production over 12 Environmental zones and then discusses four areas in which grasslands could be affected by climate change through: i) changes in the grassland phenology; ii) changes in the grassland yield; iii) changes in the composition, and iv) potential effects of changes in drought frequency and extreme events. This paper (due to space limitations) considers only the changes of agro-climatic conditions for grasslands at the European level, whilst the regional case studies (in mountain regions of Austria and France) will be included in another contribution in these proceedings.

Table 1. The proportion of arable land and grassland areas in 12 environmental zones (Figure 1a) based on the Corine land cover CLC2000-9/2007 at 100-m resolution (Copyright EEA, Copenhagen, 2007[1]).

EnZ name	EnZ acronym	Total Area (10^6 ha)	Area of land (%) Grassland	Arable	Grassland/ Arable	Grassland Productivity[2] (dt/ha)	Countries in the EnZ[3]
Alpine North	ALN	32.9	4.9	1.9	2.6	40.4	FI, NO, SE
Boreal	BOR	83.1	1.2	3.5	0.3	30.9	BY, EE, FI, LV. NO, RU, SE
Nemoral	NEM	49.7	2.8	11.5	0.2	33.6	BY, EE, FI, LV, LT, NO, PL, RU, SE
Atlantic North	ATN	29.1	29.3	23.0	1.3	74.2	DK, DE, GB, IE, IM, NL, NO
Alpine South	ALS	30.2	18.0	2.3	8.0	32.5	AD, AL, AT, BG, BA, CH, CZ, DE, GR, ES, FR, HR, IT, MK, ME, PL, RO, RE, SI, SK, UA
Continental	CON	124.8	8.1	25.7	0.3	42.9	AL, AT, BG, BY, BE, BA CH, CZ, DE, DK, FR, HR, HU, LV LI, LT, LU, MK, MD, ME, NL, NO, PL, RO, RS, RU, SE, SI, SK, UA
Atlantic Central	ATC	50.6	24.2	35.8	0.7	69.6	BE, CH, DE, ES, FR, GB, IE, LU, NL
Pannonian	PAN	42.1	6.0	43.8	0.1	19.0	AT, BA, BG, CZ, DE, GR, FR, HR, MK, HU, MD, RO, RS, SI, SK, UA
Lusitanian	LUS	19.5	13.0	17.2	0.8	52.0	ES, FR, PT
Mediterranean Mountains	MDM	54.4	4.9	5.3	0.9	21.9	AL, BA, BG, CH, GR, ES, FR, HR, IT, MK, HU, ME, PT, SI
Mediterranean North	MDN	52.4	4.1	24.2	0.2	19.0	AL, BA, BG, GR, ES, FR, HR, IT, MK, ME, PT, SI, TR
Mediterranean South	MDS	56.7	3.4	11.3	0.3	9.2	AL, ES, FR, GR, IT, MT, PT

[1] http://www.eea.europa.eu
[2] Estimated grassland productivity is based on Smit *et al*. (2008).
[3] Countries at least partly included in the zone are identified by internet country code.

Agro-climatic limitations of grassland productivity in Europe

A recent study by Olesen *et al*. (2011) used information from a set of questionnaires distributed to more than 50 agronomy experts across 12 Environmental zones in Europe (Figure 1a). The questionnaire addressed the major limiting factors for grassland production and the importance of various options for adapting to climate change by 2050. The results of the questionnaire indicate that there are major differences between individual environmental zones

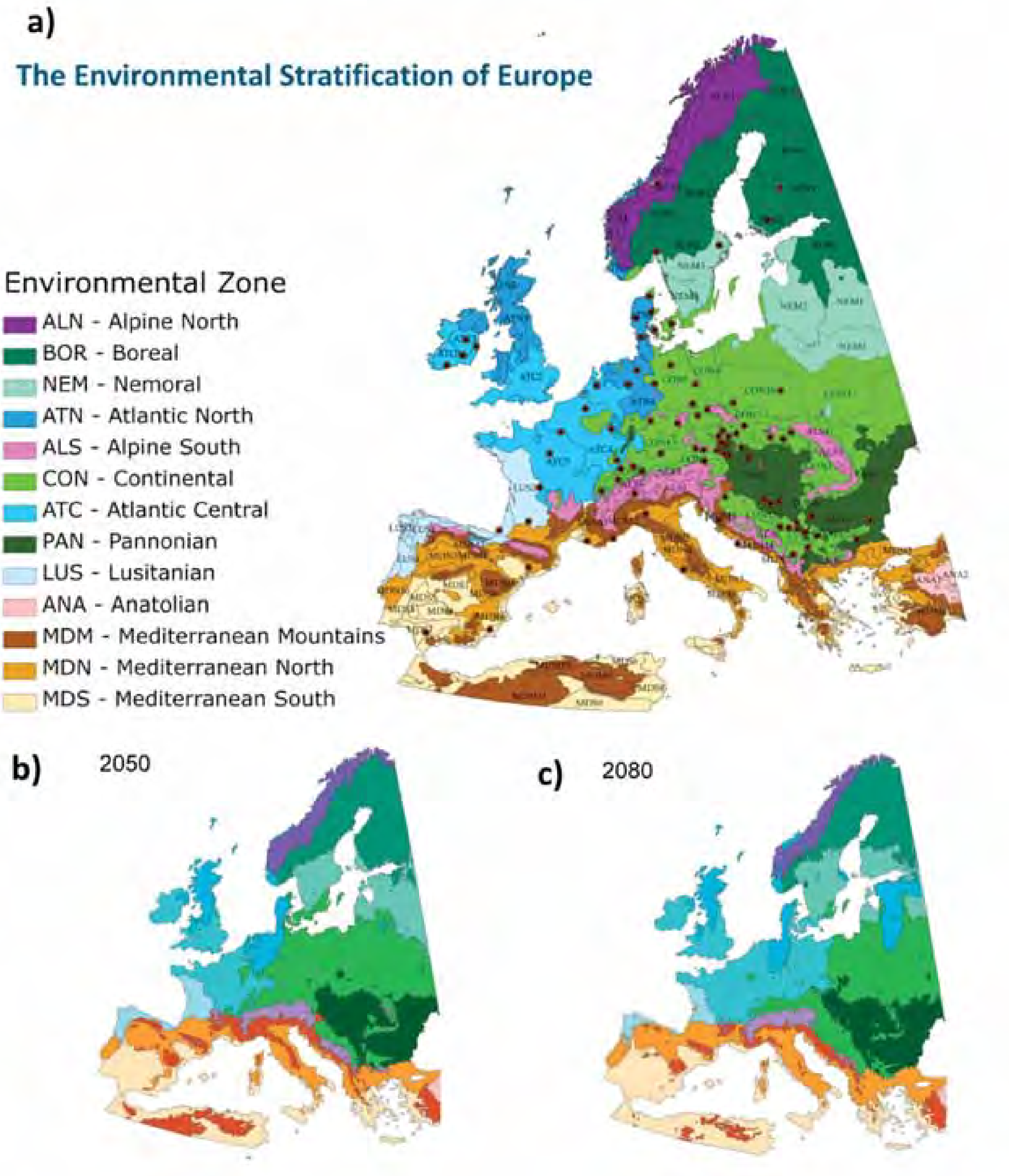

Figure 1. (a) Environmental zones in Europe according to Metzger *et al*. (2005) and Jongman *et al*. (2006) for period 1971-2000 and (b-c) Shifting environmental zones in Europe assuming one climate change scenario (CGCM2 general circulation model; A2 emissions scenario) for 2050 and 2080 according to Metzger *et al*. (2008).

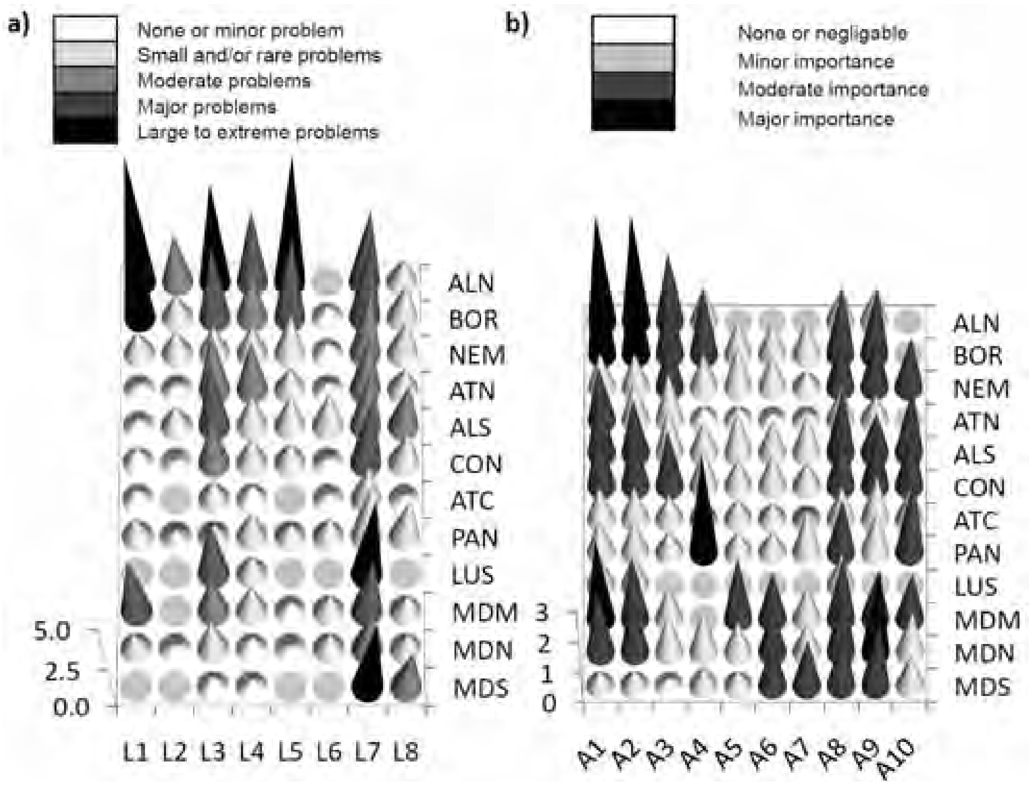

Figure 2. a) Present limitation of grassland production by climate factors: L1 Length of the growing season; L2 Occurrence of late/early frosts; L3 Rain during harvesting; L4 Occurence of floods; L5 Damage during winter; L6 Damage by hail; L7 Occurrence of drought; L8 Heat stress; b) Expected importance of adaptation measures under the expected climate conditions for grassland: A1 Cultivation timing; A2 New tillage practices; A3 Modification to the fertilisation practices; A4 Modification to the crop protection; A5 Introduction of new "climate-proof" cultivars; A6 Soil water conservation practices; A7 Focus on the soil protection from soil erosion; A8 Operational monitoring of pests and diseases; A9 Seasonal agrometeorological forecast; A10 Introduction of the crop insurance. According to Olesen *et al*. (2011).

(Figure 2). The length of the growing season is considerably limiting growth in BOR, ALN and MDM. Damage caused by late frost in spring (or early frost during autumn) are seen as minor limitation in most zones, but high frequency of rainy conditions and floods and water stagnation complicate grassland production across ALN, BOR, ATN and MDM. Overwintering and damage caused to grasslands during winter is considered to be a major problem in ALN and BOR. Hail damage is considered to be a minor problem that occurs rarely and has no detectable effect on regional production. One of the most interesting findings in this survey has been the prominence of drought as a limiting factor. Whilst drought rarely scores as the severely limiting factor it is of concern across all zones. Grassland production seems to be quite substantially limited not only within warm and dry zones (i.e. MDN or MDS) but also in the mountains (MDM and ALS) as well as in the cool and relatively wet zones in the north (ALN, BOR or NEM). For example in Finland drought interferes with grassland establishment and also re-growth after the first cut in each season.

Expected impacts of climate change on grassland phenology

Cleland *et al*. (2006) mentioned that rising temperature in recent decades is associated with accelerated phenology in many plant species (e.g. Parmesan and Yohe, 2003; Menzel, 2000). However, this pattern is not universal, as some species have displayed delayed phenology in recent decades (e.g. Fitter and Fitter, 2002). Cleland *et al*. (2006) monitored the timing of both flowering and primary productivity (estimated by canopy greenness) in an annual grassland ecosystem in response to four interacting global changes: warming, elevated carbon dioxide (CO_2), nitrogen (N) deposition, and increased precipitation. Their results showed that warming caused acceleration of flowering and greening, but elevated CO_2 and N deposition delayed the peak of canopy greenness in the grasses, which dominate primary production in this system. Jentsch *et al*. (2009) focused on flower phenology as a key ecosystem function. They assumed that there may be an analogy between the effects of gradual warming and the sudden drought on flowering dynamics. They used data from two vegetation periods in an experimental setting containing the first evidence of shifted phenological response of 10 grassland and heath species to simulated 100-year extreme weather events in Central Europe. The experiments showed that extreme drought events advance flower onset (the mid-flowering date) and extend the flowering period. Changes in the flowering period were highly significant and uniform over both years of observation. The magnitude of shifts (around 4 days) observed in their data is considerable when compared with findings from long-term observational datasets accounting for gradual warming over recent decades. Memmott *et al*. (2007) mentioned the rate of shifting of first flowering date of plants by 4 days on average in the temperate zone, and other papers also acknowledged that summer drought may result in early flowering (e.g. Franks *et al*., 2007). Bloor *et al*. (2010) studied not only the effect of gradual warming and drought but also the influence of reduction in summer precipitation (by 20%) and increasing of atmospheric CO_2 levels of 600 ppm in 2080. Their two-year experiment showed that during both years the simultaneous application of warming, drought and CO_2 significantly advanced the onset of flowering across species. In agreement with the average response (of elevated temperature, summer drought (-20% precipitation) and CO_2 enrichment), flowering commencement dates at the species level showed stronger response to elevated temperature than to the other single climate-change drivers. This reflects the dominating effect of temperature on phenology. However, drought events (starting usually as periods with lower-than-usual precipitation) are frequently made more severe by higher temperatures because these increase rates of actual evapotranspiration. On the other hand, during drought events latent heat flux is diminished leading to increase in the sensible heat flux and thus temperature. The direct cause of shifts in flowering dates (higher temperature or drought) are thus hard to clearly identify as they reinforce each other (see findings from Jentsch *et al*., 2009).

None of the studied species showed any significant change in flowering onset dates in response to elevated CO_2. These results are in agreement with study of Cleland *et al*. (2006) which show either no response or no clear pattern of response of flowering times to CO_2.The phenological changes in grasslands may thus be expected to be affected primarily by changes in temperature, which will change the temporal dynamics not only of grassland productivity, but also of the quality of the grasslands for forage.

Expected impacts of climate change on grassland yields

Atmospheric CO_2 is the sole source of carbon for plants. Levels of atmospheric CO_2 concentration limit CO_2 assimilation and, for C3 plants, increasing CO_2 concentrations will stimulate photosynthesis (Amthor, 2001). However, stimulation of photosynthesis does not directly translate into increased biomass or yield, which depends also on the length of the active phase of leaf photosynthesis and the sink capacity of grains (Fuhrer, 2003). Kimball *et al*. (2002) found that elevated CO_2 stimulates biomass in C3 grasses by an average of 12%. However, this response is strongly dependent on the N supply. Hebeisen (1997) found that the yield of perennial ryegrass (*Lolium perenne* L.) swards with high N-fertilizer input increased from 8% up to almost 30% after 3 years. Daepp *et al*. (2000) verified that with a low input of N, N-limitation strongly reduced the CO_2-stimulation of dry matter yield in ryegrass swards to below 10% over a 6-year period, as compared to 25% with high N input.

Calanca and Fuhrer (2005) analysed data on Swiss grassland production and its economic value under projected climate change. They used simulation models and climate scenarios by 2050 and 2100. Their simulation suggested that during the course of the 21st century grassland production in Switzerland could potentially benefit from elevated atmospheric CO_2 concentrations and more favourable temperature and radiation conditions. They found an increase of about 50% (of total grassland production) in the case of moderate warming and associated changes in the hydrological cycle. However, they also analysed a so-called extreme scenario, which included the year 2003 (the weather conditions of summer 2003 were extremely hot and dry in the whole of western and central Europe). So they concluded that if changes in the thermal and hydrological conditions were more pronounced, grassland production could increasingly become water-limited and subsequent strategy would be to meet the water requirements with the help of irrigation. This would mean increased production costs. In general, the costs of adaptation to climate change represent a key issue for the economic development of the agricultural sector, particularly if summers with weather such as that of 2003, become more frequent, as is expected (Solomon *et al*., 2007).

Soussana and Luscher (2007) described a Swiss experiment (by Luscher and Aeschlimann, 2006), where the yield response of *L. perenne* to elevated atmospheric CO_2 concentration increased from 0.07 to 0.32 over a number of years under high applications of N fertilizer. They interpreted these increases to be caused by removing N limitation to plant growth through the application of N fertilizer. These results are in line with those mentioned above (Daepp *et al*., 2000). Soussana and Luscher (2007) concluded that results demonstrate that the immediate response of an ecosystem to a step increase in atmospheric CO_2 concentration at the start of the experiment may not represent the long-term response of a grassland ecosystem to a slow increase in CO_2 concentration.

Finger *et al*. (2010) focused on impacts of climate change on yield levels, yield variability and the composition of a typical managed grass-clover system in Switzerland. They concluded that grassland yield will increase under projected climate change only if the benefits of rising atmospheric CO_2 concentrations are taken into account. This is an effect of elevated CO_2 concentrations also reducing plant transpiration and thus improving water-use efficiency of the sward, hence reducing the sensitivity of grassland dynamics to dryness. These results are in agreement with findings from other studies (e.g. Lazzarotto *et al*., 2010; Ruget *et al*., 2010). They also suggested that increases in the marginal productivity of Napplication induced by the CO_2 fertilization might lead to more intensive grassland management (i.e. with higher N application rates) in the future. Without this potential benefit, climate change will lead to less intensive input use and lower grassland yields.

This may imply that the actual impact of elevated atmospheric CO_2 concentrations on grass yields in farmers´ fields could be less than earlier estimates which did not take into account limitations in availability of nutrients and plant-soil interactions (Soussana and Lucher, 2007). However, the responses will depend on changes in grassland composition (between grasses and forbs and between N-fixing and non-N-fixing species) as affected by changes in temperature, droughts and CO_2 concentration.

Another important result of grassland yield simulation studies (Ruget *et al*., 2010), supported by observations, is the progressive worsening of the grassland production gap in the summer, mainly due to moderate to severe drought. Projections of climate-change impact indicate that even in the areas where there is no production gap at present (ATC, ALS or LUS), a production gap will appear byt the end of the century (Ruget *et al*., 2010, Ruget *et al*., submitted to Fourrages). This is of major importance for the livestock feeding schedule and a need will arise to complement feeding in summer by feed reserves (with higher associated costs) during periods when feeding was relatively inexpensive previously.

Expected impacts of climate change on grassland species composition

Hebeisen *et al*. (1997) studied the growth response of two grassland species (*Trifolium repens* L. and *Lolium perenne* L.) to free air CO_2 enrichment and management. They found that under field conditions, *T. repens* and *L. perenne* differed widely in their response to elevated CO_2. The consistent and marked positive of CO_2 response of *T. repens* in monocultures, and the striking increase in the bi-species mixture, was in contrast to the weak CO_2 response of *L. perenne* observed during two years of experimentation. The productivity of *T. repens* was higher in the frequently defoliated swards and was not affected by N fertilization. In contrast, the productivity of *L. perenne* monocultures was higher under infrequent defoliation and increased strongly under the high N fertilization regime. Their study concluded that the management has a great influence on the species proportion of intensively managed grassland communities. As mentioned earlier, grass species will need more N fertilization for higher yield and fitness. In grass-clover mixtures (where legumes such as *T. repens* can obtain N via biological N2-fixation), biological N fixation contributed significantly to the total system N supply, and in systems with lower N-fertilizer inputs, elevated CO_2 may favour legumes and at least in the short and medium term reduce the grass component (Zanetti *et al*., 1997). This may have long term effects on grassland yield potential, if N-fertilization is not carried out or is limited (e.g. in ecological farming). Alkemade *et al*. (2011) found that the most dramatic changes will occur in Northern Europe, where more than 35% of the species composition in 2010 will be new for that region, and in Southern Europe, where up to 25% of the species now present will have disappeared under the climatic circumstances forecasted for 2100. In a field experiment with varying levels of plant species diversity, the biomass accumulation in response to elevated levels of atmospheric CO_2 concentrations was greater in species-rich than in species-poor assemblages (Reich *et al*., 2001). In some studies, grassland communities grown under elevated CO_2 concentrations have displayed higher plant species diversity than controls under ambient CO_2 concentrations (Teyssonneyre *et al*., 2002) but this was not confirmed by Zavaleta *et al*. (2003). In the Swiss FACE experiment, the inter-specific differences in the response to elevated atmospheric CO_2 concentrations resulted in a consistent and significant increase in the proportion of *T. repens* in the binary mixtures at both levels of N supply (Lüscher *et al*., 2005). In the same experiment, and also in the mini-FACE experiment, was observed the effect of more complex mixtures containing other grass, legume and non-legume dicotyledonous species, where the proportion of legumes was significantly higher at elevated atmospheric CO_2 concentrations (Ross *et al*., 2004). Hibbard *et al*. (2001) reported that grassland may also be endangered by invasion of woody shrubs and, in warm humid climates, by invasion of C4 grassland species. Increased atmospheric CO_2 concentrations are predicted to favour C3-species over C4-species, whereas higher temperatures will favour C4-species.

Expected impacts of climate change on grassland relevant extreme events

Heat waves, floods, droughts and wildfires in particular are expected to become even more frequent and intense than was expected some years ago, with alarming consequences for terrestrial ecosystems (Beierkuhnlein *et al*., 2011). Stampfli and Zeiter (2004) studied the regeneration ability of grassland after extreme drought in a 13-year study. They observed species-rich, semi-natural meadow in three 4-year cycles, which were represented by different climate conditions: the first period was characterized by increasingly dry conditions, which was then followed by a period after extreme drought, and finally the period with increasingly wet conditions. Results showed that during the period following the extreme drought the most abundant species decreased and species with low cover increased. During the dry and wet periods they did not observe any changes in cover. Drought influenced the community composition shortly after the drought had ended and when the graminoid individuals had died and were replaced by forb species (in general the community was more open to colonization after the drought). During a drought, as the weather conditions get drier, plant growth decreases, but the community composition remains stable. However, the community composition is affected by the regeneration following the drought. Such changes from extreme drought can persist after the drought. Other studies have reported similar reductions in variables but no persistent change in major vegetation components (e.g. Willis *et al*., 1995). Tilman (1993, 1996) mentioned that biomass in a prairie grassland returned to pre-drought values within one year and the decrease in C3 versus C4 grasses and species richness were reversed within 5 years. Beierkuhnlein *et al*. (2011) explored the mechanisms for understanding the preservation and adaptation of common European grassland ecosystems to climate change, especially to the warming and extreme drought. They focused on plant traits related to ecosystem productivity, i.e. biomass and necrotic tissue. They used local ecotypes of four grassland species in Germany and other European ecotypes with almost similar climate conditions and the grass species were cultivated there. All species responded significantly to drought (necrotic tissue occurred mainly in the drought treatments and drought-warming treatments). Their results indicate that European managed grassland might be prone to strong fluctuations in biomass production, as was also reported for the drought of 2003 (Ciais *et al*., 2005).

Weißhuhn *et al*. (2011) investigated the drought response of nine common grassland species (in a greenhouse experiment), which are normally utilized for restoration of mesic grasslands. The results showed that drought influenced each species differently. Experimental drought generally reduced total biomass but this effect varied among species. Drought also reduced the allocation to below-ground biomass measured as root mass fraction (RMF), but again species differed in the degree of this reduction. Contrary to the hypothesis that drought stress should stimulate root growth (Asseng *et al*., 1998), they found reduced root biomass in seven out of nine species. However, root allocation was generally not correlated with changes in total biomass.

Changes in the agro-climatic zones and impact on grasslands across Europe

Figure 1b shows that considerable changes in the environmental zones may be expected in the 21st century, in particular for ALS and MDM, which will be reduced by 53% and 30%, respectively (Metzger *et al*., 2008). While most of ALS will be transferred to CON zone, a considerable part will change to MDM and MDN zones with significantly lower productivities (Table 1). On the other hand, a considerable area of the CON zone will change to ATC and ATN zones that under present climate conditions have the highest grassland productivity. However, the simple transposition of environmental zones using works of Metzger *et al*. (2005, 2008) is not possible as, while the zones (as depicted at Figure 1b) have similar cloud cover and precipitation profiles as under the present climate, they will all be 2 °C warmer (Metzger *et al*., 2008) than nowadays with all the discussed impacts of such change on phenology or water-stress levels.

Olesen *et al*. (2011) used the present distribution of environmental zones as a means to divide Europe in order to assess possible impacts of climate change on five selected crops. These included winter wheat, spring barley, grain maize, grapevine and grasslands, and the grasslands were estimated to be least affected by climate change. In all zones growth duration is expected to increase especially in ALN, BOR, NEM, ATN and ALS. In the same time, damage during winter and those caused by frosts are expected to decrease and the number of days suitable for harvest is thought to increase (but mostly slightly) in all zones except ALN. Only marginal negative impact is expected from hail occurrence, soil erosion, nitrogen leaching and weed occurrence, with a notable exception of ALN, where some of these parameters are changing to the worse. However, drought and changes to seasonal climate variability are expected to cause negative impacts across all zones with quite significant effect on ALN, BOR, NEM, ALS, CON, PAN and LUS zones. In the mountain zones (ALS and MDM) heat stress might become more severe on the southern slopes, even without water stress. While this is a typically 'small scale' issue, it often is not taken into account as the large scale assessments (e.g. Trnka *et al*., 2011 or Olesen *et al*., 2011) do not consider fully this topographical effects on microclimate. This is also partly true for soil erosion.

Interestingly, according to Olesen *et al*. (2011) the magnitude of changes (both positive and negative) is thought to be highest in the northernmost zones (ALN, BOR and NEM) with only small changes expected to grassland production in Mediterranean (LUS, MDM, MDN and MDS). Analysing six out of twelve environmental zones with considerable grassland cover (or high grassland/arable land ratio) it is evident that three represent mountain regions (ALN, ALS and MDM) and three maritime climate conditions (LUS, ATC, ATN). We will now concentrate on the former group.

Trnka *et al*. (2011) found that the ALN zone may expect the greatest increase in the number of effective growing days and in 2050 the increase may reach the present agro-climatic conditions of the ALS. Due to the high latitude of the ALN zone, the relative increase in the effective global radiation will be negligible. Overall, the agricultural potential of this zone is likely to improve (Figure 3). However, this is marginal in a European context due to the relatively small acreage of agricultural land in the zone (Table 1).

Environmental Zone	Effective global radiation change (%)			Effective growing days change (days)			Hugin index change (%)			Date of the last frost change (days)			Proportion of dry days in AMJ change (%)			Proportion of dry days in JJA change (%)			Proportion of sowing days - early spring change (%)			Proportion of sowing days - fall change (%)		
	E	H	N	E	H	N	E	H	N	E	H	N	E	H	N	E	H	N	E	H	N	E	H	N
ALN	3	6	7	15	16	25	12	16	19	-5	-6	-8	0	0	1	-2	-2	-2	5	7	7	0	2	2
BOR	3	4	7	13	11	17	12	23	14	-4	-6	-4	-2	0	-1	-2	1	-6	4	5	5	3	4	5
NEM	4	5	4	14	9	20	12	22	13	-5	-5	-5	2	1	1	0	4	-3	5	5	6	5	6	7
ATN	0	0	3	7	3	17	11	15	11	-5	-7	-8	-1	-1	-3	7	11	3	4	3	5	3	3	4
ALS	0	1	3	4	2	8	12	16	10	-6	-9	-6	-1	-2	-2	6	9	3	5	5	3	4	4	5
CON	-3	-3	1	-1	-2	5	11	16	11	-4	-7	-5	-1	-1	-2	9	11	4	4	4	4	4	4	5
ATC	-2	-3	1	0	-4	7	11	16	10	-6	-9	-8	-3	-3	-6	9	14	5	2	3	3	2	1	3
PAN	-15	-11	-8	-18	-13	-9	11	15	10	-5	-6	-5	2	2	0	17	16	10	3	3	2	2	3	4
LUS	-9	-9	-3	-21	-21	-6	12	16	10	-6	-7	-6	4	5	3	22	23	8	3	2	1	2	2	3
MDM	-10	-7	-3	-10	-7	-3	12	15	10	-2	-3	-2	6	7	4	14	13	7	4	3	2	2	2	2
MDN	-10	-7	-2	-11	-5	-3	9	12	8	-24	-23	-20	8	6	3	9	7	4	2	1	1	1	-1	2
MDS	-15	-14	-7	-14	-10	-6	8	12	8	-10	-11	-11	8	8	5	1	1	1	-3	-2	-1	-5	-3	0

Figure 3. Changes in the median values of selected agro-climatic indicators relative to the 1971-2000 reference period for 2030, assuming the A2 SRES scenario and a medium climate system sensitivity (according to Trnka *et al*., 2011). The grey color shading represents negative impacts of these changes and the values represent the medians of all of the sites in a particular zone. The estimates are based on three GCM models, i.e., the ECHAM (E), HadCM (H) and NCAR (N).

The potential productivity in ALS is at the higher end of all zones (Trnka *et al*., 2011) as the frequency of drought is very low, even during the summer months. The effect of climate change was estimated to be neutral to slightly positive, indicating slight increases in variability and mean sum of effective radiation and in the mean duration of effective growing days. There was, however, a marked increase in projected days with water limitation during summer and in variability of summer drought threatening productivity of permanent grasslands. This is in fact one of the largest concerns in the eastern and southern parts of the Alps (Eitzinger *et al*., 2009). Generally, in the more humid parts of ALS zone (e.g. northern part of Alps), an increased grassland biomass production potential can be expected. For arable crop production, similar effects have been projected in recent studies (e.g., Eitzinger *et al*., 2009) with increasing crop yield potential via the introduction of higher-yielding and later-ripening cultivars (e.g., maize) or new crops (e.g., soybeans and sunflower). The scenario expecting a mean global temperature increase of 5 °C tested by Trnka *et al*. (2011) would, however, lead to partial deterioration of productivity even in the ALS and ALN zones.

For the MDM the change of climate conditions would have negative effects on the productivity which is opposite to the ALN and ALS, where the overall net effect is expected to be positive. In the MDM zone the proportion of dry days for the periods from April to June and June to August is expected to increase considerably for the MDM zone as shown also by Iglesias *et al*. (2010).

The assumed adaptation (Figure 2b) responses (Olesen *et al*., 2011) put emphasis on changes in timing of grassland work as well as modification to the fertilisation practices. In the case of ALS and MDM, wider use of seasonal agrometeorological forecast and introduction of the crop insurance is considered important. Another available adaptation option is the change from grassland to arable farming by growing fodder crops for the animals. This would, however, increase CO_2 release from soils and reduce organic contents (affecting the climate-change mitigation targets) and could increase soil erosion as well. Especially within ALS or MDM this option could be applied only at a limited scale, depending on soils and topography.

Conclusions

The projections up to the mid 21st century indicate that grassland production on the European scale is likely to be enhanced rather than hampered by the ongoing climate change. This is mainly because of the improving (or at least not worsening) agro-climatic conditions in northern and north-western Europe. On the other hand the productivity of grasslands in southern Europe is likely to decrease. This can be shown in the case of southern part of ALS zone as this will change its character towards MDM and MDN zones. On the regional scale the impacts could be much more pronounced, as traditional grassland areas will either become unsuitable for grassland production (unless irrigation is provided) as this is likely to be the case of the more southern areas or they will compete less favourably with other more profitable cropping systems.

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Annex I

Table I.1. Scale used for scoring present limitations of crops to climatic conditions (Figure 2a).

Score	Explanation
NA	Not applicable (e.g. crop not grown)
NI	No information
0	No problem
1	Minor problem, occurs rarely, no detectable effects on regional production
2	Small problem, occurs sometimes, small and rare effects on regional production
3	Moderate problem, occurs occasionally, small effects on regional production
4	Major problem, occurs frequently, moderate effects on regional production
5	Large problem, occurs almost every year, major effects on regional production

Table I.2. Scale used for scoring how much different adaptation options would contribute to change in cropping systems (Figure 2b).

Score	Explanation
NA	Not applicable (e.g. crop not grown)
NI	No information
0	None
1	Minor
2	Moderate
3	Large

Oral Presentations

Operating limits to mechanisation in mountain areas

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Abstract

Previous studies suggested that a gradient of 35% is the operating limit for a standard tractor on sloping terrain. In recent years individual farmers reported working on steeper slopes with modern tractors. These statements prompted a reassessment of operating limits. On-site data surveys were carried out on farms in Switzerland, and practical experience gained on a total of 46 farms was collected and evaluated. Data on the use of two-axle mowers, transporters and tractors were recorded. Operators rated the operating limits of their machines within a wide range. By using suitably equipped tractors with front-mounted mowers a gradient of 44% could be established as the median of the steepest slopes. The range of these maximal slopes was 38 to 52%. Two-axle mowers can safely be navigated to a gradient of 48%. They require less engine power than a comparable tractor. The operating limits for tedding, turning and windrowing were 3 to 5% higher than for mowing. The absolute gradient of a slope is not the only factor determining the limits for operational use. The effects of other parameters such as contours, soil characteristics, the presence of escape routes and site development are also decisive.

Keywords: operating limit, mountain area, tractor, two-axle mower, slope

Introduction

Previous studies relating to tractor-operating limits for hillside forage harvesting give a maximum gradient of 35% (Ott, 1979; Handler and Wippl, 2003; Handler and Wippl, 2004). Expensive specialist machines like two-axle mowers and transporters are suggested for steeper slopes with gradients of between 60 and 65%. Technical discussions and media reports (Burkhalter, 2004) have shown that tractors can also navigate steeper slopes than previously assumed. The aim of the present study was to update the principles underlying current operating limits on hillsides.

Methods

Studies of operating limits were carried out on 46 farms in northern, eastern and central Switzerland. The mechanisation used in the processes of mowing, tedding, windrowing and loading was recorded with the associated machine parameters (rating and track width). Based on experience, the farmers in the study highlighted critical locations where they felt that mechanisation was hitting the operational limit. The gradient at these locations was measured using the Clinotronic Plus inclinometer (Wyler AG, Winterthur, CH) over a two metre test section. The range of results is shown as a box plot. A two sample t-test with a confidence interval of 0.95 was used to check significance.

Results and discussion

For each harvesting process the median was calculated as the operating limit.
The operating limits recorded on the farms are shown in Figure 1. The results show considerable variation in the farmers' statements. A 44% gradient was calculated as the operating limit

when mowing with a tractor. Two-axle mowers were able to negotiate steeper areas with a 48% gradient (*P* < 0.05). Significantly different operating limits for tractors and two-axle mowers (*P* < 0.05) were also found for tedding. For tedding tractors were used at a gradient of 47%, with two-axle mowers able to reach a median of 52%. The results for windrowing showed no significant differences between tractors and two-axle mowers (*P* = 0.08). For windrowing tractors operated at gradients of 49%, in extreme cases up to 57%. Two-axle mowers were used at gradients of 52%. Forage gathering using transporters and forage wagons was carried out at 47 and 45%, respectively, in locations which were slightly less steep than for the other harvesting steps. No significant differences were shown (*P* = 0.07).
The wide variations in results are due to the fact that gradient is not the only limiting factor on operation. This is also affected by rugged terrain, the inability to turn or find an escape route at the steepest points, the botanical composition of the sward, soil characteristics (moisture, texture) and the driver's willingness to take risks (Noto and Sauter, 2006). On very moist soils the sward is destroyed more quickly by the tractor tyre profile. Dry soils lead to faster slippage, as the lugs of the tractor tyres cannot mesh with the hard ground. Mowing is the most critical step in forage harvesting because of high moisture levels in grass and soil (risk of skidding). The width of access routes is also important when selecting mechanisation.

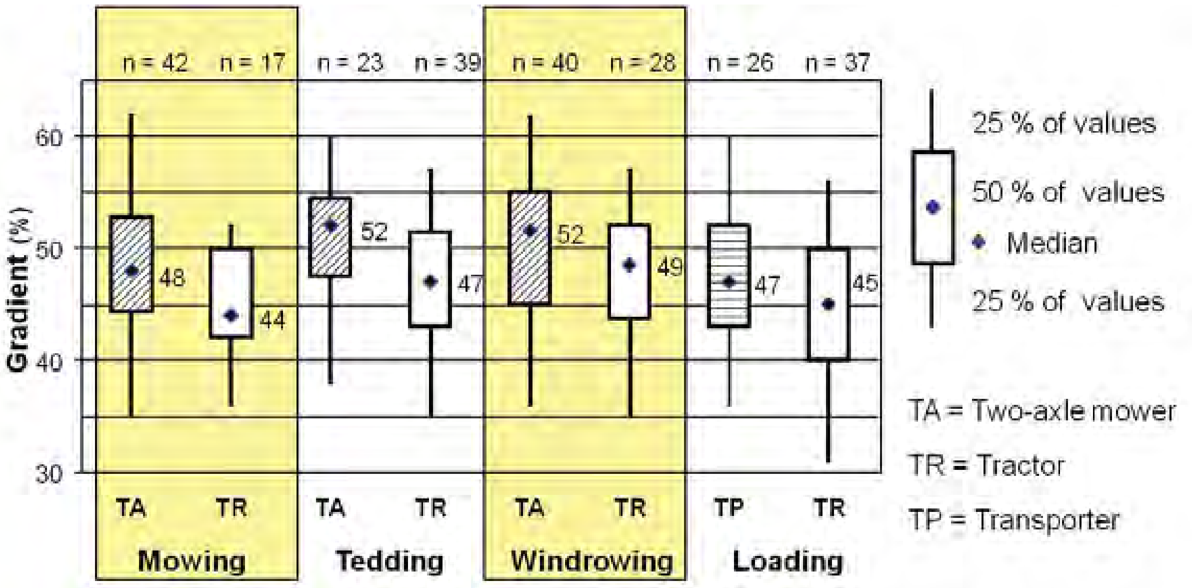

Figure 1. Operating limits of two-axle mowers, tractors and transporters on different harvesting processes (n = number of replications).

Wippl and Handler (2002) cite an operating limit of between 60 and 65% for two-axle mowers. In isolated cases such extreme values occurred in the present study as well. Because of their hydrostatic drive, low centre of gravity and light unladen weight, these vehicles can navigate steeper plots than a tractor. Farms with two-axle mowers often use a belt rake for windrowing. The centre of gravity of a belt rake, unlike that of a rotary windrower, is closer to the tractor, which improves driving safety. Belt rakes also have the advantage of being able to operate in both directions of travel, thus obviating the need for dangerous turns on the hillside.
Tractors require significantly (*P* < 0.05) greater engine power by comparison with two-axle mowers (Table 1). The average rating of the tractors investigated was 54.8 kW, while that of the two-axle mowers was 30.6 kW. This is because of the tractor's greater vehicle weight and wider track, which calls for the use of a wider mower. The wider track is due to the fact that tractors have to be fitted with dual tyres in order to compensate for the higher centre of gravity

compared with a two-axle mower. In order to avoid driving over unmown material the front mowers used must project beyond the width of the vehicle. Mowers with a 3 m working width are often used in tractor combinations. Two-axle mowers are frequently equipped with mowers having cutter bars of 2.2 to 2.5 m working width. Previous studies have shown that a tractor suitable for hillside applications can only be driven on a gradient of up to approximately 35% (Ott, 1979; Ott, 1996). The reasons for this difference are more compact design, four-wheel drive, four-wheel braking, more powerful engines and dual tyres. Side cutters have been replaced by front mowers, which reduce the risk of tipping over, particularly when turning.
As a rule, loading by forage wagon takes place on more level ground than other jobs. This is often achieved by deliberately placing the windrow on flatter terrain. On steeper slopes and under unfavourable soil conditions transporters are generally driven on the fall line. According to Wippl and Handler (2002) it is possible for transporters to drive on the contour line up to a gradient of around 45%, the operating limit being approximately 60% on the fall line, figures which tally well with the present study.

Table 1. Comparison between tractor and two-axle mower in terms of operating limit gradient at mowing, machine width and engine power ($\bar{x}$ = mean, *sd* = standard deviation).

	Gradient (%)		Machine width (m)		Engine power (kW)		Replicates
Mechanisation	$\bar{x}$	*sd*	$\bar{x}$	*sd*	$\bar{x}$	*sd*	*n*
Two-axle mower	48.4	6.65	2.15	0.26	30.65	10.28	42
Tractor	44.7	5.18	2.54	0.13	54.80	8.84	17
P-value (t-test)	< 0.05	-	< 0.05	-	< 0.05	-	

Conclusions

Factors such as rugged terrain, access routes to plots, the driver's risk-averseness, soil characteristics and botanical composition influence the maximum operating limit of machines. The operating limits tend to be lower when mowing, as at this time the ground is moist and slippery. Compared with previous studies the operating limit of tractors used for mowing has moved from a 35% gradient to one of 44%.

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Patterns of land use and ownership and their influence on pasture quality in the mountains of northern Spain

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Abstract

The extensive livestock systems of a mountain valley were defined integrating spatial information on the vegetation of pastoral value, land ownership (common and private) and livestock use (grazing and mowing). The results reflect the importance of common pastures, constituting half of the total forage production and hosting the major plant communities of high environmental value. However, the prevalence of shrub communities with low pastoral value, and the significant presence of *Senecio jacobaea* and *Pteridium aquilinum*, reflecting processes of degradation, undermines the productive capacity of the resource. In privately owned grasslands, high productivity and intensive use found close to the villages contrasts with the degradation processes caused by reduction of use observed in less-accessible areas.

Keywords: common land, extensive livestock farming, abandonment, grazing, mowing, burning

Introduction

Extensive livestock farming has traditionally been the main activity modelling mountain landscapes of northern Spain by means of a local transhumance involving private and common lands. In the last few decades noticeable changes in these systems (Puente, 2002) have frequently produced land degradation with serious ecological and socioeconomic repercussions (Busqué *et al*., 2006). In this paper we quantify the current productive and ecological value of the forage resources of a representative mountain valley of this region. We relate these to patterns of land use and ownership, identify recent changes and suggest some ideas to be addressed for the future planning of livestock farming in our mountains.

Materials and methods

The Tudanca valley, with an area of 5240 hectares, is located in the European Atlantic biogeographical region. Its climate is characterized by average annual temperatures of 12ºC and annual rainfall above 1000 mm, without significant dry periods. Its strong altitudinal gradient, between 300 and 1500 m a.s.l, combined with a varied geology, with the presence of Jurassic limestones alternating with sandstones and conglomerates of the Lower Cretaceous, define a complex mountain landscape with heterogeneous plant productivity. Beef cattle and horses for meat production are the main economic activities, with a total of 27 farms that concentrate 806 cows and 306 horses.

The spatial distribution of three variables of livestock interest has been analysed using a Geographic Information System (GIS): vegetation (type, productivity and environmental value), livestock use (mowing and grazing) and land ownership (private and common). From the definition of 43 plant functional types, a vegetation map at a scale of 1:20000 was produced using photo interpretation and a recent national land-use cartography (SIOSE, 2005), resulting in 161 homogeneous units. The cover of functional types in each unit was visually estimated in the field and subsequently aggregated in nine types of herbaceous and five types of shrub plant communities (Figure 1). An average annual productivity was assigned to each community using various sources (Busqué *et al*., 2006; Fillat *et al*., 2008), with values ranging from 1000 to 5000 kg DM ha^{-1} yr^{-1}. Habitat conservation value was evaluated depending on their inclusion in Council Directive 92/43/EEC. Types of ownership were obtained from the Land Registry, while the main livestock use was verified in the field.

Results and discussion

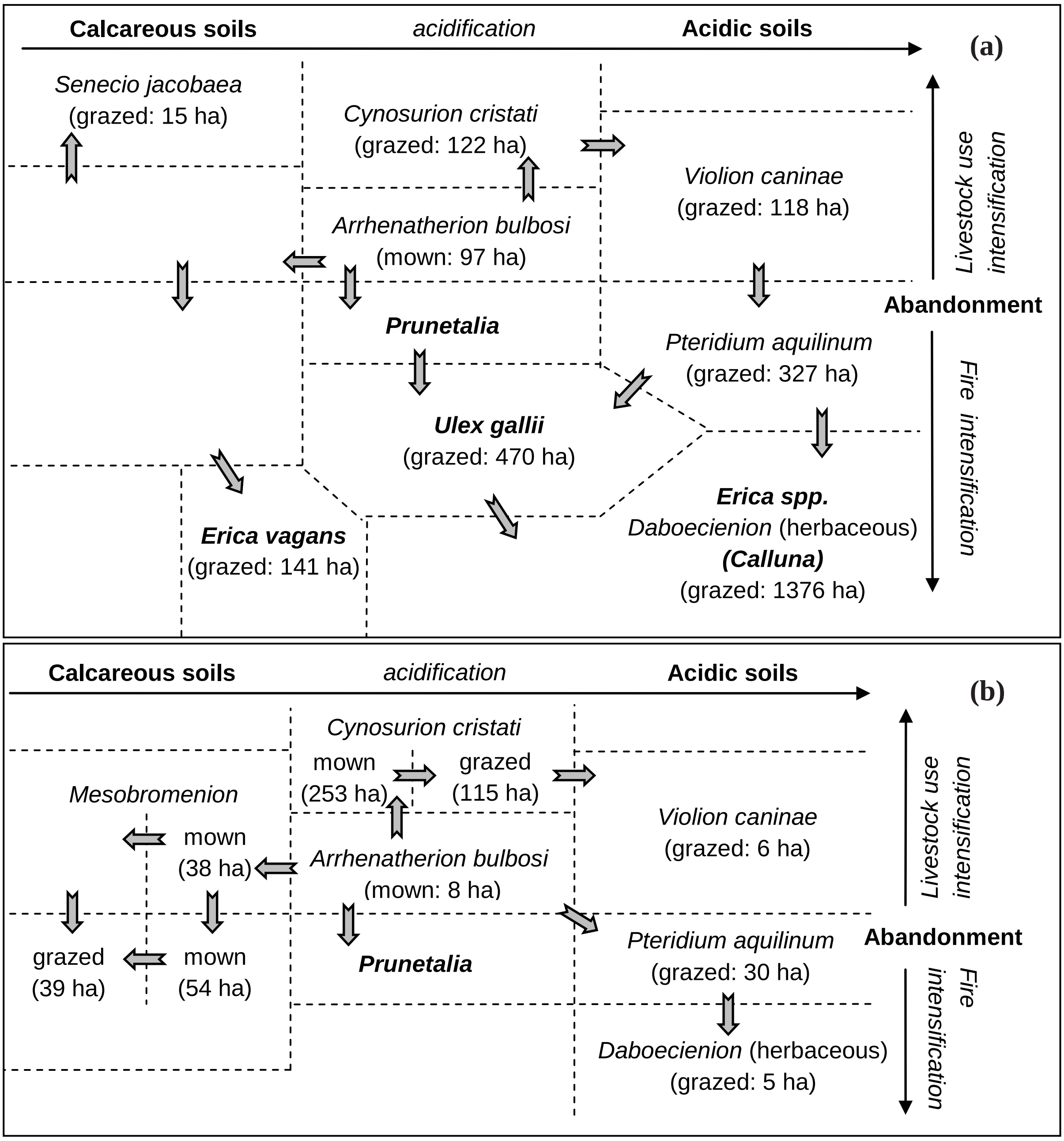

Figure 1. Models and area occupied by the pasture vegetation of the commons (a) and private land (b) as affected by the gradients of soil acidification, livestock use and fire intensification. Arrows indicate the most frequent changes. Communities in bold are shrub dominated and those in brackets are located at higher altitudes.

Common pastures represent 85% of the total area eligible for livestock use (Figure 1a). Most are shrub communities (76%) of low forage value, indicating the low current importance of the commons as pastoral land. Of these, more than half is occupied by heath species (*Erica* spp.) on degraded soils favoured by inappropriate use of burning and the strong decline in the numbers of sheep, goats and cattle of local breeds with high browsing capacity (Osoro *et al*., 1998). However, from the environmental point of view, these heath communities are priority habitats at European level, mainly due to their scarcity in North Atlantic Europe. The rest of the shrub communities, resulting mainly from recent abandonment of grazing, maintain good soil productive capacity and are easily reversible to grasslands or other forestry uses. One-quarter of the grasslands in the commons are hay meadows that are harvested once annually in late summer by all the farmers after mowing their private plots. Late harvests, absence of fertilization, limestone substrate and grazing in spring and autumn, result in the dominance of a grassland community rich in forbs (*Arrhenatherion bulbosi*), with high biodiversity, but regionally becoming rare due to land use changes (Fillat *et al*., 2008). The rest of the grassland area is shared equally between the most productive and fertilized (*Cynosurion cristati*), and those of moderately productive but higher environmental value, both on limestone (*Mesobromenion* and *Potentillo-Brachypodenion*) and on acid substrate (*Violion caninae*). The colonization of certain plant species in some areas indicates degradation processes caused by inappropriate management. *Senecio jacobaea* in *Mesobromenion* grasslands reflect an intense and out-of-season grazing, while the predominance of *Pteridium aquilinum* or *Brachypodium pinnatum* is due to the abandonment of pastoral use in previously productive grasslands (Fillat *et al*., 2008). In private grasslands (Figure 1b), the maintenance of the highly productive meadows close to the villages (mown *Cynosurion*) contrasts with the different degrees of abandonment in the management of the more remote and less accessible properties (35% of the total area). The transformation from mown to grazed-only grasslands is producing two degradation processes: the colonization by *P. aquilinum* or *B. pinnatum* and the deterioration of an important cultural heritage, stone walls and stone and wooden buildings for animal shelter and hay storage (Corbera, 2010).

Conclusions

At the valley scale, forage production is similar in the commons and in the private land, reflecting that the community resources are still important for the current farming systems. Most of the feed requirements of the existing livestock in the valley could in theory be supported by the forage produced internally. Our current research is focused on the analysis of the management bottlenecks that hinder the achievement of this goal. We think there is an urgent need to develop participatory management plans and to redesign the current subsidy schemes in order to prioritize the production of quality livestock goods based on the sustainable use and improvement of local resources.

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Managing the summer alpine pastures in a context of recurrent droughts

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Abstract

Since 2003, livestock farming systems using summer pastures in the French Alps have faced several droughts. A survey was conducted among 35 livestock farmers and shepherds in the Vercors Massif aiming at a better understanding of their perception of drought consequences on pastoral activities and on the way they adapt alpine pasture management. The following modes of adaptation were observed: decrease in grazing pressures (stock numbers and time spent on alpine pastures), increase in the grazing area allotted to animals (new sections of grazing land) and better use of the existing resource (through shepherds' technical know-how and new equipment). We identified five main types of adaptation, depending on the initial level of forage resources used, both on the alpine pastures and on the farmstead. Pastoral management requires flexibility, particularly since other environmental and heritage issues as well as constraints (predation…) also have to be taken into account.

Keywords: alpine pasture, drought, pastoral farming, adaptation

Introduction

Since 2003, a part of the French Alps has been subjected to a series of droughts of unusual severity. Often associated with heat waves, the droughts have resulted in a decrease in the pastoral resources available for animal feed stocks, sometimes going as far as to jeopardise the renewal of resource if practices were not adjusted. The livestock farmers and shepherds had therefore to react to these droughts (Nettier *et al*., 2011). In this paper, we look at the manner in which farming practices have been modified on alpine pastures, and propose a typology to characterise the diversity of adaptation modes.

Materials and methods

Our study concerns 17 areas of alpine pastures in the Vercors massif (French Prealps), chosen for the diverse ways in which they are used: sheep, cattle, or mixed grazing; permanent or non-permanent shepherding; collective or individual herds; local stockbreeders or transhumant farmers of the Mediterranean regions.

Between 2008 and 2010, thirty-five livestock farmers and shepherds, users of the 17 alpine pastures, were surveyed (semi-direct interviews) with a view to gaining insights into their perception of the droughts and the way in which they have adapted their management practices: grazing technique, configuration of the alpine pastures (Girard *et al*., 2001) and coordination in the use of alpine pastures and other areas near the farm.

Results

We established a typology based on expert knowledge, using criteria such as availability of forage resources, changes in grazing management practices and transfers from alpine pastures to the farm area. We identified five types of adaptation to drought (Table 1).

Table 1. Types of adaptation in management of alpine pastures

Type	Number of alpine pastures	Availability of forage resources according to livestock farmers: in a ‚normal year‘	in a dry year	Adaptation of grazing management practices	Coordination in use of farm and alpine pastures: transfer of grazing pressure from alpine pastures to farm
1	4	Complete consumption of resource	Resource insufficient to feed herd	Yes	Structural transfer as emergency measure from 2003
2	3	A little surplus	Not quite enough to ensure the renewal of resource for the following years	Yes	Structural transfer, from 2004 or 2005
3	4	A little surplus	Not quite enough to ensure the renewal of resource	Yes	Only in the driest years
4	5	Surplus	Almost completely used, with renewal of resource not compromised	Yes	No adaptation at this level
5	1	Surplus	Resource surplus	No	As and when required, reverse transfer (from farm to alpine pastures) in dry years

Before the drought years, the management of alpine pastures varied from completely grazed areas to standing herbage on reserve sectors at the end of the summer. These contrasting initial situations were confirmed by comparing the needs of the herds with the estimates of forage resources made during pastoral assessment. They led to different types of adaptations to the drought. Without reserve sectors, Type-1 farmers adopted emergency measures as early as the drought of 2003, and then modified their operations in anticipation of future droughts. Thanks to a little standing herbage, Type-2 farms did not need to adopt emergency measures but nevertheless decreased the pressure on the alpine pastures in the following years so as to avoid deterioration of the resource. In a similar situation, the Type-3 farmers, who had fewer possibilities for grazing on their farms in summer, made temporary adjustments during the driest years. For Type-4 farmers, a simple adjustment in grazing management was made, given that the alpine grazing resources seemed sufficient, even in dry years. As for the Type-5 alpine pasture, which is oversized in relation to needs, it serves as stand-by resources for farms in dry years.

An adaptation of grazing management is the first measure implemented on all the alpine pasture areas where there is almost no surplus, or a lack of forage resources, in a dry year (Types 1 to 4). Shepherds use their know-how: (1) on a daily basis, by choosing grazing sectors in function of the weather, and by exploring remote zones; (2) during the mountain pasture season, by grazing each range allotment at the appropriate time; and (3) from one year to the next, by preserving the reserve sectors during wet years and by fertilising (night paddocks) less-productive environments.

In the case of flexibility at the farming-system level, farmers can also adapt the way in which the use of alpine pastures is coordinated with that of the farm (transfer up to 35% of Livestock Unit Grazing Days): by temporary (Type 3) or structural decreases (Types 1 and 2) in the time spent on alpine pastures (it concerns 9 of the 17 alpine pastures studied; animals are brought down early or taken up late) and/or in the herd numbers taken up (only 4 alpine pastures).

In addition, in the study sample, during the 2003-2010 period, improvements were observed in the configuration of six alpine pastures, aimed at increasing the resource or at consuming it better (extending the pasture area, improving water reserves, or constructing huts on distant range allotments). Although such developments are more frequently observed in Types 1 and 2, they depend mainly on the opportunities available to farmers (areas available, subsidies).

Discussion and conclusion

The measures adopted depend on the grazing management before 2003 (presence or not of reserve sectors, for example), on the capacity of the farmers to preserve stand-by resources on their farms in summer, and also on the opportunities of improving the grazing areas. Livestock farming systems must also deal with other hazards (volatile prices of farm inputs and products, uncertainty about subsidies, predation by wolves, etc.). The shepherd management results from a compromise between different concerns (sectors vulnerable to predators, sectors subject to environmental issues with late grazing, etc.). Following the example of Darnhofer *et al*. (2010), we show that being able to demonstrate considerable flexibility is a necessary asset for achieving sustainability over the medium term.

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Herbage selection and landscape utilisation by suckler cows on a sub-alpine pasture

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Abstract

In many Alpine countries, the use of mountain pastures for cattle is in decline, thus favouring the development of shrubs in these areas. The objectives of this study were to assess the herbage selection and landscape utilisation by suckler cows on a pasture located at 1,800 m a.s.l., and covered by 31% of shrubland and forest. Vegetation surveys were performed during the first rotation to determine the browsing frequency of each herbaceous plant species. In addition, four cows were monitored by Differential Global Positioning System (DGPS) for a period of 3 to 5 days during each rotation (three in total).
The botanical observations showed that the largest consumption of herbaceous plants was not necessarily among those known to be the most palatable. Among woody species, cattle willingly browsed young branches of green alder (*Alnus viridis* (Chaix) DC.). As long as the height of these plants did not exceed 1.5 m, a grazing intensity of 70 LU days ha^{-1} was sufficient to prevent their expansion. The GPS monitoring showed that the animals roamed all areas of the plot, even in zones of high shrub density. The vegetation types known to be of low forage value were heavily visited by cows early in the season.

Keywords: *Alnus viridis*, mountain pasture, vegetation dynamics, GPS tracking, herbage selection, grazing intensity

Introduction

The cessation or the reduction of pasture grazing leads to an alteration in the botanical composition of grasslands and to encroachment. Thus, numerous summer pastures in the Alps have become increasingly overgrown by *Alnus viridis*. This pioneer species competes very well on the deep and nutrient-rich soils. Due to the symbiotic nitrogen fixation, it is often associated with tall nitrophilic herbs. Freléchoux *et al*. (2007) described the secondary succession pathways and the loss of species diversity that occur in the case of pasture abandonment. However, the effects of browsing on the growth of green alder have been rarely investigated and little is known about plant selection by grazing livestock in shrubby alpine pastures. The intention of this study was (i) to describe the herbaceous plant selection by the cows, (ii) to assess the effects of frequent browsing on *Alnus viridis*, and (iii) to define the relationship between the vegetation mosaic and the spatial distribution of cattle.

Materials and methods

The experiment was conducted between 2005 and 2007 on a summer pasture located in the canton of Valais (Switzerland), at 1,800 m a.s.l. The herd was comprised of 9 dry cows and 9 lactating cows with their calf (‚Hérens‘ breed). Cattle were managed in a rotational system, with two or three utilisations per season. The observations took place in two paddocks (about 2.5 ha each) located on the northern slope of the pasture. Botanical composition and herbage

selection were determined according to the method of Daget and Poissonnet (1969), along sixteen transects distributed among the two paddocks. The relevés were made in 2006 during the first rotation, two or three days after the animals began to graze. At each contact point, the hit species were recorded as ‚browsed‘ or ‚not browsed‘. Based on these data, the relative frequency in the herbage and the proportion among all consumed plants was calculated for each species. The selection index (SI) for the different species was then obtained by dividing the percentage in the consumed herbage by the percentage in the available herbage. To assess the effect of repeated browsing on green alder trees, thirty-nine of them were marked in two distinct zones and plant height and canopy area were measured over the three-year period.
The GPS tracking was conducted in 2007 in one of the two paddocks for a period of three to five days over each of the three rotations. Four animals (two lactating and two non-lactating cows) were fitted with a customized GPS tracking harness. After each observation period, the data were downloaded onto a PC and differentially corrected using virtual reference stations (VRS). The GPS data were crossed with a simplified vegetation map by means of a geographic information system (GIS). Four main vegetation types were considered: tall herb community, open pastures, half-open pastures and shrubby areas dominated by *Alnus viridis*. Lastly, the presence index (PI), defined as the ratio between the occupation time in a vegetation unit (in % of total recording time) and its surface (as % of total surface), were calculated. The statistical analysis of the PI was performed with SYSTAT 12. The analysis was made with a linear mixed-effects model (LME) using maximum likelihood procedures (REML).The raw data were log-transformed to reduce heteroscedasticity. A first analysis was run with a complete model, in order to test the significance level of the different factors. Three additional analyses were then performed and the non-significant terms successively removed (‚rotation‘, ‚cow‘ and interaction ‚cow‘×‚vegetation type‘). Finally, a simplified model using only the factors ‚vegetation type‘ and the interaction ‚vegetation type‘×‚rotation‘, was retained.

Results and discussion

Vegetation in the sixteen transects was dominated by forbs (44%) and graminoids (44%). Overall, the most-eaten herbaceous plants were the graminoids (SI of 1.3), followed by forbs (0.8) and legumes (0.7). These results confirm the major contribution of graminoids to the nutrient supply of the cattle. The relatively low SI of the legumes can be explained by the small size of the encountered species, primarily *Trifolium repens* L., *T. pallescens* Schreb. and *T. badium* Schreb., which would have protected them from selective grazing. The most-eaten herbaceous plants were not those known to be the most palatable. Thus, the highest selection indexes were observed for *Leontodon hispidus* L. (1.9), *Agrostis capillaris* L. (1.4), *Festuca rubra* L. (1.4), *Luzula sylvatica* aggr. (1.3), *Anthoxanthum alpinum* Á. & D. Löve (1.3) and *Chaerophyllum villarsii* W. D. J. Koch (1.3). Conversely, *Veratrum album* L. (0.1) and *Trollius europaeus* L. (0.1) were, not surprisingly, the least-eaten plants. The method used in the present study proved to be useful in making comparisons between species or functional groups. However, it is important to bear in mind that these values depend heavily on the botanical composition and the developmental stage of the plants.
Repeated browsing of the green alders resulted in a weakening of the shrubs, by diminishing their height as well as their canopy area (Table 1). Their localisation in the paddock had no influence on the results. In this study, a grazing intensity of 70 LU days ha^{-1} proved to be sufficient to prevent scrub expansion. The grazing, however, only impacted the small shrubs. When the bushes exceeded 2.0 m in height, the expansion process was not reversible: the cattle are too small and the growth of the alders too fast.

Table 1. Evolution of the height and the canopy surface of the green alders after repeated browsing. ANOVA with repeated measurements; n = 39.

	Year			Significance		
	2005	2006	2007	Year	Zone	Y × Z
Height (cm)	122	119	109	***	ns	ns
Canopy area (m²)	0.40	0.43	0.32	***	ns	ns

*** $P < 0.001$; ns = non significant.

The presence indexes (PI), calculated on the basis of the GPS-monitoring, are presented in Figure 1. The tall herb community was heavily visited early in the season (June), when the quality of the forage was still acceptable. This remains a hypothesis, nevertheless, since it is difficult to infer grazing activity from occupation time with exactness. The main selected species in this vegetation type were *Poa chaixii* Vill. and *Peucedanum ostruthium* (L.) W. D. J. Koch. The PI of the open zone were significantly higher than the average value. This is mainly due to the presence of many appreciated species (e.g. those mentioned above) but also to the fact that the resting places in this area were over-represented. The half-open pastures remained attractive during the entire season. Typical cattle-feeding patterns showed an alternation between herbaceous plants and young branches of small green alders. The shrubby areas dominated by *Alnus* were the least visited of the four areas.

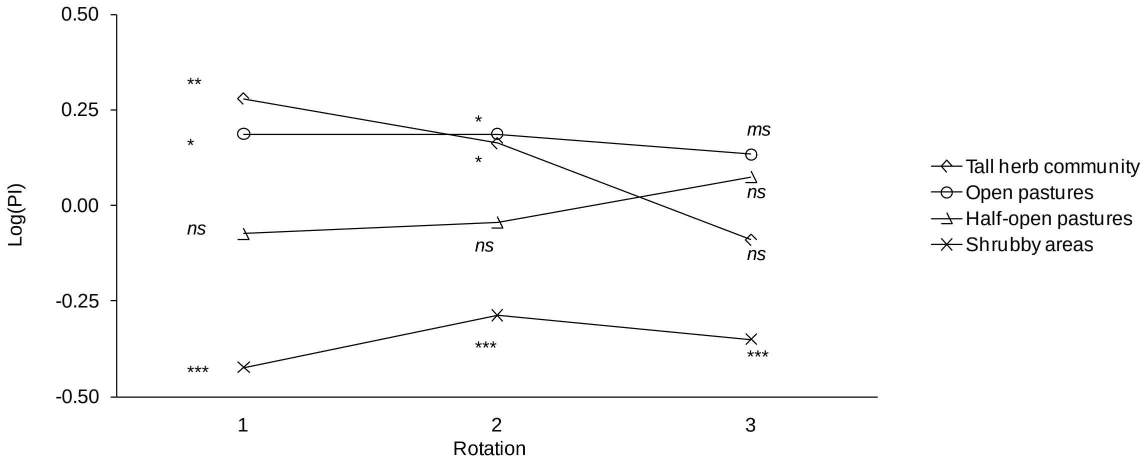

Figure 1. Effect of the vegetation type and the rotation number on the presence index (PI). The data have been log-transformed. The zero value corresponds to the mean occupation time. The values significantly different from zero are indicated on the graph; ns not significant; ms $0.05 < P < 0.1$; *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

Conclusions

The results confirmed that the selection process in shrubby subalpine areas is important. Cattle consume a large spectrum of plants. New light of the reforestation process in terms of cattle feeding opportunities have been gained from this investigation.

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A physiological approach to reduce population densities of *Colchicum autumnale* L. in extensively managed grasslands

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Abstract

In parts of Germany, high densities of toxic *Colchicum autumnale* in extensively managed grasslands cause problems in hay marketing. As a solution to reduce population densities, early mowing is indicated in the literature. However, opinions on the best date for leaf removal differ between authors. In contrast to other studies, we use a physiological approach, suggesting mowing when nutrient contents are high in above-ground plant parts and low in the storage organ. To this end, we assessed nutrient content in above- and below-ground biomass during one vegetation period. Every ten days from April until June 2009, a sample of 15 plants was collected from each of three German *C. autumnale* populations within one biogeographical region. Plant parts were analysed for N, P, K, and starch. As the plant corm is renewed every year, old and new corm were both analysed. Nutrient content in the above-ground biomass increased until the beginning of May; in the old corm most nutrients decreased until the same time, while nutrients in the new corm increased steadily. Our results suggest an optimal mowing in late April/early May to reduce plant density.

Keywords: Meadow saffron, resource depletion, starch, mowing date, segmented regression analysis

Introduction

In parts of Germany, high densities of toxic *Colchicum autumnale* in extensively managed grasslands cause problems in hay marketing. Consequently, there is a risk of management intensification or abandonment and the loss of valuable, high-diversity habitats. Under extensive management, *C. autumnale* profits from its extraordinary life cycle. At the beginning of the vegetation period, storage reserves of the corm are mobilized for leaf growth. Shortly thereafter, new storage reserves are built up in a new corm which gradually replaces the old corm. As a solution to reduce population densities, leaf removal is recommended, but opinions on the best time for management differ between authors (Stebler and Schröter, 1981; Briemle and Elsässer, 2008). Therefore, the aim of this study was to determine the optimal point for weakening the plant through mowing. In contrast to other studies, we used a physiological approach: to determine the best mowing date, we identified the point of time when nutrient contents are high in above-ground plant parts and low in the storage organ.

Material and methods

In 2009, every ten days from April until mid-June, which is the common first mowing date of the investigated grassland sites, a sample of 15 plants (each with three leaves and one capsule) was collected from each of three German *C. autumnale* populations in the biogeographical region Vorderer Vogelsberg (altitude: 180 m). Plants were separated into three fractions: above-ground parts (leaves plus capsule) and two storage organs, i.e. old and new corm. For each fraction, plants from the same population were pooled. Corms were halved, one part of corm halves and the leaves plus capsule were dried at 60°C, weighed, finely ground and analysed for concentrations of nitrogen, phosphorus, and potassium. The other corm halves were freeze-dried, weighed, ground, and analysed for starch concentration, as starch is the major storage compound in *C. autumnale* (Frankovà *et al*., 2003). Concentration of total phosphorus was analysed by the Vanadate-Molybdate-method, that of potassium by atomic absorption spectroscopy, and nitrogen concentration by a CNS analyser. Starch concentration was determined applying a starch-UV-test kit (Boehringer Mannheim GmbH/R-Biopharm). Nutrient concentrations were converted into amounts per plant part before statistically analysis. Data were analysed by segmented regression analysis (SRA; with SegReg v. 2010 by Oosterbaan, http://www.waterlog.info/segreg.htm - access 21.02.2011).

Results and discussion

In above-ground plant parts, temporal changes of nutrients were best described by a segment with a positive slope, followed by a horizontal segment (Table 1).

Table 1. Results of segmented regression analysis of *C. autumnale* (*n* = three populations) collected at 10-day intervals from April until mid-June. BP = breakpoint, n.a. = not analysed, ft = function type, hs = horizontal followed by sloping segment, l = single linear segment, sh = sloping followed by horizontal segment.

Plant fraction	Nitrogen			Phosphorus			Potassium			Starch		
	BP	*P*	ft	BP	*P*	ft	BP	*P*	ft	BP	*P*	ft
Leaves+capsule	28.IV	<0.001	sh	11.V	0.002	sh	27.IV	<0.001	sh	n.a.		
New corm	21.IV	<0.001	hs	-		L	01.V	<0.001	hs	-		l
Old corm	28.IV	<0.001	sh	10.V	<0.001	sh	28.IV	0.003	sh	-		l

Nitrogen and potassium content increased until the end of April (N given as example in Figure 1a), phosphorus content almost until mid-May. The quantities of nutrients in the new corm increased linearly to exponentially, whereas they decreased exponentially in the old corm (Figure 1b). Therefore, quantity changes of most nutrients in the old corm were characterized by a decreasing and a horizontal segment. Nitrogen and potassium reserves were mostly exhausted until the end of April, phosphorus reserves until the 10th of May. In contrast, starch content decreased steadily but was already low at the first sampling date, as the largest part of starch content is hydrolysed at the end of autumn when leaves develop underground (Franková *et al*., 2003). In the new corm, there was a steady increase of phosphorus and starch content, while nitrogen and potassium content only increased in the second half of April and the beginning of May, respectively. The major storage compound in *C. autumnale* is starch, contributing up to 50% of corm dry weight, followed by proteins with up to 22% (Franková *et al*., 2003; 2006). Thus, when judging storage reserves, emphasis should be given to starch and nitrogen content. From this point of view, reserves of the mother corm are mostly exhausted by the end of April, while storage reserves in the new corm start forming at the beginning or middle of April, suggesting the end of April as the point of lowest total storage reserves. Our results are in accordance with observations from other authors. Godet (1987) reported a large decrease of dry weight until the beginning of May in the old corm, and a fast increase of dry weight in the new corm from about mid-March. Franková *et al*. (2003) found that the largest part of starch content in the old corm was used up until the end of April, although starch reserves were not exhausted before mid-June.

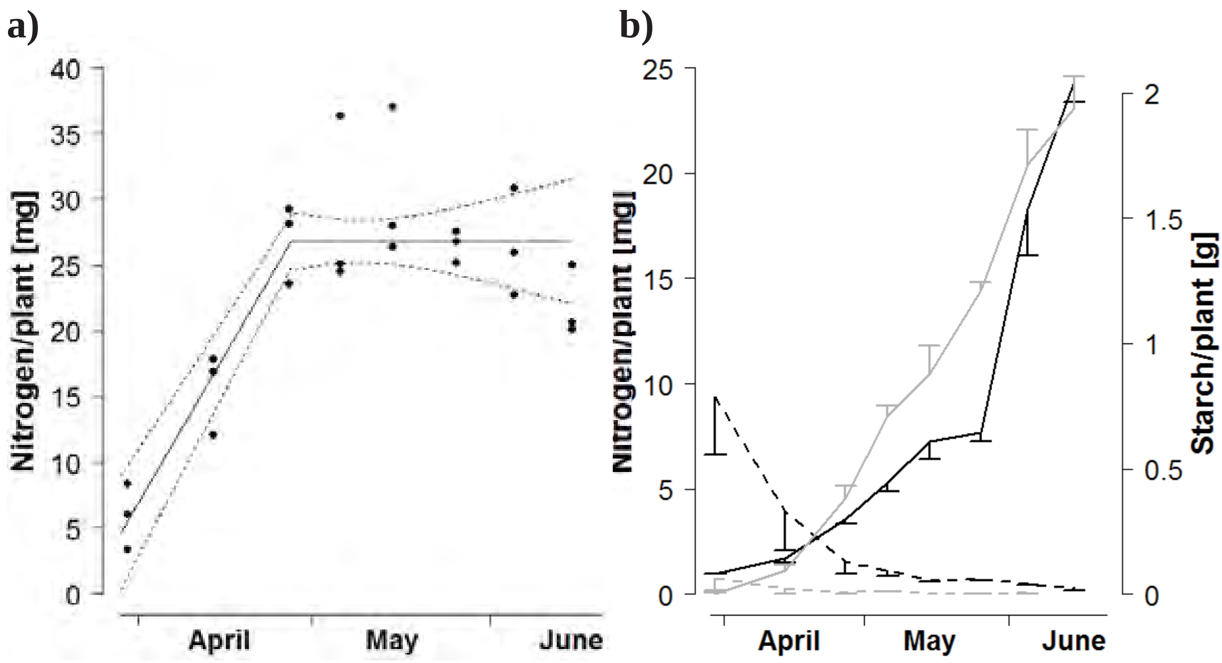

Figure 1. Temporal change of nutrient contents in *C. autumnale* (*n* = three populations) from 30.3. 15.6.2009. a) Graphical result of segmented regression analysis for nitrogen content in above-ground parts with 95% confidence interval, and b) mean of nitrogen (black line) and starch content (grey line) ± SE in storage organs, continuous line = new corm, broken line = old corm.

Besides being the point of lowest storage reserves, the end of April was also the point after which nitrogen and potassium content in leaves showed no marked increase. Under the given climatic conditions, we thus conclude that the removal of leaves and capsules of *C. autumnale* at the end of April or very beginning of May leads to the largest reduction of plant resources, and thus vitality. At the indicated date, average plant height was 25.7 ± 3.7 SD and capsules were visible, their top being located at 8 10 cm above ground.

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Poster presentations

Edaphic factors and mineral composition of *Cynosurus* pastures in the Cantabrian Mountains

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Abstract

Soil properties and mineral compositions were determined in *Cynosurus* pastures in 12 mountain passes located in western, central and eastern zones of the Asturian Massif. In June and July of 2008, 10 samples of vegetation plus 10 soil samples (depth 20 cm) were collected at each mountain-pass site, at altitudes of 700-720 m. Macronutrient concentrations in the pasture were measured and the implications for herbivores were evaluated. The concentrations of Ca and K in plant samples from the central zone, and of Ca in plant samples from the eastern zone, were adequate for herbivore requirements. The vegetation was deficient in the other minerals analysed (N, P and Mg), and the Ca:P ratios were imbalanced, except in the pasture in the two mountain passes in the western zone. Significant correlations between soil and plant Ca, K and Mg suggest that plant levels of these nutrients can be satisfactorily predicted from their concentrations in the soil. However, other significant and negative correlations indicated that factors such as availability of P and high levels of extractable Al may affect absorption of these elements by plants.

Keywords: animal requirements, foliar nutrients, mountain pastures, soil properties

Introduction

Cynosurus pastures are found in Eurosiberian mesophitic grasslands that penetrate the areas of heaviest rainfall and occupy soils that do not completely dry out in summer; the main species are *Cynosurus cristatus*, *Trifolium repens*, *Festuca rubra*, *Agrostis capillaris* (Díaz and Fernández, 1994). These pastures can provide fodder at amounts of 2.5 to 4.8 Mg DM ha^{-1} y^{-1} (Oliveira and Afif, 2010). An essential aspect in the sustainable use of grasslands, i.e. the achievement of states in which conservation and exploitation are compatible, is to maintain adequate levels of nutrients in vegetation and soil in the long term (Gómez-Sal, 2001). There is very little available data on the mineral status of soil and plants or the relationships between these in mountain grasslands. The objective of the present study was to evaluate the influence of edaphic factors on the mineral composition of *Cynosurus* pastures in several mountain passes in the Cantabrian Mountains.

Materials and methods

The data corresponded to 12 communal mountain passes, located in the western, central and eastern zones of the Asturian Massif in the Cantabrian Mountain range, where mainly cattle and sheep livestock are grazed. The climatic and topographical characteristics of the selected mountain passes are shown in Table 1. In each mountain pass, at altitudes of between 700 and 720 m and with a northeast orientation, a Dutch auger was used to obtain 10 soil samples from a depth of 0-20 cm. In the same mountain areas, 10 *Cynosurus* pasture samples were collected in June and July 2008, by use of a square metallic frame of 0.25 m^2 surface area. Soil and plant analyses were carried out according to Pansu and Gautheyrou (2006) and Jones *et al.* (1991).

Table 1. Mean annual temperature (T), mean annual precipitation (P), Thornthwaite potential evapotranspiration (PET) and some topographical characteristics of the 12 mountain passes under study. Zones: Western (W), Central (C) and Eastern (E).

Nº	Zone	Mountain pass	Slope %	Altitude M	T ºC	P mm	PET mm
1	W	Acebo	30	975	9.70	1210	772
2	W	Rañadoiro	18	1181	8.25	1595	610
3	W	Cerredo	22	1359	8.26	1934	495
4	W	Leitariegos	28	1525	6.44	1552	497
5	C	Somiedo	17	1250	9.40	1108	639
6	C	Ventana	26	1587	8.39	1238	585
7	C	Angliru	22	1570	9.20	1426	527
8	C	Cubilla	20	1336	6.30	1613	633
9	E	San Isidro	24	1520	7.45	1432	594
10	E	Tarna	20	1360	5.60	1372	564
11	E	Baeno	20	1140	9.15	1814	718
12	E	Áliva	29	1466	8.50	1850	766

Descriptive statistics (averages and standard deviations) were calculated to summarize foliar and soil data. Pearson's correlations were used to examine the linear relationships between foliar and soil nutrients (SPSS, 2009).

Results and discussion

The soils in most of the study area are shallow (0.25-0.84 m), strongly acidic (pH: 3.9-5.8), have moderate contents of organic matter (3.7-8.2%), are enriched in nitrogen, with low C:N ratios (5.8-24.9), and have low contents of exchangeable base cations, in accordance with the properties usually displayed by highly acidic grassland soils in cold, humid mountainous areas (Acero *et al.*, 2002). The textures of the soils from the western zone are mainly sandy loam and silt loam, so that these soils are notably more permeable than those in the central and eastern zones, which are clay and clay loam soils. The available P extracted with Mehlich 3 reagent was below the level considered as critical for this extractant (< 30 mg P kg^{-1}) (Mehlich, 1985). Similar deficiencies, particularly in P and extractable bases have been observed in acid mountain soils under pasture in Spain (Alonso and Garcia, 1997). The mean concentrations of five macronutrients were lower in the plant samples from the western zone than in plant samples from the other areas (Table 2). The concentrations of foliar Ca and K in the central zone and foliar Ca in the eastern zone were within the ranges considered normal for upland communities (Alonso and García, 1997). The foliar N:P ratios in the pasture community were lower than 10, so that these nutrients were clearly balanced, except in four mountain pastures (two in the western and two in the central area) in which the ratio was higher. However, foliar Ca:P ratios were imbalanced, according to McDonald (2006), except in two mountain passes in the western zone (Ca:P = 1.4). All foliar macronutrients analyzed in the western zone were deficient as regards the nutritional requirements of livestock (Table 2), whereas Ca and K were adequate in the central and eastern zones according to the results observed in mountain grassland communities in the Cantabrian mountains (Alonso and García, 1997). The positive correlations between the foliar levels of Ca, K and Mg, and the extractable Ca, K and Mg in the soil ($r = 0.78^{**}$, $r = 0.61^{*}$ and $r = 0.87^{**}$, respectively) suggest that foliar levels of these nutrients can be satisfactorily predicted from their concentrations in the soil, although other factors such as availability of P and high levels of extractable Al may affect absorption of these elements by plants (Tisdale *et al.*, 1993; McDonald, 2006).

Table 2. Mean concentrations (in mg g^{-1}) of nutrient elements in the plant material (standard deviations are shown in brackets) and adequate mineral requirements for cattle and sheep, according to Grace (1983), in terms of the concentrations in grasslands.

	Concentration					Foliar relationships	
Nº	N	P	K	Ca	Mg	N:P	Ca:P
1	6.20 (0.61)	2.21 (0.54)	2.67 (0.15)	5.95 (0.68)	0.51 (0.05)	2.81	2.69
2	34.39 (1.76)	2.76 (0.49)	3.95 (0.51)	3.88 (0.53)	0.37 (0.03)	12.46	1.41
3	4.72 (0.14)	1.30 (0.18)	2.08 (0.61)	1.84 (0.65)	0.99 (0.22)	3.63	1.42
4	20.53 (1.56)	1.42 (0.27)	2.94 (0.21)	3.10 (0.66)	1.26 (0.25)	14.45	2.18
5	25.80 (2.31)	2.67 (0.56)	4.14 (0.36)	7.93 (0.38)	0.42 (0.07)	23.13	2.97
6	19.69 (0.98)	2.71 (0.20)	8.11 (0.46)	7.72 (0.76)	1.29 (0.31)	7.26	2.85
7	14.82 (0.37)	2.23 (0.34)	5.20 (0.26)	10.30 (0.74)	1.72 (0.25)	6.65	4.62
8	33.99 (2.57)	1.47 (0.25)	7.36 (0.77)	7.70 (0.92)	1.75 (0.62)	23.12	5.23
9	11.38 (1.28)	2.73 (0.26)	7.66 (0.41)	8.63 (0.54)	1.45 (0.14)	4.16	3.16
10	11.19 (1.20)	2.15 (0.25)	3.07 (0.07)	1.40 (0.33)	0.82 (0.16)	5.20	0.65
11	13.23 (2.14)	1.64 (0.19)	7.65 (0.61)	9.78 (2.35)	1.15 (0.17)	8.07	5.96
12	14.76 (0.57)	1.99 (0.15)	3.08 (0.14)	4.80 (0.40)	0.96 (0.11)	7.42	2.41
Cattle	-	3.2	5.8	4.4	1.9		
Sheep	-	2.0	3.6	2.9	1.2		

Conclusion

The data presented suggest that some soil properties may be limiting factors for plant growth in the grasslands under study. The concentrations of exchangeable cations were lowest in the acidic soils from the western zone. Analysis of the mineral composition of the mountain grasslands revealed deficiencies as regards the nutritional requirements of animals, although foliar Ca and K were adequate in the central and eastern zones. The significant correlations between soil properties and nutrient concentrations in pastures suggest that foliar nutrient levels can be satisfactorily predicted from nutrient concentrations in the soil.

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Differences in persistence in red clover cultivars as an important trait for their use in permanent grasslands

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Abstract

Red clover increases herbage quality and production of temporary and permanent grasslands at low fertilization requirements, but its main disadvantage is its insufficient persistence. Once the plants in the second or third harvest year disappear, the remaining grass sward needs more nitrogen fertilizing, overseeding or renovation. Hence the breeder's effort is focused on improving persistence of new red clover cultivars. In this trial the dry matter (DM) production and proportion of eight tetraploid and fourteen diploid cultivars of red clover grown in mixture with grasses were assessed. The highest DM forage yield in the third harvest year was reached by Swiss cultivars Astur, Milvus and Pavo, followed by the German cultivar Lucrum and Christie (Canada). The ratio between the yields in the 3rd and 1st harvest year is another indicator of cultivar persistence. The highest ratio was realized with Astur (1.13), followed by Pavo (94.0) and Lucrum (93.6). The productivity and persistence of tetraploid cultivars did not differ from diploids. Considering the differences in persistence among cultivars of red clover, the most persistent cultivars should be preferred for grassland mixtures.

Keywords: Red clover, persistence, cultivars, forage yield

Introduction

Red clover was introduced in the European agriculture approximately 1000 years ago in Andalusia, Spain and from there its cultivation spread to other countries (Kjaergaard, 1994). Before the discovery of synthetic-N production in 1909 by Haber, the main source of nitrogen for agricultural crops was symbiotic fixation by legumes. The production of synthetic N fertilizers markedly increased after World War II, which resulted in a rapid shrinkage of red clover cropland in Europe and North America (Taylor, 2008).

Although red clover occurs ordinarily in permanent grasslands of central Europe as the most common native legume, this wild form does not reach the productivity of bred genotypes which originated probably by mutations and following selection (Kjaergaard, 1994). Cultivars which were bred for crop rotations on arable land are used for permanent grassland mixtures today. Persistence of these cultivars is not evaluated during registration tests. The aim of this contribution was to find the differences among red clover cultivars. The most persistent varieties should be used preferably for leys and for the establishment of permanent grasslands or for sod seeding. The use of more persistent cultivars would lead to reduced requirements of N fertilizers, increased forage yield and quality as well as to extended intervals between red clover overseeding. This would lead consequently to decreased inputs in cattle rearing and reduced costs of animal products (Komárek *et al*., 2010).

Materials and methods

Experimental site

The trial was established at the Forage Research Station in Vatín (49°15‘5“N, 15° 58‘15“E), Czech Republic. The site is situated at an altitude of 540 m a.s.l.; mean annual precipitation and mean annual temperature are 617.5 mm and 6.9°C, respectively. Soils are acidic cambisols, sandy loam developed on the deluvium of orthogneiss. Soil pH was strongly acidic (4.75), available P content was moderate, K was high and Mg was moderate (Mehlich III method).

Stand establishment, treatment and assessment

Twenty-two varieties of red clover of declared higher persistence were sown (Table 1) on 9 June 2006 by drilling into rows 125 mm, in a mixture with meadow fescue and timothy. Sowing rates were 14 kg ha^{-1} of red clover, 4 kg ha^{-1} of meadow fescue and 6 kg ha^{-1} of timothy. The trial was established by the method of randomized plots, each of 1.25×4 m (5 m^2) in 4 repetitions without a cover crop. In the year of sowing, the stand was harvested twice without assessment of production. In the three production years, the stands were harvested three times, the first and second time when 50% of flower heads opened in most varieties. The experiment was fertilized only with 30 kg P (Hyperkorn) in the spring of production years; no other fertilizers were used. The cover of red clover was estimated in June 2009, just before the first cut.

Statistical analysis

Statistical analyses were performed using ANOVA (Statistica 7.1, StatSoft) with multiple comparisons according to Tukey ($P < 0.05$). Assessment of difference in dry matter (DM) content between diploids and tetraploids was evaluated by t-test using Levene test for judge homogeneity of variances.

Results and discussion

Table 1 presents DM yields of individual red clover cultivars in the third production year and shows a comparison of production in the third and first production years. Varieties with the highest ratio should be those with a higher persistence and better disease resistance (Halling *et al*. 2004). Red clover gives the highest yields most frequently right in the first year after stand establishment. In our experiment, however, the production of forage in most varieties was higher in the second year, and once in the third harvest year, than in the first year, which was conditioned by the weather.

Swiss varieties Astur, Milvus and Pavo gave the highest forage yield in the third production year. The lowest forage production was given by Swedish varieties Betty, Jesper SW Torun, which related to their one-cut character, but also by Austrian variety Reichersberger Neu which is two cuts type. Astur, Pavo and Lucrum cultivars showed the highest ratio of forage production in the third production year, while the lowest ratio was found for the cultivar Reichensberger. The correlation coefficient between the yield in the third harvest year and the ratio of yields in $3^{rd}/1^{st}$ production year was high ($r = 0.725$). Also, the relationship between the proportion of red clover in swards before the 1^{st} cut in the 3^{rd} harvest year and the annual yield in the 3^{rd} harvest year was high ($r = 0.74$). Due to the small database, the relationship between ploidy and persistence is not discussed.

According to many authors, the limited persistence of red clover is contributed to by unfavourable environmental conditions, agricultural technology and diseases. Nevertheless, a progressive decline in annual DM production with age is typical of clover swards, even in the absence of pests and diseases, due to natural decline in plant populations. However, according to our observation and in compliance with some authors (e.g. Taylor, 2008) genotype plays a great role in affecting the persistence.

The highest losses of plants are recorded in winter, the main cause of the decay of plants in western and northern Europe being infestation by fungus *Sclerotinia trifoliorum* and by

Table 1: Forage yield ($t.ha^{-1}$) in the third production year (2009) and cultivars description

Cultivar	DM yield	statistical difference*	yield ratio 2009/07	ploidity	country of origin	2009 cover proportion**
Astur	17.1	a	1.14	4 n	CH	77.5
Milvus	15.5	ab	0.86	2 n	CH	87.8
Pavo	15.4	ab	0.96	2 n	CH	66.5
Lucrum	15.1	abc	0.94	2 n	D	72.5
Christie	14.6	abc	0.76	2 n	CAN	40.0
Start	14.1	abcd	0.84	2 n	CZ	69.0
Tedi	13.9	abcd	0.74	2 n	NL, F	67.5
Spurt	13.8	abcd	0.75	2 n	CZ	75.3
Amos	13.4	bcde	0.74	4 n	CZ	43.8
Gumpensteiner	13.2	bcde	0.92	2 n	A	78.0
Nemaro	13.0	bcdef	0.73	2 n	D	41.3
Dolina	12.9	bcdef	0.82	4 n	CZ	40.8
Endure	12.9	bcdef	0.73	2 n	CAN	68.8
Beskyd	12.8	bcdef	0.71	4 n	CZ	63.8
Radegast	12.8	bcdef	0.84	4 n	CZ	75.8
Vltavín	12.7	bcdef	0.74	2 n	CZ	67.3
Veles	11.7	cdef	0.64	4 n	CZ	67.0
Charlie	11.0	def	0.74	2 n	CAN	76.3
Jesper	10.6	def	0.77	2 n	SE	50.0
SW Torun	10.3	ef	0.77	4 n	SE	58.8
Reichersberger	9.6	f	0.59	2 n	A	68.8
Betty	9.5	f	0.71	4 n	SE	52.5

* different letters in the column show significant differences at $P = 0.0047$; LSD = 1.55 t ha^{-1}

** cover was estimated immediately before the 1st cut (%)

nematodes. In central Europe, the dieback of plants can be attributed to fungi from genus *Fusarium* and viruses - esp. BYMV, CMV and RCVM. The most feared pest is the field mouse (*Microtus arvalis*).

The comparison of these experimental results with older works shows that great progress has occurred in the last 40 years in breeding red clover varieties for persistence.

Conclusion

Presented results show the importance of the right choice of suitable red clover cultivars for permanent or temporary grassland. Regarding the adaptability of individual cultivars to specific environment, the results presented are not necessarily generally applicable for all sites in central Europe.

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Forage management in mountainous bovine systems is constrained by geographical characteristics of the field pattern

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Abstract

The impact of geographical characteristics of field pattern on forage management was investigated in 72 mountainous farms (France) managing dairy cows and possibly suckler cows. Forage management types at the field-pattern level were described with principal component and hierarchical cluster analyses. Relationships with the field pattern characteristics were established through one-way ANOVA. The farms were separated into five types of forage management: extensive grazing (ExG), intensive dairy cow grazing (IDG), management turned onto one early cutting (EC) or intensive cutting (IC) and specialised grazing (SG). We highlighted significant differences between the five types in terms of elevation and field area. ExG was located at a higher elevation than the other types and corresponded to sloping field patterns with relatively large field area. IDG was associated with relatively large fields and grouped field patterns. EC was linked with fragmented field patterns less favourable for grazing, with the smallest field area. IC corresponded to intermediate relatively flat field patterns adapted to cutting. SG management was associated with large undivided field patterns. These results highlight that geographical characteristics of field patterns constrain forage management in mountainous bovine systems.

Keywords: grassland use, cattle, field pattern, geographical characteristics

Introduction

In recent decades, cattle farms in France have increased their agricultural used area whilst at the same time the workforce has remained stable. Livestock farmers have to manage increasingly widespread field patterns, split up by the pressure on land. There can be serious consequences of these constraints on forage management in mountainous areas with additional problems caused by slope and altitude. Previous studies gave some insights on the fields characteristics (mean and variability between fields) in the field pattern expected to constrain the forage management: slope, distance, area, altitude (Andrieu *et al*., 2007); distance and area being associated with fragmentation and dispersion of the field pattern. Gibon *et al*. (1995) also highlighted some relationships between the geographical field pattern characteristics and forage management. To our knowledge, there is no clear typology in the literature of forage management in relation to the field pattern structure. Our objective was to identify the relationships between forage management and field pattern characteristics in mountainous grass-based livestock systems.

Materials and methods

In 2005 we carried out surveys on 72 farms representing traditional farming system (43 ± 19.8 cows, 81 ± 37.5 LU, 78 ± 33.5 ha, with 0.95 as permanent grasslands) located in the mountainous area of the Massif Central, France. This farming system uses the Salers breed and manages dairy cows that simultaneously suckle their calf. The farms were characterized in terms of herd composition and production and purchase of conserved forage. Each field was described by the farmer: area, distance to farmstead, slope and altitude. Each farm was characterized by the proportion (Prop) of each of 15 field use types (Garcia-Launay *et al*. 2011 and Table 1) in the field pattern. Data analyses were conducted with the field pattern as the statistical unit (n = 72). Principal component analysis (PCA) was applied using SPAD software with all the Prop variables minus one. The resulting six first factors were subjected to a hierarchical cluster analysis. The differences between the forage management types obtained in terms of forage management, herd composition, forage autonomy and field pattern geography were tested by one-way ANOVA (SAS) and multiple comparisons test with a Tukey adjustment, with an angular transformation for the proportion of area with slope and a log transformation for distance to farmstead to achieve normal distribution of the residues.

Results and discussion

The PCA applied on field patterns explained 0.68 of the variability. The farms were separated into five classes (Table 1) labelled according to the main characteristic of their forage management: extensive grazing (ExG), intensive dairy cow grazing (IDG), early cutting (EC), intensive cutting (IC) and specialised grazing (SG). ExG has the lowest mean stocking rate and total grazing intensity (Table 1) with the highest proportion of grazed-only area. The IDG, EC, IC and SG categories were characterized by similar and high total grazing intensity and mean stocking rate. They are consequently separated by more detailed characteristics. IDG was characterized by the highest dairy cow grazing intensity and the highest proportion (0.47) of cut and grazed area. EC is characterized by field use types with one early cutting (early cutting, early cutting followed by grazing, and one cutting with one or two grazing) and by a high proportion of cut only area. IC presents the highest proportion of the area cut twice and cut early before grazing. SG farms have the highest proportion of suckler cows (0.18) and of mixed cows (0.38), being milked only at the beginning of lactation. This class has the lowest proportion of the area with unspecialised grazing, with the highest proportions of the area devoted to suckler cow grazing and young heifer grazing. In this class, most of the meadows are cut late (Table 1) relative to ear emergence, which means that farmers give priority to the quantity of conserved forage rather than the quality. Field patterns were characterized by their fragmentation and their dispersal. A fragmented field pattern refers to many fields, as opposed to an undivided field pattern with few fields. A grouped field pattern corresponds to fields close to farmstead opposite to a spread field pattern with fields far from farmstead. Field pattern area was not significantly different between the groups, due to a large variability. ExG was characterized by an elevated, sloping and spread field pattern. All the farms of this class have elevated and sloping fields leading to forage management focussed on grazing at low stocking rate. IDG field patterns are grouped (lowest number of fields) and undivided (short distance to farmstead) what enables intensive use of fields (highest mean stocking rate) with dairy cow grazing and cut and grazed fields used three times per year. Field patterns of the EC group are most fragmented (29 fields) and relatively spread, which is unfavourable for grazing. IC field patterns are quite equilibrated with intermediate field area, altitude, and distance to farmstead. They appear more favourable to cutting, with moderated slope area. Forage management is characterized by fields cut twice and grazed or cut early and grazed. Noteworthy, both in EC and IC, forage management is oriented towards cutting, and particularly early cutting. This may be linked to the observed high forage autonomy with very low forage purchase and high amount of harvested forage by livestock unit. The SG exhibited large undivided and grouped field patterns favourable to the grazing of large herds. Associated to the observed moderate

Table 1. Description of the farms according to the 5 forage management types

	ExG (n = 17)	IDG (n = 19)	EC (n = 9)	IC (n = 18)	SG (n = 9)
Fields' geographical characteristics (average of the fields in each farm)					
Altitude (m a.s.l.)	1,038^{b}	805^{a}	805^{a}	864^{a}	852^{a}
Distance to farmstead (km)	1.21	0.75	1.53	1.39	1.15
Area (ha)	4.0^{ab}	3.8^{ab}	2.5^{a}	3.0^{ab}	4.3^{b}
Sloping area (Prop. of field pattern area)	0.37	0.32	0.39	0.30	0.33
Field pattern area (ha)	89	70	69	70	98
Number of fields	24^{ab}	19^{a}	29^{b}	24^{ab}	24^{ab}
Cut only area (Prop.)	0.021^{a}	0.005^{a}	0.061^{b}	0.018^{a}	0.087^{b}
Grazed only area (Prop.)	0.63^{b}	0.53^{a}	0.55^{ab}	0.58^{ab}	0.60^{ab}
External forage (MgDM y^{-1})	18^{ab}	24^{b}	1^{a}	7^{ab}	16^{ab}
Harvested forage (MgDM LU^{-1})	1.62	1.44	1.66	1.65	1.42
Mean stocking rate (LU ha^{-1})	0.91^{a}	1.16^{b}	1.12^{b}	1.12^{b}	1.01^{ab}
*Grazing intensity (LU*d ha^{-1})*					
Dairy cow	87^{a}	146^{b}	113^{ab}	125^{ab}	96^{a}
Suckler cow	29^{a}	23^{a}	47^{ab}	29^{a}	73^{b}
Total grazing intensity (all animals)	179^{a}	249^{b}	251^{b}	236^{b}	244^{b}
Proportion of each field use type in the farm area					
Early cutting	0.003^{a}	0.003^{a}	0.05^{b}	0.001^{a}	0.017^{a}
Late cutting	0.015^{a}	0.002^{a}	0.002^{a}	0.002^{a}	0.071^{b}
Two cuttings	0.005^{a}	0.000^{a}	0.007^{ab}	0.014^{b}	0.001^{a}
Grazing followed by cutting	0.012^{a}	0.001^{a}	0.012^{a}	0.003^{a}	0.066^{b}
Early cutting followed by grazing	0.019^{a}	0.067^{ab}	0.078^{ab}	0.090^{b}	0.047^{ab}
Late cutting followed by grazing	0.178^{b}	0.041^{a}	0.031^{a}	0.028^{a}	0.080^{a}
One cutting with one or two grazings	0.035^{a}	0.027^{a}	0.133^{b}	0.031^{a}	0.021^{a}
Grazing, cutting and grazing	0.086^{a}	0.297^{b}	0.100^{a}	0.087^{a}	0.088^{a}
Two cuttings followed by grazing	0.009^{a}	0.008^{a}	0.001^{a}	0.081^{b}	0.016^{a}
Calves grazing	0.013^{a}	0.013^{a}	0.026^{ab}	0.026^{b}	0.013^{ab}
Young heifers grazing	0.055^{a}	0.065^{ab}	0.066^{ab}	0.074^{ab}	0.108^{b}
Old heifers grazing	0.023	0.027	0.030	0.046	0.021
Dairy cows grazing	0.082	0.210	0.181	0.173	0.139
Suckler cows grazing	0.026^{a}	0.039^{a}	0.098^{a}	0.048^{a}	0.231^{b}
Unspecialised grazing	0.434^{b}	0.172^{a}	0.151^{a}	0.213^{a}	0.080^{a}

stocking rate, these findings explain the continuous specialised grazing of the fields that constitute a simplified management of grazing.

Conclusions

We have highlighted a relationship between forage management and field pattern characteristics. These results will be synthesized into farm types to simulate the influence of field pattern on forage autonomy and sensitivity to climatic uncertainty, with a dynamic model of interaction between forage production and animal requirements.

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Challenge and problems of forage conservation in mountainous regions of Austria

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Abstract

A comprehensive silage monitoring project has been carried out in the years 2003, 2005, 2007 and 2009 in Austria. More than 3,670 grass silage samples from different Austrian sites were collected and analysed for dry matter content, nutrients, minerals, energy concentration and fermentation quality. Important management data were recorded by means of questionnaires and interviews. Apart from unfavourable natural weather conditions in mountainous areas the main reasons for unsatisfactory silage quality are obvious in management mistakes. Late harvest times resulting in high content of crude fibre, low concentration of easy fermentable sugar and difficulties with the compaction of such bulky material are still the main problems in practice. Forage contamination causing an increased risk of clostridia, respectively butyric acid in the fermentation process, is another serious problem that has to be faced. The results show that there is a considerable potential in Austria to improve silage quality in practice. Strong efforts have to be undertaken therefore to advise farmers specifically how to improve the ensiling procedure and to increase silage quality.

Keywords: forage conservation, silage quality, forage contamination, clostridia, butyric acid

Introduction

Grassland covers up to 95% of agriculturally used areas in mountainous regions of Austria. In these disadvantaged areas grassland and dairy farming represent the main source of agricultural production, which is characterised by harsh conditions of climate, topography and infrastructure. Due to the short vegetation and grazing period, forage has to be conserved in sufficient amounts for indoor feeding periods which last up to 7 months. Since forage conservation results in high costs, it is of great economic interest to obtain high quality of hay, aftermath hay and silage, which account for nearly 40% of the total grassland yield in Austria. Beside numerous experiments on silage quality covering a wide range of different aspects, a silage monitoring project was initiated by AREC Raumberg-Gumpenstein to i) record the status quo of silage quality in practice, ii) point out the possible reasons for fermentation problems and iii) offer specific advice to improve silage quality.

Materials and methods

The Austrian silage monitoring project started first in 2003 and was repeated in the years 2005, 2007 and 2009 in cooperation with the regional agricultural chambers. Seven of the nine Federal provinces of Austria participated in this project with 3,670 silage samples in total. In addition to the silage sampling a comprehensive collection of management data (e.g. farming system, grassland type, harvesting time, silage and mowing system, chopping length, charging procedure, use of silage additives) was done by means of questionnaires. Silage samples were analysed for dry matter content, crude nutrients, minerals and fermentation quality according standardized methods, whereas energy concentration was estimated by equations. Statistical data analyses were done by using Statgraphics-Plus (Version XV.1) for General Linear Model - procedures respectively PASW Statistics (Version 17.0) for descriptive analysis.

Results and discussion

Data analyses showed a high proportion of well pre-wilted silages with an average content of 374 g DM kg^{-1} FM. Nearly 60% of the samples met the given target range of 300 to 400 g DM kg^{-1} FM, 13% were below it. The three prior-determining factors of the multivariate analyses for the DM-content were weather conditions at harvest, year and growth (Table 1). The average content of 262 g crude fibre and 148 g crude protein kg DM^{-1} indicate that most of the forage was harvested early enough at the time of ear and panicle emergence of the main grasses. But there is still a remarkable proportion of samples (38%) with a high content of crude fibre

Table 1. Impact of fixed effects and quantitative factors on nutrient content (CP = crude protein, CF = crude fibre), ash, energy concentration and fermentation properties of silages

parameter	DM	CP	CF	ash	energy	pH-value	lactic acid	acetic acid	butyric acid
unit	(g kg^{-1} FM)	(g kg^{-1} DM)			(MJ NEL kg^{-1} DM)		g kg^{-1} DM		
mean value	**374.3**	**148.3**	**262.2**	**103.6**	**5.96**	**4.5**	**43.8**	**11.6**	**10.9**
standard deviation	74.1	19.6	26.7	21.6	0.34	0.35	24.4	7.1	9.6
R^2 in %	16.8	37.4	39.1	19.3	85.9	23.1	14.3	14.6	38.5
fixed effects	significant if p-value < 0,05								
farming system	0.227	0.000	0.000	0.000	0.327	0.070	0.013	0.012	0.019
year	0.000	0.000	0.000	0.000	0.099	0.000	0.000	0.000	0.033
growth	0.000	0.000	0.000	0.000	0.000	0.001	0.168	0.101	0.000
grassland type	0.006	0.000	0.000	0.000	0.000	0.006	0.001	0.000	0.001
mowing system	0.014	0.000	0.000	0.000					
cutting height			0.339	0.000	0.003	0.094	0.007	0.912	0.043
tedding frequency	0.028	0.159	0.025	0.008					
cutting time	0.000					0.369	0.596	0.043	0.044
weather conditions	0.000	0.248	0.004	0.137	0.819				
silo system		0.345	0.014	0.891	0.778	0.000	0.000	0.269	0.000
harvesting technique	0.000			0.068					
chopping length	0.535		0.732	0.645	0.246	0.001	0.046	0.000	0.000
compaction level					0.036	0.006	0.004	0.532	0.027
silage additives					0.329	0.000	0.004	0.000	0.000
sample packaging						0.000	0.410	0.634	0.024
quantitative factors	significant if p-value < 0,05								
dry matter		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
crude protein			0.000		0.000				
crude fibre	0.543	0.000		0.000	0.000	0.000	0.000	0.165	0.000
crude ash		0.000	0.000		0.000	0.000	0.000	0.516	0.000
prior-determining factors									

that causes serious problems in the fermentation process and leads to lower digestibility and energy concentration in forage (Pötsch *et al*., 2010).

There was a significant impact of the cutting height on the content of ash in silages, which on average was at 104 g kg DM^{-1} with a standard deviation of 22 g. The results show that the ash content in practice is still too high and some farmers seem not to be aware of mistakes in management. Two-thirds of the silage samples had an energy concentration between 5.6 and 6.3 MJ NEL kg DM^{-1}. Nearly 70% fulfilled the requirements of > 5.8 MJ NEL kg DM^{-1} which can be seen as a good basis for sufficient milk or fattening performance from forage. Energy

concentration was mainly determined by crude fibre and ash content but also by the number of growth, where the first growth reached more than 6.0 MJ NEL kg DM^{-1} on average.
The overall average pH-value of 4.5 corresponded well with the critical pH-value for silages pre-wilted between 30-40% DM (Weissbach, 2002). Beside the package system of the samples the content of crude fibre (= vegetation stage) and ash (= contamination) were the strongest significant factors that influenced the pH-value. Whereas the content of dry matter had an unexpected slight impact on the pH-value of the silages, the time between baling and wrapping showed a significant and strong influence. Two-thirds of all samples met the recommended range of the concentration of lactic acid and acetic acid which were strongly determined by the pre-wilting level and by the year of investigation (Resch, 2010). A significant effect of silage additives could be found for the concentration of fermentation acids. Silages conserved with bacteria products had a higher content of lactic acid (+6.2 g kg DM^{-1}) and lower concentration of butyric acid. Only 25% of all samples were below the given limit of 3 g kg DM^{-1} of butyric acid, which was strongly determined by the pre-wilting level as well as by crude fibre and ash content.

35% of all analysed forage samples were harvested well-timed (< 270 g crude fibre kg DM^{-1}) and pre-wilted between the recommended range of 300-400g DM (represented by the intersection area in Figure 1). Adding the criteria of forage contamination (ash content >100g kg DM^{-1}) as an important issue, the percentage of optimal grass silages is reduced to 14%! Probably the used classification system is too strict but we must not forget that the silage samples of this project are representing the premium third. No farmer would provide silages of bad quality for a monitoring project which is at the same time a silage competition.

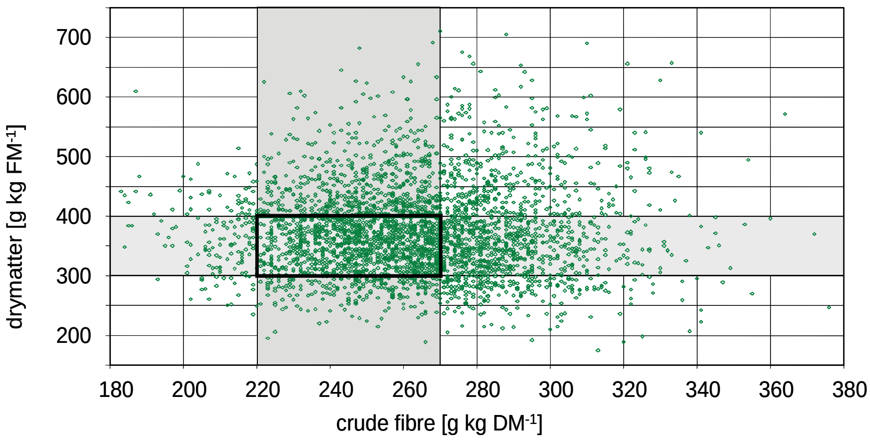

Figure 1. Distribution of grass silages concerning pre-wilting level and crude fibre content expressing stage of vegetation (data of the Austrian silage monitoring project, 2003-2009)

Conclusions

The results of the Austrian silage monitoring project clearly indicate a high potential of improvement concerning forage and silage quality in practice. Many of the analysed silages showed a disappointing high content of crude ash and concentration of butyric acid - so farmers have to be specifically advised to avoid management mistakes in forage conservation.

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Can *Senecio aquaticus* be controlled in agricultural grassland?

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Abstract

This study aimed at identifying an optimal combination of measures for the control of *Senecio aquaticus*, a poisonous species in agricultural grassland in Central Europe. A detailed field experiment was set up at five sites in Switzerland to test six treatments: ploughing followed by re-sowing with a ley mixture; harrowing followed by re-sowing; herbicide application; pulling or digging of individuals; mowing once a year; and a control without any manipulation. In addition, the soil seed bank of *S. aquaticus* was recorded prior to the study.

In the short-term, herbicide application ($P < 0.001$) and mowing once a year ($P < 0.01$) reduced the number of individuals of *S. aquaticus* most efficiently, but no clear effects were observed for the remaining control measures. Three years following the application, the measures that were the most effective in the short-term still performed best, but hardly any significant reduction was achieved compared to pre-treatment conditions. *Senecio aquaticus* formed large seed banks of more than 1000 germinable seeds m^{-2}, which contributed to the failure of the treatments, because any elimination of *S. aquaticus* individuals resulted in re-germination and replacement with new seedlings. We conclude that the control of established populations of *S. aquaticus* remains challenging and requires a combination of different measures applied over several years. Thus, the formation of populations with a soil seed-bank of *S. aquaticus* should be hindered by any means.

Keywords: control measures, ploughing, herbicide, pulling/digging, one annual mowing

Introduction

In recent years, *Senecio aquaticus* Hill (marsh ragwort) is increasingly observed in agricultural grassland of mountainous regions in Central Europe (southern Germany, eastern Austria, Switzerland). The species could become a threat to animal and human health because it contains pyrrolizidine-alkaloids that are toxic for cattle and other livestock (Evans and Evans, 1949). *Senecio aquaticus* often occurs in wet grasslands that are mown once or twice per year, but it can also exist on sites with moderate-to-high management intensity, because it resists frequent defoliation (Suter and Lüscher, 2008). It thus cannot be controlled by mowing alone. While recent research has shown which grassland is prone to the establishment of *S. aquaticus* (Suter and Lüscher, 2008), efficient measures for the species' control when it is already present in grassland are lacking. This study aimed at identifying an optimal combination of measures for the control of *S. aquaticus* in agricultural grassland. To meet this, a field experiment was set up in the northern pre-alps of Switzerland to test various measures, most being applicable in organic farming. Moreover, the seed bank of *S. aquaticus* was investigated, allowing for further evaluation of the efficiency of control measures, as seed banks in grasslands are closely linked to population dynamics.

Materials and methods

Five locations were selected for experimentation, all of which were permanent grasslands managed by farmers. The grasslands were selected so as to provide a diverse range of nitrogen fertilisation intensities (0-130 kg of N ha^{-1} $year^{-1}$) and defoliation frequencies (1-5 $year^{-1}$) and were infested with *S. aquaticus* for more than five years prior to the study. On average, at least ten individual plants m^{-2} of *S. aquaticus* occurred at all sites.

Six treatments were established: ploughing to 25 cm depth followed by soil cultivation and sowing of a ley mixture, harrowing to 20 cm depth followed by sowing of a ley mixture, application of a selective herbicide against dicot weeds (Banvel Extra, 6 l ha^{-1}), pulling or digging of individuals, reduction of management intensity to one annual mowing, and an untreated control. These treatments were established in June 2007 on plots of 3 m×5 m, which were replicated threefold at each of the five sites. Plots under one annual mowing were cut once in September and received no fertiliser, while all other measures, including the control, were mown twice each year and were fertilised annually with a complete fertiliser (30 kg Nitrogen, 9 kg Phosphorus, 14 kg Potassium ha^{-1} year^{-1}). Individuals of *S. aquaticus* were recorded in May 2007 before applying any treatments, and this counting was repeated three times in September/October 2007, 2008, and 2009. Data were analysed with generalised linear models taking into account the initial number of individuals of *S. aquaticus* per plot.

To evaluate the soil seed-bank in the topsoil (0-10 cm), soil samples were cored from all control plots at each of the five sites in May 2007, were prepared for germination following methods of Ter Heerdt *et al.* (1996), and were brought to germination in a shaded glasshouse for a period of eight weeks. Seedlings of *S. aquaticus* were recorded once they could be distinguished from other species, at a size of 2-3 cm.

Results and discussion

In the short-term, herbicide application ($P < 0.001$) and one annual mowing ($P < 0.01$) led to the most pronounced reduction in the number of *S. aquaticus* individuals (Figure 1, Year 1). Pulling/digging all individuals of *S. aquaticus* was only weakly effective in reducing the species' numbers. Similarly, ploughing was not successful, while harrowing even favoured *S. aquaticus*.The number of individuals of *S. aquaticus* generally increased over the three years (Figure 1). For example, with herbicides a steep and significant rise in the species was observed between years one and two ($P < 0.001$), and a similar situation was observed for one annual mowing between years two and three ($P < 0.01$). Nonetheless, a carry-over effect was detectable and the most successful short-term measures also performed best in year three. Overall, the final number of individuals after three years was similar to or greater than the number observed in the control treatment in year one.

The observed seed bank of *S. aquaticus* was large, with an average of 1025 germinable seeds m^{-2} (Table 1); the great standard errors implicate large spatial variation. The large seed bank, being greater than that of many other grassland species (Wellstein *et al.*, 2007), must be related to the life cycle of *S. aquaticus*. As a biennial forb, the species must partially regenerate from seeds every year to maintain its population size and thus has to ensure efficient seed production. A proportion of these seeds will remain viable to form a transient seed bank maintaining germination, and we argue that re-germination of *S. aquaticus* following treatment application explains the failure of measures after three years.

Re-germination was most clearly seen after pulling/digging, because all *S. aquaticus*, including small seedlings, were removed in this treatment: four months after the application, we found

Table 1. Germinable seeds of *Senecio aquaticus* m^{-2} in the topsoil (0-10 cm) at five study sites. Displayed are means (n = 3) ± 1 standard error (SE). The five sites are located within the centre of the geographical distribution of *S. aquaticus* in Switzerland

Site	Mean	(± SE)
Kriens I	458	(± 253.5)
Kriens II	1542	(± 480.5)
Kriens III	1792	(± 1358.5)
Rothenthurm	1208	(± 546.5)
Sattel	125	(± 125.0)

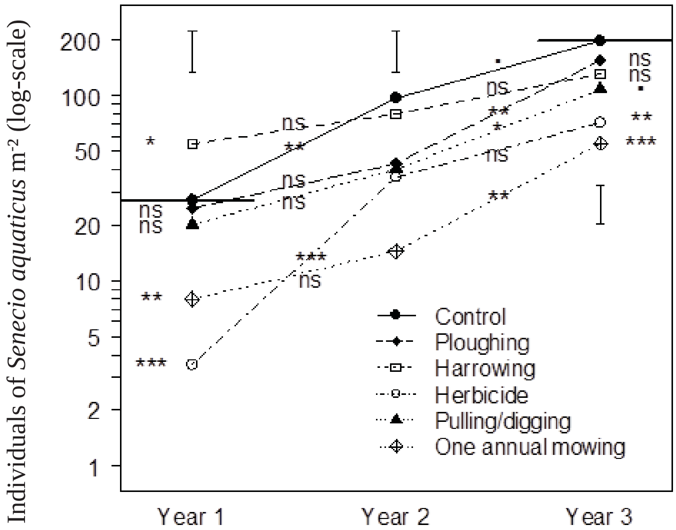

Figure 1. Effect of six measures on the number of individuals of *Senecio aquaticus*. Displayed are predicted means based on a generalised linear model; year 1 represents the short-term effect 4 months after measures were applied. I = 1 SE; — = Level of the control in years 1 and 3, respectively. Significance tests are against the control in years 1 and 3, and within measures between years; lines between years are drawn to improve clarity. ***: $P \leq 0.001$; **: $P \leq 0.01$; *: $P \leq 0.05$; •: $P \leq 0.1$; ns: not significant

similar numbers of *S. aquaticus* as compared to the control (Figure 1, Year 1). Therefore, these individuals must have germinated from the soil seed-bank. Removing large numbers of plants creates gaps in the sward, favouring seed germination (Silvertown and Smith, 1989). Re-germination is also responsible for the increase in individuals one year following herbicide application. When adult plants died, the soil seeds must have profited from available light and space and reacted with enhanced germination and growth. The failure of ploughing can be explained by too-deep soil cultivation after ploughing to prepare the seed bed, as this may have brought seeds of *S. aquaticus* back to the surface. To conclude, even the two most efficient measures - herbicide application and one annual mowing - were not adequate, because some individuals remained following initial application (Figure 1, 1 plant m^{-2} = 10000 plants ha^{-1}). Given that *S. aquaticus* is able to establish new populations from few individuals (Suter and Lüscher, 2008), one should target zero tolerance in agriculturally managed grassland.

Conclusions

The control of established populations of *S. aquaticus* remains challenging and we expect any measure applied only once to fail in the long-term. Initial application of a measure should strongly reduce a population of *S. aquaticus* and, following such treatment, surviving or re-germination individuals must be controlled by e.g. pulling/digging or herbicide application to single individuals, which may have to be performed for several years. Therefore, our study emphasises that efficient control of *S. aquaticus* must hinder the new formation of populations when the species first arrives at a site and few individuals exist; the emergence of a soil seed-bank should be avoided by any means.

Acknowledgments

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Effects of the application of nitrogen on the fatty acid profile of grass in coastal zone meadows in Cantabria (Spain) used for pasture

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Abstract

The aim of this study is to analyse the fatty acids (FAs) of meadow grass used for grazing cattle from April to October and fertilized with 0, 12 and 24 kg N ha^{-1} month^{-1} during 2007 and 2008. The experiment was carried out a site at 43°24‘N and 3°45‘W, soil type ‘Gleisol eútrico/Regesol spoli-autropico,’ at 44 m above sea level. The application of N increased the concentration of all FAs ($P < 0.001$). The N content of the grass was positively correlated with C16:0, C18:0, C18:1, C18:2 and C18:3. The highest concentration of FAs was found in grass harvested in April and October, coinciding with the higher leaf/stem ratio. The largest responses were obtained under fertilization with 12 kg N ha^{-1} month.

Keywords: grazing, herbage quality, linoleic, linolenic, nitrogen fertilizer

Introduction

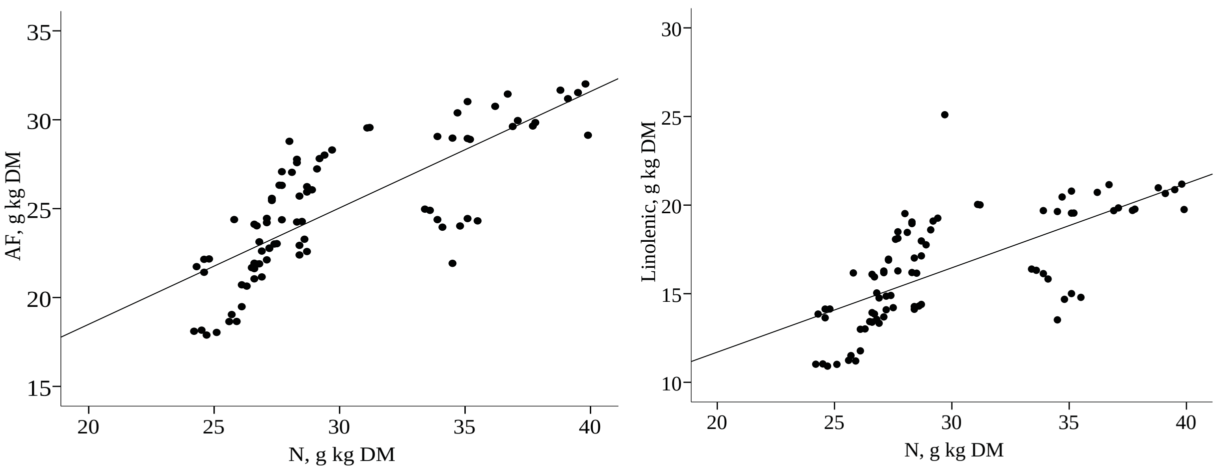
Green grass is a rich natural source of polyunsaturated fatty acids, particularly linolenic acid and linoleic, ω3 precursors present in meat and milk, followed by palmitic and small amounts of oleic (Walker *et al*. 2004). Fatty acids are mainly C16:0, C18:2 and C18:3. Their concentrations vary depending on the species, variety, preservation technique (Boufaïed *et al*., 2003) and between different parts of the plant, with lower concentration in stems than in leaves (Boufaïed *et al*., 2003). Nitrogen (N) fertilization increases the C16:0, C18:2 and C18:3 content (Elgersma *et al*., 2005). The main objective of this study was to analyse the fatty acids (FAs) content of meadow grass used for grazing cattle from April to October and fertilised with 0, 12 and 24 kg N ha^{-1} month^{-1} in 2007 and 2008.

Materials and methods

The botanical composition of the grass comprised *Lolium perenne* (67%), *Holcus lanatus* (8%), *Festuca arundinacea* (5%), *Dactylis glomerata* (2%), *Agrostis* (1%), *Trifolium repens* (3.3%) and *Trifolium pratense* (0.8%), plus other species including *Plantago*, *Ranunculus*, *Taraxacum officinale* (12.1%). The N fertilizer was distributed by hand evenly after removal of the animals from the pasture. From each grazing area, samples of grass were taken by cutting three squares (0.5×0.5 m) with a manual battery-driven scythe within each treatment and replication, and these were then transferred to plastic bags. Subsequently, they were oven-dried at 60°C for 24 hours, ground with a knife mill fitted with a 1 mm mesh and stored in 250-ml airtight containers. Approximately 30% of each sample was used to determine the chemical composition and the remaining ca 60%, was analysed for the fatty acid content. Ash was measured by incineration of the sample at 550°C, with prediction of organic matter (100-ash); total N as N-Kjeldahl with Kjeltec™ 2300; and neutral detergent fibre (NDF) by method of Goering and Van Soest (1970). Enzymatic digestibility of organic matter *in vitro* (D_e) was done using the NDF-cellulase method (Riveros and Argamentería, 1987). The crude fat was extracted with petroleum ether 40-60°C with a Soxtec™ in the Laboratorio Agroalimentario de Santander del Ministerio de Medio Ambiente, Medio Rural y Marino. The methyl esters preparation of the fatty acids in the fatty material of the forage used was in accordance with the ISO 15884/FIL 182:2002 standard, and the determination of the fatty acid composition of the fatty material by gas chromatography. Results were analysed by ANOVA using the GLM procedure from the SPSS 11, using the REPEATED option (grazing month) in accordance with an experimental design of randomized blocks. For the 7 months of grazing (April to October) and dose of N fertilizer applied (0, 12 and 24 kg N ha^{-1} $month^{-1}$), linear and quadratic effects were tested using the orthogonal contrasts test.

Results and discussion

Nitrogen fertilisation increased significantly (P < 0.001) the FAs, in total and individually (Table 1). The largest responses for the different FAs were recorded with inputs of 12 kg N ha^{-1} month and grazing, with increased percentages, compared with the unfertilized treatment, of 7.5%, 19%, 10%, 7.3% and 23% for the previously mentioned FAs. Regardless of the contribution of N, the total concentration of FAs, C16:0, C18:0, C18:1, C18:2 and C18:3 were 25.0, 3.28, 0.56, 1.29, 3.51 and 16.3 g kg^{-1} DM respectively, with differences between months (P < 0.001), but not years. The highest values were found in the months of April and October, attributed to increased leaf/stem ratio and a lower degree of lignification (Table 2). The correlation coefficient obtained between the concentration of N in pasture (g kg^{-1} DM) and N fertilization (kg ha^{-1}) is low (r = 0.24, P < 0.05) and positively related to total FAs, C16:0; C18:0; C18:1; C18:2 and C18:3 (Table 2). However, higher determination coefficients are obtained with the concentration of N in pasture (C18:0, R^2 = 0.53 P < 0.001; C18:1, R^2 = 0.68 P < 0.001; C18:2, R^2 = 0.66 P < 0.001 and C18:3, R^2 = 0.46 P < 0.001 and R^2 = 0.59 P < 0.001 the FAs), with no relation for C16:0. In *L. perenne* pasture land fertilized with 0, 45 and 110 kg N ha^{-1}, Elgersma *et al*. (2005) obtained greater concentrations of FAs when the N content of forage increased, with average gradients of 0.67 g kg^{-1} DM, similar to 0.65 in this experiment (Figure 1). Under rotational grazing conditions, the observed nutritional variable that negatively affects the different FAs is neutral detergent fibre (Table 2).



G, g kg^{-1} DM FAs = 5.39 + 0.65 N g kg^{-1} DM; ±2.4 r^2 = 0.59 C18:3, g kg^{-1} DM = 2.17 + 0.47g kg^{-1} DM; ±2.2 r^2 = 0.46

Figure 1. Relationship between N content of the pasture (g kg^{-1} DM) and the concentrations of FAs and C18:3

Table 1. Chemical composition and profil of fatty acids the grass

N, kg ha-1 month	DM g kg-1	N g kg-1	NDF g kg-1	OMD g kg-1	Fat g kg-1	FA g kg-1	C16:0 g kg-1	C18:0 g kg-1	C18:1 g kg-1	C18:2 g kg-1	C18:3 g kg-1
0	170	28,6	556	662	27.9	21.8	3.05	0.47	1.18	3.27	13.9
12	171	29.7	551	667	28.3	25.7	3.28	0.56	1.30	3.51	17.1
24	167	31,1	542	669	28.9	27.1	3.51	0.64	1.40	3.75	18.1
SEM	*3.13*	*0.48*	*4.32*	*3.83*	*0.26*	*0.11*	*0.02*	*0.017*	*0.032*	*0.047*	*0.096*
						Probabilities					
Dose N	ns	***	***	***	***	***	***	***	***	***	***
Month	***	***	***	***	***	***	***	***	***	***	***
Year	***	ns	***	***	ns	ns	ns	*	ns	ns	ns
D×M	*	ns	***	***	ns	*	ns	***	***	ns	***
D×Y	ns	ns	*	ns	ns	*	*	***	***	ns	ns
M×Y	***	ns	***	ns	ns	ns	ns	ns	ns	ns	ns
D×M×Y	ns	ns	***	ns	ns	ns	ns	ns	ns	ns	ns
Dose (L)	ns	*	ns	ns	ns	***	***	***	***	***	***
Dose (Q)	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	*
Month (L)	***	ns	**	***	***	***	**	***	ns	ns	***
Month (Q)	***	***	***	***	***	***	ns	***	***	***	***

SEM: standard error of mean, L: linear effect, Q: quadratic effect * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$, NS: not significant

Table 2. Correlation between N contribution, the chemical composition and the FA content (g FA) in grazing pastures fertilized with N

	C16:0	C18:0	C18:1	C18:2	C18:3	FAs
DM	NS	-.40**	-.58**	-.57**	.61**	-.64**
N	.25*	.73**	.82**	.81**	.70**	.77**
NDF	ns	-.62**	-.68**	-.70**	-.49**	-.56**
OMD	ns	.35**	.65**	.53**	.58**	.61**
Fat	.59**	ns	.40**	.36**	.61**	.55**
N_f	.71**	.43**	.29**	.44**	.56**	.57**

N_f: kg N ha-1 of fertilizer, * $P < 0.05$, ** $P <0 .01$, NS: not significant

Conclusion

The lowest concentration of fatty acids in pasture land is recorded in the months of July and August and the highest in spring and autumn. The total fatty acids and C18: 3 increased with increasing concentration of N in the grass, as a result of nitrogen fertilizer.

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Nutritive value of meadows in the Northeast of Portugal

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Abstract

Meadows continue to be the most important source of pasture and hay for beef cattle production in the hill and upland areas in the NE region of Portugal. The aim of this study was to evaluate CP contents and IVOMD values during the year, in three harvests (spring, hay cut and autumn) under the effect of three rates of N fertilisation in seven mountain meadows. The results showed that the highest CP and IVOMD occurred in the beginning of spring when meadows are in active vegetative growth. Effects of N fertilisation on CP and IVOMD occurred only in oligotrophic meadows, but in an irregular way, and mainly on IVOMD.

Keywords: nutritive value, nitrogen fertilisation, legumes, grasses, pasture

Introduction

Mountain meadows are an important source of feed for livestock in the NE of Portugal, especially when harvested as hay for the winter period. Adequate nutritive value of herbage is essential for a high rate of live weight gain and overall livestock performance. Pasture production and its nutritive value is determined by factors such as proportion of living and dead tissue, proportion of leaves *vs.* stems, as well as existing biodiversity between different species of plants (grasses and legumes). All these variables could vary between plant growth stages within a given growing season (Ball *et al.*, 2001). Another factor that can change the quality of pasture is nitrogen fertilisation, because of its effect on the relative proportion of legumes and grasses in a pasture (Valencia *et al.*, 2001) and this could reduce animal gains due to the generally lower feed value of grasses compared to legumes.

Material and methods

Seven meadows (M) reported in this paper (Table 1) were studied for crude protein content (CP), and digestibility (IVOMD) from 1998 to 1999. Three meadows were located in Vinhais/Bragança, which has long-term average annual rainfall of 741 mm, and four were located in Miranda do Douro, a more arid region (long-term annual rainfall of 554 mm). Meadows were subjected to three levels of N fertilisation (N0 = 0; N1 = 75 and N2 = 150 kg ha^{-1} y^{-1}), top-dressed when meadows were rested (March/April), after the usual winter/spring grazing period. The experimental design was a hierarchical completely random split-plot, where meadows were the main plots and N fertilisation the sub-plots. Three samples were harvested inside exclosure cages, with surface areas of 0.25 m×0.25 m, within sub-plots, at the beginning of spring (March/April), at the hay cut (June), and at the end of autumn (November/December). Samples were dried to constant weight at 60ºC (48 h). IVOMD was analysed by the Marten and Barnes (1980) method and the CP after macrokjeldahl digestion. CP content and IVOMD were considered as dependent variables, and M and N fertilisation as independent ones. Data were analysed by PCA based on a correlation matrix for the dependent variables, followed by multivariate and univariate analyses of variance and mean separation (Tukey's HSD test).

Table 1. Meadow description. (G, L, O: percentage of grass, legume and other families in the first year during hay growth without N-fertilisation)

Meadow	Community	Environment	m a.s.l.	Region	G	L	O
M1	*Bromo-Cynosuretum cristati*	Eutrophic	820	Vinhais/Bragança	74	10	16
M2	*Anthemido-Cynosuretum cristati*	Mesotrophic	1060	Vinhais/Bragança	24	26	45
M3	*Gaudinio-Agrostietum cristati*	Mesotrophic	880	Vinhais/Bragança	48	6	46
M4	*Gaudinio-Agrostietum cristati*	Oligotrophic	750	Miranda do Douro	76	0	24
M5	*Bromo-Cynosuretum cristati*	Oligotrophic	750	Miranda do Douro	97	0	3
M6	*Genisto anglicae-Nardetum strictae*	Oligotrophic	820	Miranda do Douro	76	2	22
M7	*Bromo-Cynosuretum cristati*	Oligotrophic	670	Miranda do Douro	64	1	35

Results and discussion

PCA was significant (P < 0.001) in the explanation of dependent variables. The first axis (PCA1) (49% of total variability) illustrates the relationship between CP and IVOMD, and separated the meadows into two groups: (i) meadows with the highest CP and IVOMD values (M1, M2 and M3), and meadows with lowest ones (M4, M5 and M6) (Figure 1). In this last group, N fertilisation treatments had a significant effect on CP (P < 0.01) (Figure 2). In this case, the fertiliser rate (N1) had a reduced CP content compared to the high rate (N2) in M4 and M5, and compared to no fertilisation (N0) in M6.

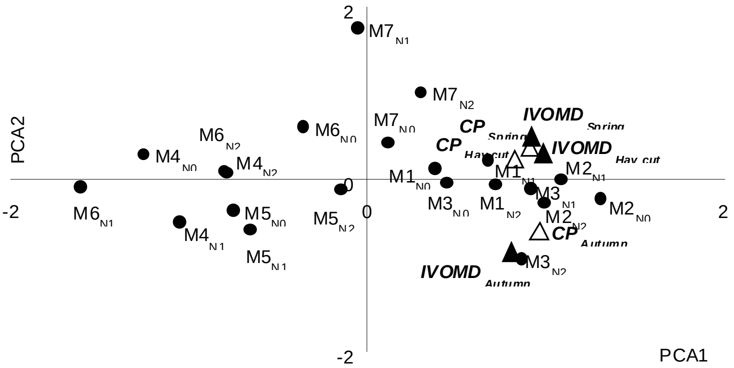

Figure 1. Loadings and scores of the two first PCA and significant effect of meadow type (M1-7). N0 = 0 kg N ha^{-1}; N1 = 75 kg N ha^{-1} and N2 = 150 kg N ha^{-1}

These results could be explained by the different floristic composition of meadows (Table 1), while M1, M2 and M3 had the highest proportion of legumes, and therefore, the highest CP and IVOMD values, M4, M5 and M6 had lower proportions of legumes, and consequently, the lowest CP and IVOMD. N2 fertilisation rate increased the proportion of grasses on meadows (unshown data), because legumes do not respond, or respond less, to N fertilisation (Sun *et al.*, 2008).The results showed a significant effect (P < 0.001) of fertiliser treatments on IVOMD. IVOMD decreased on M6 (spring) and M7 (hay cut) when fertiliser (N1 and N2) was applied, while in M4 (spring) it increased IVOMD (Figure 2). N fertilisation greatly increases the CP content (Duru, 2003) and often, when N fertilisation increased, no changes or a decrease on herbage digestibility has been observed (Angell and Bailey, 1998). The second axis (PCA2) (18% of total variability) represented the variability of CP and IVOMD during the three harvests (Figure 1). In general, meadows had the highest nutritive values in spring (Figure 2), when grasses were at the end of tillering and beginning of stem elongation, and the lowest values in the hay cut (flowering to ripening stages) and in the autumn, when the low mean temperatures (< 0ºC) led to minimal plant growth (< leaf ratio/stem ratio) and consequently, lower nutritive values (Mut *et al*., 2010), despite the tillering stage of grasses in this season.

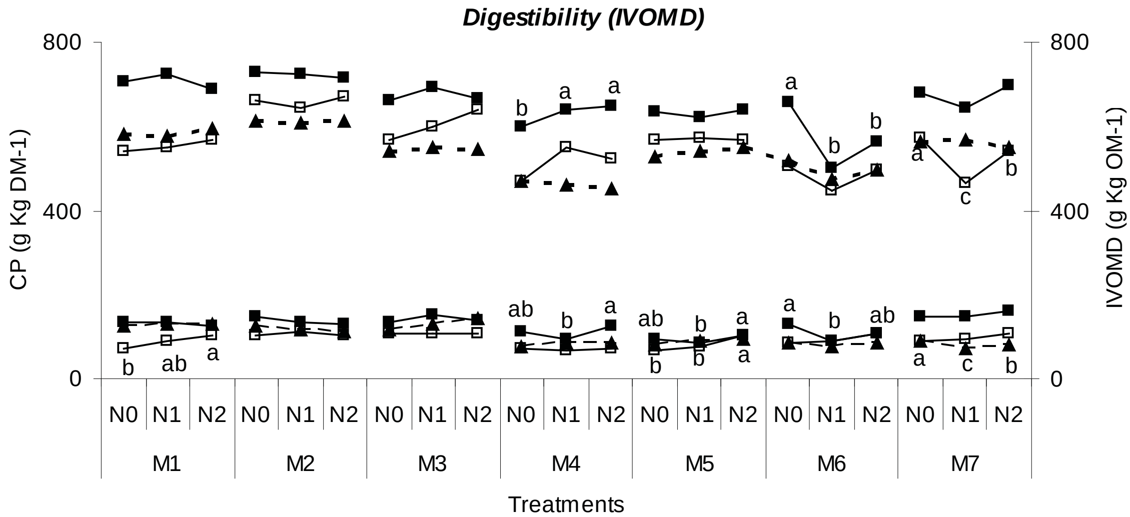

Figure 2. CP and IVOMD of meadows (M1-M7) in the three seasons and treatments. Different letters indicate significant differences between N treatments in the same harvest and meadow.

Conclusions

The nutritive value of meadows is in line with the type of plant communities and the agroecological potential of the environments where they are located (eutrophic, mesotrophic, and oligotrophic). The effect of N fertilisation on CP and IVOMD occurred only in oligotrophic meadows, but in an irregular way, mainly on IVOMD. CP and IVOMD are higher at the beginning of spring than in other seasons, even in autumn.

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Influence of organic fertilization on nitrogen content in lucerne under water deficiency stress

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Abstract

A study of nitrogen changes in yield in total plant biomass of lucerne in relation to mineral and manure fertilization under water-deficit conditions was carried out at the Institute of Forage Crops, Pleven, Bulgaria. Ammonium nitrate and well-matured cattle manure as a source of mineral and organic nitrogen were used. The plants were grown for seed production under optimum moisture conditions (75-80% of Field Capacity [FC]), and water deficiency (37-40% of FC). Nitrogen in the yield of dry aboveground mass under optimum water supply increased by 44 and 53% for mineral and manure fertilization, applied at the dose of 70 mg N kg^{-1} soil. Under water-deficit conditions, manure fertilization at the dose of 70 and 210 mg N kg^{-1} soil, increased nitrogen in the yield by 33 and 38%, respectively. Plants treated with manure were less susceptible to the stress conditions of water deficiency. Other compounds than N in the manure supported plants to be more resistant to drought stress.

Keywords: lucerne, nitrogen in yield, dry mass, mineral fertilizer, manure, water deficit

Introduction

Lucerne is the main source of forage and the most-used legume crop in Bulgaria (Vassilev, 2003). It has the ability to accumulate significantly more nitrogen in its biomass than other legumes due to its deeper root system (Jarvis, 2005). Nitrogen is a very important element for the formation of dry mass (Serraj *et al*., 1999). Although lucerne is tolerant of drought, it is negatively affected by moisture shortage (Frame *et al*., 1998). Of particular importance in searching for ways to overcome the negative effects of water deficiency stress is the balance nitrogen nutrition and fertilization (Olesen and Bindi, 2002).

The application of organic nitrogen to lucerne has showed greater capacity to overcome the depressive effect of water-deficiency stress with regard to forage productivity, dry root mass and nitrogen in yield (Vasileva and Kostov, 2002). The aim of this study was to determine the changes of nitrogen in yield of dry aboveground mass related to mineral and manure fertilizing of lucerne grown for seed in the conditions of water-deficiency stress.

Materials and methods

The experiment was carried out with leached chernozem soil from the region of Pleven (Bulgaria) under the conditions of a pot trial with 10 treatments and 4 replications. Pots of 10 L capacity were used and 4 plants were grown in each pot. The following design was used:

1. Soil	(Control 1) + N0PK+ 75-80% Field Capacity (FC)	
2. Soil	+ mineral N70 + PK (MN70PK)	+ 75-80% FC
3. Soil	+ organic N70 + PK (ON70PK)	+ 75-80% FC
4. Soil	+ mineral N210 + PK (MN210 PK)	+ 75-80% FC
5. Soil	+ organic N210 + PK (ON210 PK)	+ 75-80% FC
6. Soil	(Control 2) + N0PK	+ 37-40% FC
7. Soil	+ mineral N70 + PK (MN70 PK)	+ 37-40% FC
8. Soil	+ organic N70 + PK (ON70 PK)	+ 37-40% FC
9. Soil	+ mineral N210 + PK (MN210 PK)	+ 37-40% FC
10. Soil	+ organic N210 + PK (ON210 PK)	+ 37-40% FC

Optimum moisture content (75-80% of FC) was maintained for all treatments during the vegetation period. From treatment 6 to 10, a 10-day water-deficiency stress at the 5-6 leaf stage was imposed by stopping the watering till the moisture dropped to 37-40% FC. The following levels of N fertilization were applied: N0 - unfertilized, N70 - 70 mg N kg^{-1} soil, N210 - 210 mg N kg^{-1} soil. Nitrogen was applied as ammonium nitrate (mineral nitrogen - MN) or matured cattle manure (organic nitrogen - ON). All treatments were treated against a background of P and K. The level of soil moisture was controlled by means of daily pot weighing. Lucerne cv. Victoria was grown for seeds. Dry aboveground mass was recorded (dried at 60°C). Nitrogen in dry mass was calculated as a product of dry mass and total nitrogen content (determined by standard method). The total content of nitrogen in yield was calculated as a sum from this in aboveground and root mass. The experimental data were statistically analysed using ANOVA Excel for Windows 2003.

Results and discussion

Dry root mass of lucerne increased by a relatively low amount for mineral fertilizing (by 6%), and significantly more (by 34 and 24%) for manure after mineral and manure fertilization at the doses of 70 and 210 mg N kg^{-1} soil (Vasileva, 2008). Mineral and manure fertilization, applied under optimal moisture at the dose of 70 mg N kg^{-1} soil, increased productivity of dry aboveground mass by 29 and 44%, respectively (Table 1). The increase of productivity of dry aboveground mass was greater at the dose of 210 mg N kg^{-1} soil.

Table 1. Dry aboveground mass and nitrogen in yield of lucerne after mineral and manure fertilization

Treatments	Dry aboveground mass g pot^{-1}	C1 compared to C2 %	Nitrogen in aboveground mass mg kg^{-1} dry mass	C1 compared to C2 %
		optimal moisture (75-80% FC)		
N0PK (C1)	38.84	-	219.52	
MN70PK	50.00	+29	315.00	+44
ON70 PK	55.80	+44	335.47	+53
MN210 PK	46.45	+20	287.25	+31
ON210 PK	48.60	+25	247.08	+13
SE (*P* = 0.05)	2.75		21.32	
		water deficiency stress (37-40% FC)		
N0PK (C2)	27.00	-	223.45	-
MN70PK	31.40	+16	254.34	+14
ON70 PK	35.50	+31	297.06	+33
MN210 PK	41.20	+53	280.00	+25
ON210 PK	45.20	+67	308.44	+38
SE (*P* = 0.05)	3.27		15.30	

Results showed that water-deficiency stress slightly decreased the quantity of dry aboveground mass at the higher doses for both fertilizers (7-11% decrease). Nitrogen in yield at dry aboveground mass under the conditions of optimal moisture content was higher when applied manure at the dose of 70 mg N kg^{-1} soil, followed by the application of mineral fertilizer at the same dose. Increase to the unfertilized control was 53% and 44%. Under the conditions of water-deficiency stress, nitrogen in yield was the highest for the treatments with manure, and increases to the unfertilized control were 33% and 38%.

The total N content in yield (dry aboveground mass and dry root mass) is shown in Figure 1. Under the optimal moisture, it was the highest at the dose of 70 mg N kg^{-1} soil for the both fertilizers tested. Under the conditions of water deficiency and applied mineral fertilizer the total content of N in the yield at the dose of 70 mg N kg^{-1} soil was unchanged. The applied manure in two tested doses increased total content of N in yield by 31%.

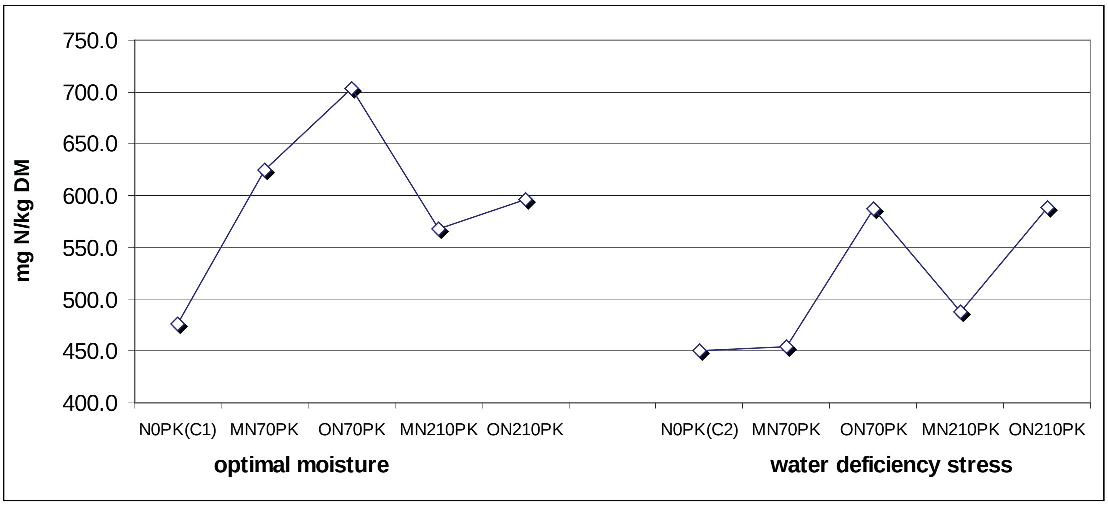

Figure 1. Changes in total nitrogen content of lucerne after mineral and manure fertilization

Water-deficiency stress decreased total content of N in the yield by 27% at a dose of 70 mg N kg^{-1} soil applied as mineral fertilizer, but for the untreated control it was 31%. For the higher dose of mineral fertilizer, 210 mg N kg^{-1} soil, the decrease in total content of N in the yield was as low as 14%.

Conclusions

Nitrogen in the dry mass of lucerne grown for seed under conditions of water-deficiency stress increased by 33 and 38% for organic fertilizer, applied at doses of 70 and 210 mg N kg^{-1} soil. The total content of nitrogen in the yield (dry aboveground and root mass) increased by 9% for mineral fertilization and by 31% for manure, at the doses of 70 and 210 mg N kg^{-1} soil, respectively. Both doses of manure contribute to overcoming the depressive effect of water-deficiency stress on the nitrogen content in lucerne.

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Irrigated meadows and virtual water: the case study of Greece

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Abstract

Water scarcity and society's urgent need for increasing water quantity and quality - considered to be very significant public goods -, force scientists and policymakers to reexamine and exclude water-demanding cultivations from areas with water scarcity. The concept of virtual water (green and blue), provides a significant task towards rational usage and utilization of natural resources. The revision of CAP measures and the increasing demand for quality goods makes it necessary for Greek farmers to invest in the quality of animal products, not quantity, in order to survive. Thus, they need to re-discover the wealth and the value of vegetation of the natural grasslands in conjunction with the creation of meadows. However, which plants should be used for the creation of these meadows? What are their needs in virtual water? These questions need to be answered, which is achieved better through the economic science (scarcity cost, negative externalities, opportunity cost). This paper examines lucerne meadows, which consume large amounts of water, and therefore policymakers have to reconsider the potential of replacing lucerne with water-efficient and drought-resistant plant species.

Keywords: lucerne meadows, virtual water (green and blue), public goods

Introduction

The earth's population is expected to double to 12 billion inhabitants by the year 2050. Therefore, the need of proteins for human consumption as well as for feeding domestic animals will dramatically increase. Legumes are expected to play a vital role in resolving this problem, as far as the production of proteins of plant origin is concerned. Plants such as soya, vetch, peas, lucerne and trefoils seem to be of higher importance compared to other legumes. Beyond their nutritional value, these legumes also fix atmospheric nitrogen, which assists in sparing nitrogenous fertilizers, thus protecting the environment from nitrate losses to ground water. However, legumes require serious quantities of water for their growth, either from precipitation or from irrigation. In semi-dry areas such as Greece, the water from precipitation is not adequate, which makes irrigation necessary in order to increase crop yields. On the other hand, 'managing water is highly capital-intensive, and capital is also scarce' while 'there are environmental consequences to almost any intervention in the water cycle whilst the economy depends upon the environment' (Green, 2003). In Greece, the importance of rural economy is reflected in the fact that 20% of the country's economically active population is employed in agriculture (Latinopoulos, 2005). Moreover, 38.2% of the country's overall agricultural land can be potentially irrigated but only 31.4% is irrigated at the moment (Eurostat, 2009). It is estimated that 86% of the overall consumption of water is spent in agriculture. Lucerne is the main hay crop in Greece, cultivated on more than 150,000 ha. Most of this area is irrigated in order to ensure high yields. This crop is mainly used for feeding livestock during the winter months. The present paper examines lucerne production in Greece in the context of virtual water, and analyses its connection to the economic parameters and the protection of the environment.

Materials and methods

In terms of this research, we took into account Greek and international literature as well as conclusions of scientific conferences and meetings. The basic tools used for the analysis are virtual water and the estimated water needs for irrigation of lucerne production.

Results and discussion

1. Virtual water

Virtual water is the water consumed but also incorporated in a product during its production process (Alan, 1998). There is actually a virtual flow of water from the exporting towards the importing countries. It is implicit that countries that possess large stocks of water may produce goods that demand consumption of great amounts of water; conversely, it is advisable for countries with small water supplies to import the above products and dispose their water to other uses. Meanwhile, the policy of restructuring agriculture production and utilizing pastures in a more effective way should start on the basis of the amount of virtual water attributed to the various products (Christodoulou, 2005). When examining the water spent on the production of goods it is significant to focus not only on the amount of water consumed but also on the source from which it is drawn. More specifically, emphasis needs to be given on the percentages of the consumed water, namely either 'green water' or 'blue water'. Green water comes from precipitation or is contained in the soil in the form of moisture. Both precipitations and moisture may be used directly by the plants and do not have alternative uses. Blue water is collected through costly constructions (dams, transportation networks, etc.) as well as through groundwater. It has several alternative uses in economic activities beyond agriculture and a higher socioeconomic and environmental result.

2. The revised CAP

The international trends and the new CAP (2004) suggest that lands cultivated with cotton should be released and used as artificial pastures, livestock farms, or for the establishment of manufacturing units in the livestock husbandry sector, or a combination of all of the above. Subsidies should not depend anymore on the volume of production, while special attention has to be attributed to the protection of the environment and public health on behalf of producers. Within this framework, various proposals have been made, such as converting these lands (about 40,000 ha) into lucerne meadows (Mylona, 2004).

3. Irrigated meadows

The artificial meadows in Greece are distinguished into those established in communal lands and those in privately owned lands. The latter are further distinguished into rainfed and irrigated ones. They cover an area of 150,000 ha of which 111,000 ha are lucerne meadows with an annual hay production of 1.2 Mg (NSSG, 1999). There is very high production of lucerne on privately owned arable lands with irrigation and the amount of water used there is determined on the basis of soil type, the climate conditions, the age of cultivation, the season of irrigation etc. (Kontsiotou, 2005). Depending on the soil texture, the amount of water per irrigation required is 800-1,200 m^3 ha^{-1} (for sandy soils 1,000 m^3 ha^{-1}; for sandy-loamy soils 1,200 m^3 ha^{-1}; and for loamy soils 1,800 m^3 ha^{-1}). The establishment of lucerne requires at least 5 irrigations/year; namely, 1-2 irrigations in the spring and 2-3 irrigations in the summer, if it is cut 5-7 times between May and September (Papakosta-Tasopoulou, 2005). Therefore, for 6 cuttings $year^{-1}$ the annual requirements in water of lucerne range between 12,000 and 24,000 m^3 ha^{-1}. It is obvious that large amounts of water are spent but the question that remains unanswered is to which category they belong (blue or green water) and which are the exact proportions among them. This depends mostly on the specific area, the altitude and the seasonal distribution of precipitation within a year. While examining the blue/green water proportion, a series of question arise once more: Is irrigated water offered to farmers for use at a low price, through government subsidies? If yes, these low prices do not reflect the scarcity cost of the source or the respective externalities from a possible over-pumping of water. Has the opportunity cost of this water been determined and, consequently, its best alternative solution? Prochaska *et al*. (2008) for instance, have found that if Thessaly (in central Greece) imported cotton instead of exporting it (as it does today), and if it produced more vegetables and edible plants instead of importing them, we would save at least 540 million m^3 $year^{-1}$ water. Thessaly is the principal agricultural region of Greece and suffers the most from water-scarcity, while at the same time it exploits its water recourses principally through agricultural activities, by producing and exporting agricultural products, mainly industrial crops and cereals, which require a lot of water. On the other hand, it imports goods, mainly arable crops, vegetables and olives, whose water needs are not so high (Prochaska *et al*., 2008). Obviously, these three economic parameters (scarcity cost, externalities, opportunity cost) constitute crucial elements that every decision-maker should take into account.

Conclusion

Virtual water may and should be used as a key tool by decision-makers concerning the production of lucerne and the rational use of water resources. Due to the fact that the amount of virtual water used in the production of lucerne is large it is necessary to re-examine its use, taking into account the opportunity cost and the water shortages. If blue water contributes significantly to the production of lucerne in a specific area then its production should be reviewed. If the price of irrigated water remains low for farmers due to government subsidies then these low prices definitely do not reflect the scarcity cost of the resource or the respective externalities from over-pumping of water. The economic and environmental significance of blue water should constitute the basis for decision-making because it has many environmental uses, high cost of usage and negative environmental consequences.

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Influence of hay or silage on cow-milk fatty acid composition

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Abstract

Hay or silage was fed to cows to investigate the influence on the fatty acid contents in the milk. Forage of the first growth from the same plot was either ensiled in square bales with dry matter contents (DM) of 39% (A) and 57% (B), respectively, or conserved as hay dried by barn ventilation (C). After an adaptation period of two weeks with the same forages for all cows, the two silages and the hay were fed to three groups of 10 cows for three weeks. The cows were supplemented with concentrate according to their milk production. The conservation method influenced the DM intake of the roughage, but not total feed intake. The average milk production amounted to 22.4, 23.7 and 22.5 kg for the groups A, B and C, and these differences were not statistically different. The group fed the silage containing 39% of DM (A) had less saturated fatty acids and more unsaturated fatty acids in the milk in comparison to the hay (C) or the high dry matter silage group (B). The highest CLA-content was also found in treatment A (A: 0.63; B: 0.42; C: 0.53 g 100 g^{-1} fat). Differences in omega-3 fatty acids in milk were not statistically different among the three groups.

Keywords: conservation method, silage, hay, fatty acid content, CLA, Omega-3

Introduction

Studies reporting a direct comparison of the effect of forage conservation method on milk fatty acid profiles are limited (Huhtanen *et al*., 2010). Morel *et al*. (2005 and 2006) showed that the proportion of saturated fatty acids (SFA) in milk of cows fed silage or hay was higher than in milk of cows fed with green grass. In addition to the conservation method, both the botanical composition and the age of the forage, also influence the fatty acid profile in milk fat (Wyss and Collomb, 2007). The wilting process during hay making, and to a lesser extent during ensiling, decreases some fatty acids in the forage due to oxidative losses and leaf shatter (Dewhurst *et al*., 2006).
The objective of this study was to investigate the influence of the conservation method on the fatty acid composition in the forage as well as in the milk fat.

Materials and methods

In 2008, forage of the first growth from a ley from the same plot cut at the same development stage with 62% of grasses (mainly *Lolium perenne*, and 36% of clover, *Trifolium pratense* and *Trifolium repens*) was conserved. Part of the forage was pre-wilted and ensiled in square bales with dry matter contents of 39 (A) and 57% (B). The rest of the forage was dried by barn ventilation (C).
The three produced forage types A, B and C were used in a feeding trial with 30 middle- and late-lactating dairy cows in total. Cows were allotted to treatments according to their milk production and milk composition. The adaptation period lasted two weeks during which the cows were grazing half of the day and were supplemented with hay (hay K) and concentrates. During the last four days of the adaptation period the cows had no access to pasture. The experimental period lasted three weeks. The three forage types were fed *ad libitum*. Five kg of hay

K was offered in addition to concentrate and minerals varying according to milk production. Feed intake was recorded automatically using the roughage intake control system of Insentec BV (Marknesse, The Netherlands) and a concentrate dispenser.

Samples of the fresh grass at cutting and of the conserved forages during the experimental period were collected to determine the nutrient contents as well as the fatty acid composition. Crude fat in forages was assayed by the Berntrop method. For the fatty acids, fat was extracted using a mixture of dichloromethane and methanol and analysed by gas chromatography. Milk yield was registered twice a day. Milk samples were taken once a week and analysed for milk composition. After the adaptation period, as well as in the third week of the trial, milk samples of every cow were taken and the fatty acid composition in the milk fat was analysed. The milk fat composition was analysed according to Collomb and Bühler (2000). Results were analysed by analysis of variance and Bonferroni test.

Results and discussion

The conservation method significantly influenced the ash, crude protein, crude fibre, sugar and energy contents of the three forages (Table 1). With respect to the fatty acid concentrations, no differences were found for palmitic (C16:0), stearic (C18:0) and oleic (C18:1) acids; this was in contrast to linoleic (C18:2) and linolenic (C18:3) acids, which differed significantly. In comparison to the fresh grass, fatty acid contents were generally higher in the conserved forage types except for C18:3 in hay. Obviously, the DM content, i.e. pre-wilting degree, and fermentation intensity influence fatty acids. Similar effects were found by Morel *et al*. (2005 and 2006).

Table 1. Chemical composition and fatty acids in experimental feedingstuffs.

	Hay K	Concentrate	Fresh grass	Silage A	Silage B	Hay C	SE	Sig.[1]
Dry matter (g kg^{-1})	880	877	168	375[c]	534[b]	875[a]	9.7	***
Ash (g kg^{-1} DM)	99	48	76	90[a]	87[a]	79[b]	1.1	**
Crude protein (g kg^{-1} DM)	147	120	124	152[a]	137[b]	128[b]	2.7	**
Crude fibre (g kg^{-1} DM)	282	28	196	236[a]	234[ab]	224[b]	2.3	*
Sugar (g kg^{-1} DM)	92	44	140	62b	136[a]	142[a]	5.9	***
Fat (g kg^{-1} DM)	23	24	27	26	18	19	3.2	ns
NEL (MJ kg^{-1} DM)	5.3	8.0	6.2	5.9[a]	5.9[a]	5.7[b]	0.02	**
C16:0 (g kg^{-1} DM)	1.88	3.39	1.69	2.42	2.23	1.97	0.12	ns
C18:0 (g kg^{-1} DM)	0.18	0.36	0.15	0.20	0.20	0.18	0.01	ns
C18:1 (g kg^{-1} DM)	0.33	4.63	0.27	0.40	0.34	0.30	0.03	ns
C18:2 (g kg^{-1} DM)	1.84	13.64	2.14	2.79[a]	2.54[ab]	2.15[b]	0.09	**
C18:3 (g kg^{-1} DM)	5.84	0.79	9.67	11.46[a]	10.18[ab]	8.33[b]	0.33	**

[1] The statistical analyses were only calculated for the three forages A, B and C; SE: standard error
ns: not significant; * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$

Table 2. Feed intake.

	Adaptation period					Experimental period				
	Silage A	Silage B	Hay C	SE	Sig.	Silage A	Silage B	Hay C	SE	Sig.
Cows	10	10	10			10	10	10		
DMI hay K (kg)	17.8	17.6	16.9	0.77	ns	2.1[ab]	2.5[a]	1.5[b]	0.21	**
DMI forage A-C (kg)	-	-	-	-	-	15.4[ab]	14.4[b]	16.5[a]	0.49	*
Concentrate DM (kg)	1.9	1.9	1.7	0.53	ns	1.6	1.9	1.9	0.56	ns
Minerals DM (kg)	0.3	0.3	0.3	0.00	ns	0.3	0.3	0.3	0.00	ns
TDMI (kg)	20.0	19.9	19.0	0.95	ns	19.4	19.1	20.2	0.67	ns

DMI: dry matter intake; TDMI: total dry matter intake; SE: standard error; ns: not significant; * $P < 0.05$; ** $P < 0.01$

However, differences should not be overemphasized, as fat extraction in forage may not be complete.

During the adaptation period, feed intake did not differ between treatments (Table 2). The conservation method influenced the dry matter intake of the roughage, but not total feed intake. No differences were found with respect to milk production as well as fat and protein contents during adaptation and experimental periods (Table 3). The highest concentration of saturated fatty acids (SFA), lowest concentration of poly-unsaturated fatty acids (PUFA) and conjugated linoleic acid (CLA) were found in the high DM silage group. The opposite was found in the treatment A. Hay feeding caused intermediate fatty acid profiles. Omega-3 fatty acids there were not affected by forage type. Rouillé and Montourcy (2010) found in their investigation on 17 farms no differences in SFA, MUFA and CLA between hay and grass silage diets. There was only a significant difference for PUFA.

Table 3. Milk production, milk composition and fatty acid profiles.

	Adaptation period					Experimental period				
	Silage A	Silage B	Hay C	SE	Sig.	Silage A	Silage B	Hay C	SE	Sig.
ECM (kg d^{-1})	22.0	22.8	21.6	1.58	ns	22.4	23.7	22.5	1.74	ns
Fat content (g kg^{-1})	40	42	39	1.80	ns	45	46	43	1.90	ns
Protein content (g kg^{-1})	34	34	34	0.80	ns	35	35	35	0.80	ns
SFA (g 100 g^{-1} fat)	61.48	63.24	61.93	0.89	ns	63.57^{b}	66.34^{a}	65.20^{ab}	0.60	*
MUFA (g 100 g^{-1} fat)	22.41	21.15	21.80	0.75	ns	20.35^{a}	18.66^{ab}	18.32^{b}	0.54	*
PUFA (g 100 g^{-1} fat)	4.10	3.79	4.00	0.15	ns	3.74^{a}	3.29^{b}	3.71^{ab}	0.12	*
CLA (g 100 g^{-1} fat)	0.89	0.90	0.89	0.07	ns	0.63^{a}	0.42^{b}	0.53^{ab}	0.04	**
Omega-3 (g 100 g^{-1} fat)	1.36	1.22	1.31	0.08	ns	1.40	1.29	1.52	0.07	ns

SE: standard error; ECM: energy corrected milk; ns: not significant; * $P < 0.05$; ** $P < 0.01$

Conclusions

- Grass silage (39% of DM) and hay produced from the same plot and cut at the same stage of development differed in nutrient and fatty acid contents, particularly with respect for C18:2 and C18:3.
- The conservation method influenced the dry matter intake of the roughage, but not total feed intake.
- The SFA, MUFA, PUFA and CLA concentrations in the milk fat varied depending on the conservation method.

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Management of young cattle on alpine pastures using a GPS-based livestock tracking system

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Abstract

On two alpine pastures, 36 young cattle (19.2 livestock units (LU)) were managed using a GPS-based livestock tracking system (LTS) on 8 animals. The LTS showed a static accuracy between 7.5 and 11.2 m (median deviation from true position). The position of the LTS at the neck (*dorsal vs. lateral*, tested on one animal) had a significant influence on the median number of received records (88.2% *vs.* 33.3%). During 64 d, a median ratio between 42.9% and 87.5% of the expected records of the other 7 LTS could be received. The total labour input for livestock control, especially for the unforeseeable task "searching for animals" could be reduced for the whole season by 3.9 h LU^{-1} or 4.8 h $head^{-1}$. Significant differences were found for the hourly walked distances between the groups and the alpine pastures. Areas used and preferred by the cattle could be clearly identified. The grazing management of heterogeneous and large alpine pastures benefits to a high degree from the use of a LTS.

Keywords: livestock tracking system, alpine farming, labour input, grazing management

Introduction

There are a number of publications about studies that have worked with, developed and/or tested GPS-based livestock tracking systems (LTS) on cattle, sheep or goats (e.g. Clark *et al*., 2006). LTS can be used to monitor the activity of livestock (e.g. walked distance, speed, grazing and resting time (e.g. Trotter *et al*., 2010)), the habitat preferences (e.g. grazing sites and intensity, resting sites (e.g. Putfarken *et al*., 2008)) and thus to support the herdsman. In several cases the LTS was additionally supplemented with sensors for heat and/or health monitoring (e.g. Nagl *et al*., 2003). So far, all tested LTS were prototypes. Therefore, many of them were only suited for experimental use, because of difficult handling, limited energy supply and/or the lack of appropriate software. Since a few years, two LTS for use in practice, Hotsure (Hotgroup, South Africa) and GPRS-Terminal (Telespor, Norway), are commercially available. The aim of this study was to examine the GPRS-Terminal on two alpine pastures grazed by young cattle. The static accuracy and the number of correctly received position records were controlled. The effects of the LTS on labour input, its potential for monitoring cattle activity and for improving the grazing management could be evaluated.

Materials and methods

Two Austrian pastures, Koglalm (1,290 m above the Adriatic) and Seekaralm (1,475 m above the Adriatic), were the location for the evaluation. They were characterised by open areas (Koglalm 8 ha, Seekaralm 40 ha) and mixed areas with pasture and trees (Koglalm 40 ha, Seekaralm approx. 250 ha). Grazing started in early summer at Koglalm (7 June 2010), and after a month the animals moved on to Seekaralm. Before they came back to the valley (11 Sept. 2010) they spent another fortnight at Koglalm. Traditionally, the cattle were grazing from late afternoon throughout the night till mid morning and were housed during the day.

During grazing, the 36 animals (19.2 livestock units (LU)) from two farmers split themselves into four groups, one group of heifers and calves for each farmer with 6, 8, 9 and 13 animals. Eight animals, at least one in each group, were equipped with a LTS (GPRS-Terminal). Each LTS was programmed to send one record every hour to a web database via general packet radio service (GPRS), containing the geographical coordinates (WGS1984) of the current position and a time stamp. Data were recorded with 8 LTS from 20th June to 28 August 2010. The Telespor web page, Google Earth and a simple software tool (Cow2KML, geo-konzept) were used by the herdsman to check data and to visualise the position of the animals. There was no additional navigation system to guide the herdsman to the animals. The static accuracy of the position record was measured for ten LTS on Seekaralm. The share of correctly received records compared to the expected records was evaluated for 7 LTS that were fixed in *dorsal* position at the neck during 64 d. Additionally the effect of the carrying position, *lateral* (25 d) *vs. dorsal* (27 d) at the neck, on this ratio was investigated with two LTS fixed simultaneously at one animal. Evaluations about the areas used for grazing and possible consequences for grazing management were carried out with ArcGIS (Version 9.3, ESRI Inc.). The minimum distance walked by the animals per hour was evaluated for each group, using the mean hourly positions of the group during seven days in each month. Labour input was manually recorded by the herdsman in 2009 (without LTS, 86 d) and in 2010 (with LTS, 68 d). Thirty-five young cattle (23.4 LU) were grazing in 2009, 36 in 2010 and grazing dates were similar. In 2009 the herdsman had to search for the animals for inspections and in the morning to bring them back to the barn. In the afternoon he had to bring the animals out of the barn and sometimes he drove them to certain places (e.g. with high productive pasture), hoping they would stay there until the next morning. During 2010 (with LTS) the herdsman knew where the animals were and searching or driving was not necessary. Statistical analyses were carried out in SAS 9.1 (SAS Institute Inc.) and significance was declared at $P < 0.05$.

Results and discussion

The static accuracy of the GPRS-Terminals varied from 7.5 to 11.2 m (median horizontal deviation from true position) with maximum deviations between 22.4 and 67.4 m. Similar results (99.9% of points within 20 m, UNEtracker II collar) were reported from Trotter *et al*. (2010). Agouridis *et al*. (2004) found under open field conditions lower horizontal deviations from the true position (mean maximum deviation = 8.83 m, Lotek collar). When using post-processed corrected data, the horizontal accuracy could even be higher (Clark *et al*., 2006, Clark ATS). However, the static accuracy of the LTS was sufficient for the herdsman to locate the animal groups. The percentage of correctly received position records compared for two LTS at one animal showed significant differences between the positions *lateral* (median = 33.3%) and *dorsal* at the neck (median = 88.2%). For all other LTS, the same ratio showed that the LTS with the poorest accuracy also had the lowest number of received records (median = 42.9%). Two LTS, that were, according to the herdsman, not always at the *dorsal* position, had medians below 70%. These three LTS differed significantly from the remaining LTS, which had a median ratio of received records between 80.0 and 87.5%. Therefore, a perfect fit of the LTS at the animal and regular checks are necessary. During 2009, the herdsman needed, on average, 3.12 h d^{-1} for getting the animals into the barn. This figure decreased on average to 2.38 h d^{-1} in 2010 with the LTS, saving 0.73 h d^{-1}, because there was no need for searching and additional inspections. Furthermore, the herdsman could check in the morning where the animals were located and in which direction they were walking. In case the animals were already walking towards the barn, he regularly checked their position and waited for them to come closer to the barn before he started to get them into the barn. For the afternoon activities the herdsman saved 1.20 h d^{-1}, because he saw no necessity of driving the animals but also a change in routine was contributing to the time savings. The total labour input for the whole grazing period could be reduced from 21.4 h LU^{-1} in 2009 to 17.5 h LU^{-1} in 2010 or from 14.3 h $head^{-1}$ to 9.5 h $head^{-1}$, respectively (total labour input in 2010 extrapolated to 86 d). Compared to the labour input needed on lowland farms for young cattle, the labour input in a mountain area, even with a LTS, is still on a very high level. However, the often unforeseeable and especially in bad weather conditions strenuous searching activities for animals could be avoided with the LTS. Therefore, the LTS can contribute to an easier scheduling of all activities during grazing on alpine pastures. The minimum distance walked by the animals per hour differed significantly between the alpine pastures and between the groups. During seven days in June (Koglalm) the animals walked on average 78.9 ± 22.0 m h^{-1}, whereas during seven days in August (Seekaralm) the animals walked significantly further (100.4 ± 24.8 m h^{-1}). Over all months there were also significant differences between the heifers (87.8 ± 19.4 m h^{-1}) and calves (85.7 ± 21.2 m h^{-1}) of farmer A and the heifers of farmer B (102.5 ± 27.0 m h^{-1}). Compared to other evaluations (Trotter *et al*., 2010: steers walking 216 m h^{-1}), they were not walking fast. Geographical evaluations of the mean group positions during seven days in July and August showed that the cattle first grazed the open areas without trees close to the barn and only searched for grass in the more remote areas partly covered with trees during the last month. This indicates that it would be necessary to guide or to fence the animals in a way that they gradually climb from the lower towards the higher areas according to the growth of the grass in order to have always the best fodder quality. Furthermore, some areas on both alpine pastures were not grazed during 2010.

Conclusions

LTS are an appropriate tool to improve grazing management and to reduce labour input and workload. Further technical development is necessary to enhance the number of received position records. Reduced energy consumption would provide a system with an increased data rate and avoid battery changes during the grazing season. Implementation of bidirectional communication would help the herdsman for faster animal location. Before the LTS can be widely used, user-friendly software with different analysis options (e.g. daily walked distance or grazed areas) is needed also for mobile devices. The completion of LTS with the functions of a virtual fence would lead to an even more sophisticated grazing management.

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Persistency of *Festulolium loliaceum* strains in comparison with other species depending on the method of utilization

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Abstract

There are no perfect grass species that combine persistency, stability of yields and nutritive value. Breeders constantly search for better grass species and cross-breeding of genera within the *Lolium*-*Festuca* complex is an important direction of research. It is relatively easy to obtain *Festulolium braunii* hybrids, while the breeding of *Festulolium loliaceum* hybrids is much more difficult and breeding a persistent and stable variety is shown by the fact that there are only a few in a world. The studies were carried out in 2002-2010 in Sosnowica (eastern Poland). Two methods of utilization (grazing and simulated grazing) and 6 mixtures containing the species tested (*Poa pratensis*, *F. braunii*, *F. loliaceum* - 2 strains, *Lolium perenne* and *Festuca pratensis*) were included. The strains were bred at the Institute of Plant Genetics PAS in Poznań. *Festulolium loliaceum* hybrids showed a high persistency, which indicates a considerably higher share in the sward in comparison with the share in the seed mixture. After 8 years of studies, a high share of *L. perenne*, *F. braunii* and *P. pratensis*, and a significantly lower share of *F. pratensis* were observed among the species tested.

Keywords: *Festulolium loliaceum*, grazing, simulated grazing

Introduction

The development of new cultivars with improved persistency, including tolerance to a range of abiotic and biotic stresses, is one of the most important goals of current research. Recently, attention has focused on the crossing of *Lolium* and *Festuca* species to obtain hybrids exhibiting many desirable traits of both parents. As a result, some *Festulolium* cultivars (*Festuca pratensis*×*Lolium multiflorum*) have been developed in Europe and the USA (Humphreys *et al*., 2003; Cernoch *et al*., 2004). It is relatively easy to obtain *Festulolium braunii* hybrids, whereas the breeding of *Festulolium loliaceum* (*F. pratensis*×*Lolium perenne*) hybrids is much more difficult. Many morphological traits of *F. loliaceum* are similar to *L. perenne* (e.g. spike-like inflorescence), but visual distinction is possible due to the occurrence of an inner glume within the hybrids' spikelet (Kulik *et al*., 2005). The degree of difficulty in breeding a persistent and stable variety is shown by only 4 amphiploid cultivars (FuRs9806, Prior, Saikava, Sping Green) and 3 resulting from introgression (Barfest, Duo, Matrix), but only one (Spring Green) is registered in OECD Festulolium list (Cernoch *et al*., 2004; Ghesquière *et al*., 2010). The first *F. loliaceum* cultivar was Prior (Lewis *et al*., 1973), which was tested in Europe (Akgun *et al*., 2008) and hybrid plants found to be more productive than parental species, as well as in the USA (Casler *et al*., 2001; 2002). In America hybrids are characterized by the higher yielding and ground cover in comparison to *F. braunii*. The 'Spring Green' cultivar was registered as a result of its high suitability for North American climate conditions. However, *F. braunii* hybrids accounted for 85% of its genealogy, while *F. loliaceum* (Prior cv.) for as little as 15% (Casler *et al*., 2001). For many years, studies on this hybrid have also been conducted in Poland, which has led to the breeding of several strains that have been subjected to field experiments. Thus far they have not been registered as cultivars due to the relatively low seed setting (seed yield).

Materials and methods

The studies were carried out in 2002-2010 in Sosnowica (eastern Poland) on mineral soil. Experiments were set up on pasture in split-plot design with 4 replications of 15m² plots. Two methods of utilization (grazing and simulated grazing) and 6 mixtures containing the species tested were taken into account (Table 1). The strains were bred at the Institute of Plant Genetics PAS in Poznań. Breeding materials were developed at the Szelejewo Plant Breeding. During 9 years of studies controlled fertilization (N - 75, P - 31 and K - 75 kg ha^{-1}) was applied. Pasture sward was grazed by Limousine cattle 5-6 times during the grazing season, and the ‘simulated grazing’ was cut the same time. The sward species composition was determined by botanical-weight analyses. Results were analysed by means of Tukey’s Least Significant Difference (LSD).

Table 1. Species composition of mixtures in the year of sowing

No.	Species tested in mixture	Share in cover (%)	Weight share (kg ha^{-1})	Constant components	Share in cover (%)	Weight share kg ha)
1	*Poa pratensis* cv. SKIZ	30	7.1	*Phleum pratense*	35	6.4
2	*Festulolium braunii* cv. Felopa	30	12.3	cv. Obra		
3	*Festulolium loliaceum* strain I spreading type	30	10.2	*Dactylis glomerata*	10	2.0
4	*Festulolium loliaceum* strain II erect type	30	10.8	cv. Areda		
5	*Lolium perenne* cv. Solen	30	9.1	*Trifolium repens*	25	5.5
6	*Festuca pratensis* cv. Skra	30	26.9	cv. Romena		

Results and discussion

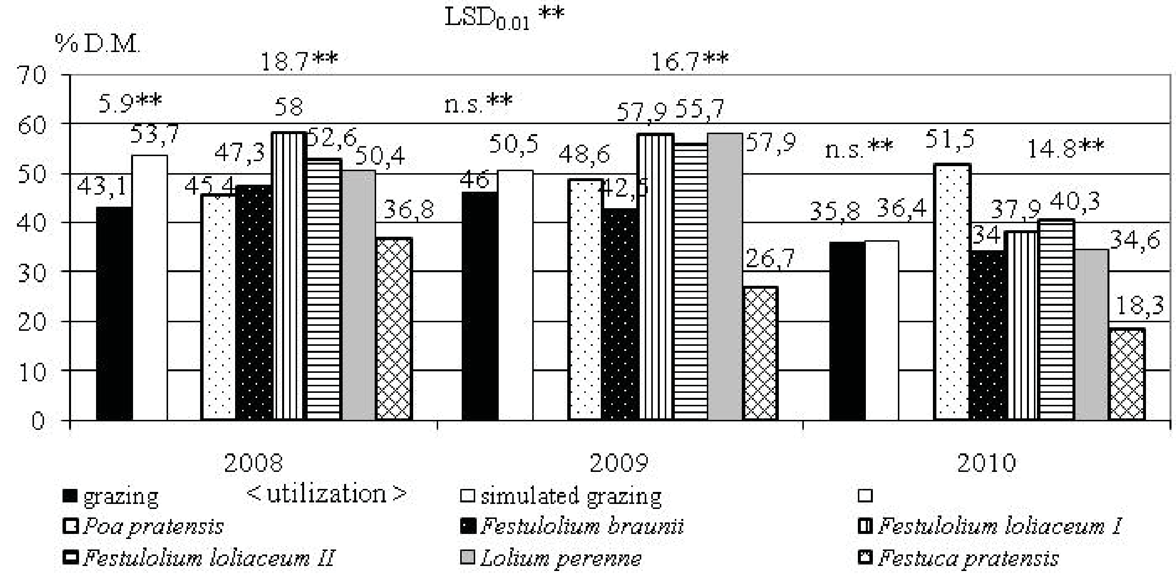

Figure 1. Share of tested species dependence on utilization method

Regardless of the type of use, the *Festulolium loliaceum* strains were characterized by a higher share in the sward in the years 2008-2010 (*Fl* I - 37.9-58.0%; *Fl* II - 40.3-55.7%) compared with the amount of seeds sown. In 2008-2009, the share of these hybrids was higher than for other species (though differences not statistically significant, except for *F. pratensis*). All species tested had a significantly higher share in the sward than *F. pratensis*. In 2010, *P. pratensis* had the highest share in the sward (51.5%). The persistence of the hybrids was similar to *Festulolium braunii*, *L. perenne* and *P. pratensis*, and much greater than *F. pratensis*, the parent species. Similar patterns were observed in 2002-2007 (presented in Kulik, 2009). In the year of sowing *P. pratensis* had a small share, but in the following years it became increasingly dominant. Furthermore, *Dactylis glomerata* was an aggressive species in mineral soil conditions, and *Phleum pratense* decreased in the sward (Kulik, 2009). The findings of the 9-year field experiment indicate a strong persistence of the hybrids, which confirms their suitability for grassland mixtures. From the perspective of persistence, the strains tested could be registered as original cultivars. In this case, however, the low seed yield still poses a problem. It confirms a difficulty in breeding a persistent and stable variety (Ghesquière *et al*., 2010). Despite considerable differences in the share of the individual species in the sward, the results of the LSD test were very high. This can be explained by the high variance between replicates, possibly due to the randomly distributed effects of treading and cattle excreta. The share of the species in the study years was higher in the 'simulated grazing' sward than in the grazing sward, but differences were significant only in 2008. In 2002-2007 higher shares of *L. perenne* and *Trifolium repens* were observed (Kulik, 2009).

Conclusions

Regardless of the type of use, the *Festulolium loliaceum* strains were characterized by a higher share in the sward in the years 2008-2010 compared with the amount of seeds sown. The persistence of the hybrids was similar to *F. braunii*, *L. perenne* and *P. pratensis*, and much greater than *F. pratensis*, the parent species. The findings of the 9-year field experiment indicate a strong persistence of the hybrids, which confirms their suitability for grassland mixtures. From the perspective of persistence, the strains tested could be registered as original cultivars. In this case, however, the low seed yield still poses a problem.

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Effects of biogas digestates on the above and below ground biomass of *Lolium perenne* L.

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Abstract

The integrated fuel and biogas production from biomass system (IFBB system) holds the potential of utilizing lignified biomasses and thereby maintaining the plant diversity of extensive grassland areas. The system separates the silage into an indigestible and lignin-rich solid fraction used as solid fuel and a digestible liquid fraction used in a biogas plant. We compared the effects of the IFBB-generated digestates (IFBB) with whole-crop digestates (WCD) and mineral N fertiliser (MIN). A five-month, completely randomised pot experiment with perennial ryegrass (*Lolium perenne* L.) was conducted under standardized conditions in a greenhouse. Fertilisers were applied at five N application levels: 0, 50, 100, 150 and 200 kg N_{min} ha^{-1}. The aboveground biomass (harvestable biomass and stubble biomass) and the root biomass were assessed at three consecutive cutting dates. Dry matter (DM) yield of the accumulated harvestable biomass showed values from 0.34 up to 0.71 kg m^{-2}. MIN produced the highest DM yields and showed, as well as WCD, a positive correlation across the whole range of application levels. Application of IFBB resulted in an increase in DM yield up to the 150 N-level, and no further rise at higher fertiliser levels.

Keywords: pot experiment, grassland, dry matter yield, perennial ryegrass, biogas slurry

Introduction

Conventional use of biomass from extensive grasslands for energy production is associated with undesirable effects. Due to high lignification, this biomass is of low nutritional value to methanogenic archae and the production of biogas. Furthermore, the combustion of grassland biomass results in high nitrogen oxide emissions and causes corrosion processes in the furnace (Hartmann, 2001). The integrated fuel and biogas production from biomass system (IFBB system) overcomes these restrictions by separating the silage into an indigestible and lignin-rich solid fraction used as solid fuel, and an easily digestible liquid fraction used for biogas production. This allows the utilization of lignified grassland biomass and therefore supports an extensive cutting management, which is favourable for high plant diversity. The IFBB-generated digestate, usable as fertiliser, differs mainly from conventional whole-crop digestates in having lower dry matter and organic matter contents. There is a lack of knowledge concerning the effects the IFBB-generated digestate on plant production. The aim of this study was to compare the effects of the IFBB-generated digestate, a whole-crop digestate and mineral N fertiliser on above-ground and below-ground dry matter (DM) yield.

Material and methods

A five-month pot experiment with a fully randomised design was conducted with perennial ryegrass (*Lolium perenne* L.) in a greenhouse at the University of Kassel/Witzenhausen. Standardized Kick-Brauckmann pots (diameter 21 cm, surface area 346 cm², height 25.5 cm) were filled with air-dried and sieved (5 mm) loamy sand (9.9 kg FM per pot) with an organic carbon and total nitrogen content of 9.06 g kg^{-1} and 0.76 g kg^{-1} respectively. The sowing date was the 25.06.2010. After 40 days of growth and two initial cuts to initiate tillering, three fertiliser types were applied nonrecurring and in four replicates: (i) an IFBB-generated digestate (IFBB), (ii) a whole-crop digestate (WCD) and (iii) a mineral N fertiliser (MIN). The fertilisers were applied at five N-levels: 0, 50, 100, 150 and 200 kg N_{min} ha^{-1}. Due to the heterogeneity of digestates, the actual N_{min}-rates (nitrate-N and ammonium-N) varied among the fertiliser types (50 N-level: mean 55.2 N_{min} kg ha^{-1}, standard deviation (sd) 4.6; 100 N-level: mean 110.9 N_{min} kg ha^{-1}, sd 9.9; 150 N-level 166.1 N_{min} kg ha^{-1}, sd 14.5; 200 N-level: mean 221.3 N_{min} kg ha^{-1}, sd 19.1). The pots were irrigated biweekly to up to 80% of the water holding capacity with demineralised water. Harvestable biomass was assessed at 3 cm above ground and at three consecutive cutting dates. Additionally, stubble biomass and root biomass were assessed at the third cut for the 0, 100 and 200 N-level. The roots were washed over sieves (1 mm) with cold water. DM of the plant fractions was measured after drying at 60°C for three days. To reveal effects of N_{min} application and fertiliser types a two-way ANOVA was conducted with N-level and fertiliser type as factors.

Results and discussion

DM yields of all plant fractions increased with increasing N-level (Figure 1). Corresponding to that, the ANOVA revealed significances ($P < 0.001$) for N-level on the DM yields for all plant fractions (Table 1). The accumulated DM yields of the harvestable biomass for the three cuts showed mean values from 0.34 up to 0.71 kg m^{-2}. The ANOVA revealed no significant effect of fertiliser type on accumulated DM yield of harvestable biomass and stubble biomass, although NH_3 losses can not be ruled out, especially for the digestates. The results suggest that above-ground biomass was not influenced by the fertiliser types when similar N_{min} rates were applied. These findings are consistent with results reported in a field experiment analysing DM yields of *L. perenne* after application of whole-crop digestate and mineral N fertiliser (Wienforth *et al*., 2009). However both WCD and MIN showed a linear positive response across the whole range of N-levels, while IFBB levelled off above 150 N-level (significant N × F interaction ($P < 0.05$) on harvestable biomass).

Table 1. Results of ANOVA for the effects of N-level (N) based on Nmin and fertiliser type (F) and their interaction on different plant fractions of *L. perenne*. Harvestable biomass as the sum of the DM yields of three cuts, stubble and root biomass at the third cut and total biomass as the sum of the three fractions. Significant effects at $P < 0.05$; ns: no significant effects.

	Harvestable biomass		Stubble		Roots		Total biomass	
Source of variation	F-value	*P*-value	F-value	*P*-value	F-value	*P*-value	F-value	*P*-value
N	231.2	< 0.001	21.9	< 0.001	19.0	< 0.001	191.7	< 0.001
F	2.5	ns	0.4	ns	12.2	< 0.001	8.7	< 0.01
N×F	2.5	< 0.05	0.2	ns	4.8	< 0.01	3.0	< 0.05

Fertiliser type obviously affected root and total biomass as the sum of all plant fractions. MIN produced the highest root DM yields with a mean of 0.25 kg m^{-2}, whereas WCD produced 0.21 kg m^{-2} and IFBB only 0.16 kg m^{-2}. With increasing N-level, the increase in root DM yield was more pronounced in the order MIN > WCD > IFBB (significant N×F interaction on root biomass). The root:shoot ratio was 0.25 for IFBB, 0.30 for WCD and 0.36 for MIN at the 200 N-level. Salminen *et al*. (2001) found an inhibition of root growth after digested material application, caused by organic acids present in the digestates. This may have occurred also in the present study, explaining lower total and harvestable biomass production at the 200 N-level for the digestates.

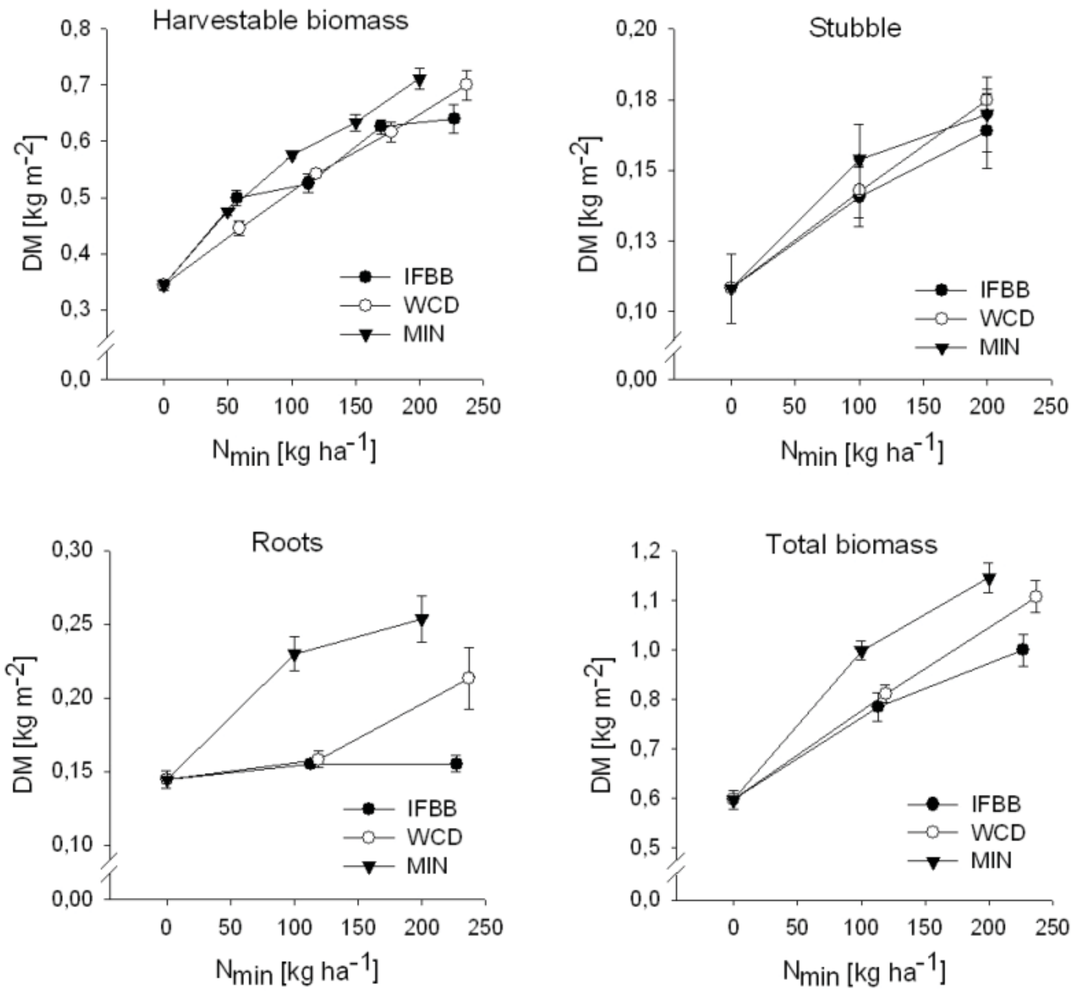

Figure 1. Mean DM yields of different plant fractions of *L. perenne* after 105 days of plant growth and three cutting dates in a greenhouse with differing mineral N-input for IFBB, WCD and MIN. Harvestable biomass as the sum of the DM yields of three cuts, stubble and root biomass at the third cut and total biomass as the sum of the three fractions. Error bars describe standard errors of means; n = 4.

Conclusion

The results of the present study indicate a lower root yield along with similar above-ground biomass yield for digestate application as compared to mineral N fertiliser application. This highlights the relevance of below-ground biomass for the assessment of fertiliser effects on plant growth. Further research will focus on parameters which characterise the turnover of carbon and nitrogen in the soil-plant system.

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The effect of soil type and age on yield in grass fields on dairy farms

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Abstract

Ten perennial forage grass fields in northern Iceland, differing in age (two classes) and soil profile (four classes), were selected on three dairy farms that have excellent records of cultivation history and manure/fertilizers applications. On each grass field one factorial experiment was laid out with four rates of nitrogen (N) and phosphorous (P) treatments in three replicated randomized plots. All plots were cut twice during the growing season for dry matter (DM) yield and nutrient recovery determination. At the same fertilizer rates, old grass fields gave higher DM, N and P yield compared to young grass fields ($P < 0.0001$) with the exception of grass fields on old histosol, which gave lower DM yield compared to young grass fields on histosols. It was concluded that the observed variation in total DM, N and P yield could mostly be explained by variable age and inherent soil fertility levels in the studied grass fields.

Keywords: Sub-arctic dairy farming, fertilizing rates, grass fields, N, P recovery, DM yield

Introduction

Dairy farming in Iceland is based on on-farm grass feed production from semi-permanent cultivated fields. The majority of these grass fields are 10 to 50 years old, while the remainder are in rotation with barley or other annual crops. The fields receive annually high amounts of nutrients from cattle manure and industrial fertilizers which are only partly recovered with the harvest (mowing and/or grazing). The Icelandic agricultural soils are mostly of volcanic origin, and histosols, histic andosols and brown andosols are common. In North Iceland vitrisols on moraines (cambic) and riverbeds (sandy) are also common. Long-term grass fields that receive manure frequently and fertilizers annually are known to accumulate organic matter and nutrients in the topsoil, particularly in cold regions. This results in changes in soil properties with time, which has consequences for plant growth and nutrient use. The aim of this study was to quantify possible changes in chemical soil composition over time in grass fields on different soil types and its effect on nutrient uptake. This paper will only deal with DM, N and P uptake.

Materials and methods

Experimental plots were established in the spring 2009 on total ten selected forage grass fields on three dairy farms in the Hörgá valley, North Iceland. Meteorological information during the growing season for this area is shown in Table 1. The climate in the area can be described as maritime and cool but dry. Midsummer drought on lighter mineral-rich soils is often a limiting factor for plant growth and soil mineralization. Dominating forage species varied between grass fields, with timothy (*Phleum pratense*), meadow grass (*Poa pratensis*), meadow foxtail (*Alopecurus pratensis*) and tufted hairgrass (*Deschampsia caespitosa*) were the main species. The fields were grouped into four soil classes (histosol [3 fields], brown andosol [2 fields], cambic vitrisol [3 fields], sandy vitrisol [2 fields]) and two age classes (< 10 years old [4 fields], > 30 years old [6 fields]). On each grass field one factorial experiment in three randomized replicated 2×6 m plots was laid out with four different rates of N-P fertilizers: 0N-0P, 30N-3P, 60N-6P or 90N-9P kg ha^{-1}, on grass fields that had received approximately 30 t ha^{-1} cattle

slurry after the growing season in 2008 and before the 2009 growing season. Plots on grass fields that did not receive any slurry before the growing season in 2009 received: 0N-0P-0K, 40N-3.6P-7K, 80N-6.6P-15K or 120N-9.9P-22K kg ha^{-1}. The fertilizer was applied during 9-16 May 2009. All plots were cut twice during the growing season for dry matter yield and nutrient recovery determination. Combined top soil samples for chemical analyses were taken with 5 cm deep probes after the second cut in all plots that did not receive fertilizer.
Standard statistical regression models and variance analysis were used to determine the effect of soil class (4), age (2) and fertilizer rate (4) and their interactions on total DM, N and P yield. Non significant interactions were excluded from the models.

Table 1. Meteorological data from Möðruvellir Station (at 65°46.239'N. 18°15.080'W), which is within less than 14 km radius from all experimental sites, during the growing season.

	2 m air temperature °C			Soil temperature °C		Precipitation
Month	mean	max.	min.	5 cm	10 cm	mm
May	7.0	18.2	-3.2	6.1	4.7	24
June	9.4	19.8	-1.6	11.5	10.4	15
July	11.0	23.2	-0.1	13.2	12.5	17
August	10.1	20.0	-0.7	12.3	11.9	47
September	7.1	20.3	-4.8	9.0	9.3	56
Mean/total in 2009	8.9	20.3	-2.1	10.4	9.7	159
15-year mean	8.7					135

Results, discussion and conclusion

Old grass fields were richer in organic matter (ignition loss, C and N) and minerals than younger grass fields within the same soil class, with a few exceptions in sandy vitrisol (Table 2). This is in agreement with European studies in intensively managed grasslands that show marked increase in soil organic matter with time (Sørensen, 2004; Schröder *et al.*, 2007; Riley, 2008).
Total DM, N and P yield was significantly ($P < 0.0001$) affected by soil and age classes (Table 3). The statistical model, including significant interactions, explained 89%, 85% and 83% of the variation in DM, N and P yield, respectively. Soil classes explained 37%, 43% and 18%; age classes 18%, 24% and 50%; and fertilizer rate 17%, 29% and 25% of the variation in total DM, N and P yield, respectively. Interactions between soil and age classes were significant ($P < 0.0001$) due to different response in grass fields on histosols from other soil classes, particularly in DM yield.
Average DM yields, and N and P yields, were lowest in fields on cambic vitrisols and highest on fields on histosols, being 3.6 and 5.8 t DM ha^{-1}, 77 and 136 kg N ha^{-1} and 9.4 and 14.1 kg P ha^{-1}, respectively (Table 3). Similar differences in DM and N yield between mineral-rich and organic soils were reported by Vellinga *et al.* (2010). DM, N and P yields were higher in old fields than in young fields in three out of four soil classes. DM yields in old fields on histosols, compared to young fields on histosols, were 5.0 and 6.6 t ha^{-1} respectively. However, there was no difference in N and P yield between old and young fields on histosols (Table 3). The biggest difference in DM yield between old and young fields was on sandy vitrisols, of 6.1 and 3.6 t DM ha^{-1}, respectively.
These results are useful in fertilizer management for grass fields in this area of Iceland, since they allow discrimination between fields based on age (and history) and soil type. N-P fertilization can be reduced on well-managed and fertilized old grass fields compared to young grass fields, particularly on histosols.

Table 2. Soil description at the 10 experimental sites and soil analysis mean values from combined top 5 cm cores taken after second cut in plots that did not receive fertilizer.

Soil class	[1]Age class	Ignition loss %	pH	Soil content, g kg^{-1} DM C[2]	N[2]	P[3]
Histosol	old	58	5.2	296	23	0.15
Histosol	young	43	5.1	206	14	0.06
Brown andosol	old	43	5.6	212	17	0.12
Brown andosol	young	23	6.1	100	7	0.05
Cambic vitrisol	old	56	5.3	241	19	0.17
Cambic vitrisol	young	27	5.9	126	10	0.04
Sandy vitrisol	old	15	5.5	64	4	0.12
Sandy vitrisol	young	23	5.2	109	9	0.11
Means (and s.e.)	old	43 (1.7)	5.4 (0.02)	203 (14)	16 (1.0)	0.14 (0.01)
	young	29 (2.0)	5.6 (0.02)	135 (17)	10 (1.1)	0.07 (0.02)

[1] old = more than 30 years old, young = less than 10 years old since first cultivated
[2] by Dumas combustion method
[3] Ammonium lactate (AL) soluble fraction measured with ICP

Table 3. The effect of soil and age class on dry matter (DM), nitrogen (N) and phosphorus (P) yield in 10 field experiments on grasslands. Least square means of four N-P fertilizers rates.

Soil class	[1]Age class	DM yield t ha^{-1}	[2]s.e.	N yield kg ha^{-1}	[2]s.e.	P yield kg ha^{-1}	[2]s.e.
Histosol	old	4.98	0.10	136	3.3	14.1	0.4
Histosol	young	6.58	0.14	136	4.6	14.1	0.5
Brown andosol	old	4.63	0.14	97	4.6	13.3	0.5
Brown andosol	young	3.75	0.14	59	4.6	8.7	0.5
Cambic vitrisol	old	4.08	0.10	92	3.3	12.1	0.4
Cambic vitrisol	young	3.11	0.14	63	4.6	6.6	0.5
Sandy vitrisol	old	6.06	0.14	107	4.6	14.7	0.5
Sandy vitrisol	young	3.56	0.14	88	4.6	10.4	0.5
Means	old	4.94	0.12	108	4.0	13.6	0.4
	young	4.25	0.14	87	4.6	10.0	0.5
Model fit (R^2)		0.89		0.85		0.83	
P (both soil and age classes)		<0.0001		<0.0001		<0.0001	

[1] old = more than 30 years old, young = less than 10 years old since first cultivated
[2] s.e. = standard error

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Seasonal changes in nutritive value of the understory vegetation of an open coppice oak forest during the grazing period

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Abstract

The purpose of this study was to investigate the effect of grazing on the nutritive value of the understory vegetation of an open coppice oak forest grazed mainly by goats during the growing season. The research was conducted in Evros prefecture, northeast Greece. A lightly grazed experimental plot of utilization percentage (UP = 18%) was selected. An area of 25 m² in the plot was fenced in the autumn of 2008, in order to be protected from grazing. Hand-plucked samples from the grazed plots and the protected ones were collected at monthly intervals from April to June and October. The chemical composition of the understory vegetation samples was determined and their *in-vitro* digestibility (IVOMD) was assessed. As a result of maturation, CP and IVOMD decreased, whilst neutral detergent fibre (NDF) and acid detergent lignin (ADL) content increased from April to June, for both grazing and protected plots. Grazing resulted in significantly higher CP and IVOMD of the regrowth vegetation in October. Generally, the light grazing increased the nutritive value of understory vegetation, mainly in the early stage in April and on the regrowth in October.

Keywords: silvopastoral system, grazing intensity, small ruminants, forage quality

Introduction

Oak forests, mainly the open coppice ones, are grazed by livestock, as silvopastoralism is well adapted to the Mediterranean environment (Papanastasis *et al*., 2009). Management of oak coppice forests by livestock grazing could utilize properly the forest‘s potential (Tucker, 2008) as both understory herbaceous and ligneous species contribute to animal nutrition. Moreover, as the forest's canopy delays plants' maturity, it provides higher nutritive value forages, especially during critical periods of the year (Papachristou *et al*., 2005). Therefore, understanding the influence of livestock grazing on nutritive value of understory vegetation in open oak ecosystems is an important tool for a sustainable management through the seasons. In the present study the seasonal effects of small-ruminant grazing on the nutritive value of the understory vegetation of an open coppice oak forest were investigated.

Materials and methods

The study was carried out in an open coppice forest (*Quercus frainetto*) in the area of Pentalofos which is located in Evros prefecture, northeast Greece at 200 m a.s.l. This area was grazed by 200 sheep and 950 goats. The climate of the area is classified as sub-Mediterranean, with a mean air temperature of 13.7°C and an annual rainfall of 560 mm. The understory vegetation consisted of 25% shrubs, 34% grasses and 41% forbs. An area of 25 m² in the forest was fenced in the autumn of 2008, in order to be protected from grazing. Hand-harvested samples of the understory vegetation were collected in 2009 at three vegetative stages: vegetative, elongation and reproductive (in the middle of April, May, and June respectively) and at regrowth (early October) in protected and grazed areas by sampling in three and six quadrats (of 0.5×0.5 m) quadrats respectively (Cook and Stubbendieck, 1986). The samples were oven-dried at 60°C for 48 hours and weighed in order to calculate the utilization percentage of vegetation as the difference between the protected and grazed production (Cook and Stubbendieck, 1986). The dried samples were ground through a 1 mm screen and analysed for N using a Kjeldahl procedure (AOAC, 1990). Crude protein (CP) was then calculated by multiplying the N content by 6.25. Additionally, neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) were determined according to Van Soest *et al*. (1991). *In-vitro* organic matter digestibility (IVOMD) of the samples was determined the using Tilley and Terry (1963) method as modified by Moores (Harris, 1970). General linear models procedure (SPSS 14) was used for ANOVA, and the difference among means was detected by LSD at the 0.05 probability level (Steel and Torrie, 1980).

Results and discussion

Forage utilization was found to be 18%. This finding indicates light grazing, probably due to the small number of head of livestock that exist in the experimental area.

Table 1. Monthly variation of chemical composition (g/kg DM) and IVOMD (g/kg DM) of hand-harvested samples in grazed (G) and protected (P) areas

	CP		NDF		ADF		ADL		IVOMD	
	G	P	G	P	G	P	G	P	G	P
April	211^{a}	208^{a}	494^{de}	409^{f}	257^{c}	201^{d}	45^{d}	53^{cd}	830^{a}	809^{b}
May	119^{c}	141^{b}	566^{bc}	462^{ef}	316^{b}	260^{c}	57^{cd}	74^{a}	526^{e}	619^{d}
June	97^{d}	103^{d}	543^{cd}	616^{ab}	367^{a}	375^{a}	64^{ab}	59^{bc}	407^{g}	414^{g}
October	116^{c}	95^{d}	246^{g}	633^{a}	148^{e}	378^{a}	28^{e}	72^{ab}	789^{c}	461^{f}
LSD	11		61		37		13		11	

* Means for the same component followed by the same letter are not significantly different ($P \leq 0.05$)

Season had a significant effect on all nutritional parameters, whilst grazing affected NDF content and the IVOMD ($P < 0.05$). Additionally, there was a significant interaction of grazing × season ($P < 0.001$). The CP content (g/kg DM) of the understory vegetation was higher in April and declined with the advancement of maturity (Vázquez-de-Aldana *et al.*, 2000) in both the grazed and protected plots. However, CP content tended to be higher in the protected plots compared to the grazed ones, but significant difference was detected only in May. This could be explained by the fact that the plants in the protected plot in this vegetative stage had more leaves, which have higher content of CP than stems (Mero and Uden, 1997), whereas the vegetation of grazed plots consisted mainly of stems. Conversely, CP of regrowth vegetation in October was significantly higher in grazed than in protected plots. Similar results have been reported by Papachristou *et al*. (2005).

At the same time, there is an increase due to maturity (Jacobs *et al*., 1998) in NDF, ADF and ADL contents ($P < 0.001$) from April to June in both grazed and protected plots.

Moreover, at the early stages (April and May) NDF and ADF contents tend to be higher, whereas ADL content was lower in the grazed plots than the protected plots. No significant differences were observed in June. On the other hand, the opposite trend was detected in October. The same trend with CP was observed for IVOMD ($P < 0.001$) in all vegetative stages. It is well documented that maturation causes changes in chemical composition resulting in a decline in digestibility (Van Soest, 1994). Nutritive value was higher in the regrowth in October than in the earlier growth stages, as the IVOMD was higher and the cell wall components were lower, while the vegetation had similar CP contents. Light grazing increased the nutritive value of understory vegetation mainly at early stage in April and on regrowth in October.

Conclusions

Although grazing can control the growth of vegetation and its regrowth, it seems that light grazing did not maintain the nutritive value at high levels except at early stage in April and in October.

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Cover of species and leaf area index of a regional mixture after the application of soil amendments

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Abstract

A model project for the reclamation of a problematic area (sandy soil, drought locality) has been running at a location in Ratíškovice, Czech Republic, since 2008. This project includes the use of soil amendments for the reclamation of unfavourable soils. A regional multi-species mixture was used for improving biodiversity. In the experiment the effect of the soil amendments (hydroabsorbent, lignite and zeolite) on the cover of species, density, visual quality and leaf area index (LAI) of the regional mixture was studied. The use of soil amendments had no significant influence on LAI. The LAI differed significantly between measuring dates, but not between soil improvement additive treatments.

Keywords: hydroabsorbent, lignite, zeolite, leaf area index, growth

Introduction

This project is concerned with options for the use of soil amendments, plants and lesser known drought-tolerant grasses and clovers for the recultivation of dry soils in the conditions of South Moravia (in the south of the Czech Republic), where critical water shortages are already occurring in places. The project goal was to propose remedial measures for increasing ecological stability and biodiversity in the region. This contribution offers partial results and includes the evaluation of soil amendments and their effects on selected characteristics.

Soil amendments are increasingly being used during the establishment and treatment of herbage in problematic areas, mainly in cases where the structure and other properties of the soil are not in an optimum state for the development of plants (Straka and Straková, 2003). The use of amendments is also effective in revitalising dumps after mining operations (Straková *et al*., 2009). A soil amendment is a substance with no active amount of nutrients that affects soil in a biological, chemical or physical way, improves its condition or enhances the efficiency of fertilisers.

Materials and methods

The experiment was organised in randomized blocks with three replicates in 2008. The size of each plot was 864 m^2. Before sowing, the soil amendments - hydroabsorbent, lignite and zeolite - were applied to the soil. The potassium-based hydroabsorbent copolymer (polyacrylate, in the form of Agrisorb) was applied at 20 g m^{-2}. Lignite is, geologically, the youngest and least-carbonised brown coal and it was applied (in the form of TerraClean) at a dose of 1,000 g m^{-2}. Zeolite is a crystalline hydrated aluminosilicate of alkaline metals and alkaline earth metals (applied dose of 3 l m^{-2}). The experiment also featured a control treatment without the application of any improvement additive. The seeding rate of the mixture was 10 g m^{-2} and the botanical composition was: grasses 69.5%, clovers 26.75% and herbs 3.75%. The growth was mulched twice a year (in June and at the end of the vegetation season).

Site description: soil - arenic regosol; soil texture - sandy.
Low water retention capacity; extremely high aeration; soil pH 4.54.
Precipitation: long term annual average precipitation 569 mm; 355 mm of precipitation per vegetation period.
The cover of sown species, weed species and bare soil (%) was monitored in 2-week periods in 2010. Density and visual quality of the mixture were evaluated using the following scales:
Density scale: 1 - very sparse, 3 - sparse, 5 - medium, 7 - dense, 9 - very dense
Visual quality scale (all aspects of quality integrated): 1 - very poor, 3 - poor, 5 - medium, 7 - good, 9 - very good.
Three times in 2010 (May, August and October) the leaf area index was measured using a 'SunScan' mobile device (Delta-T Devices, UK). Leaf area index (LAI) is defined as the surface area of leaf vegetation divided by the ground surface area (m^2 m^{-2}). The data were evaluated using the analysis of variance STATISTICA 9.1 (StatSoft Inc., USA).

Results and discussion

The averages of monitored characteristics are shown in Table 1. In the zeolite treatment, the cover of sown species was the highest and the cover of weed species was the least, but not statistically significant. Density of growth was medium and visual quality was medium. There were no statistically significant differences between the soil amendment treatments in these characteristics. Figure 1 shows the cover of species and bare soil in 2-week periods. Generally, the cover of sown species was the highest in June and September in every treatment of soil amendment. The cover of weed species was the highest at the beginning of the vegetation period and the cover of bare soil was high in May and August.
There were no statistically significant differences in LAI between treatments of soil amendments in each term of evaluation. Statistically significant differences were determined between the dates of measurement (Table 2). In October the leaf area index was statistically significantly higher (2.45) than in May (1.58) and August (1.56). The mean LAI of growth in the experiment

Table 1. Cover, density and visual quality of vegetation following different soil amendment treatments

	Coverage (%)				
Treatment	Sown species	Weed species	Bare soil	Density	Visual quality
Control	64.8[a]	15.5[a]	19.7[a]	4.9[a]	5.1[a]
Hydroabsorbent	63.9[a]	15.3[a]	20.8[a]	4.7[a]	5.3[a]
Lignite	64.5[a]	15.0[a]	20.5[a]	4.8[a]	5.3[a]
Zeolite	68.95[a]	11.5[a]	19.5[a]	5.3[a]	5.9[a]

[a] no significant differences ($P < 0.05$)

Table 2. Leaf area index in relation to soil amendment treatments

	Leaf area index (m^2 m^{-2})			
Treatment	May	August	October	Mean
Control	1.77	1.43	2.67	1.96[a]
Hydroabsorbent	1.63	1.73	2.13	1.83[a]
Lignite	1.33	1.60	2.30	1.74[a]
Zeolite	1.57	1.47	2.70	1.91[a]
Mean	1.58[a]	1.56[a]	2.45[b]	1.86

[a,b] different letters denote significant differences between values within a row or column ($P < 0.05$)

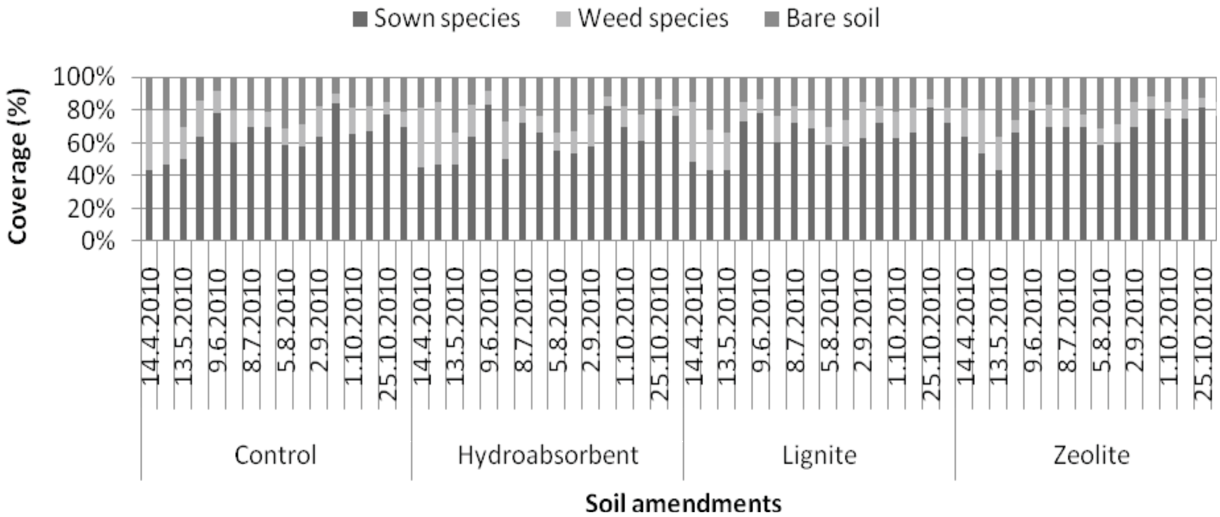

Figure 1. Cover of species after application of soil amendments in 2-week periods

was 1.86. That corresponds with results published by Scurlock *et al*. (2001) who determined a mean LAI 1.71 ± 1.19 m^2 m^{-2} for grassland and 3.62 ± 2.06 m^2 m^{-2} for crops.

Conclusion

In the experiment the impact of soil amendments on the cover of sown species, weed species and bare soil was not detectable two years after establishment. Density and visual quality were not influenced. Differences in leaf area index were detected between dates of measuring, but not between soil amendment treatments.

Acknowledgements

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Influence of liquid nitrogen fertilizer injection (CULTAN) on production potential of grass-clover mixtures

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Abstract

A new system for grassland fertilization (Controlled Uptake Long Term Ammonium Nutrition) has been studied in the Czech Republic at the Jevíčko site. The experiment was established in two sowing cycles: 1st cycle: sown in 2007 and harvested in 2008 and 2009; 2nd cycle: sown in 2008 and harvested in 2009. This paper compares the CULTAN system with a traditional method (wide spreading of mineral fertzilizer) of nitrogen application during the growing period of clover-grasses mixtures. Two clover-grass mixtures with different varieties were compared: 1) grass-clover mixture (Festulolium cv. Perseus 70% and red clover cv. Vltavín 30%, 2) grass-clover mixture (Festulolium cv. Felina 70% and red clover cv. Vltavín 30%). The aim of our study was to improve growing conditions of clover in clover-grass mixtures. Ammonium nitrate (27% N) was spread in the form of granules in the traditional method. The CULTAN method was performed by spraying and injecting of urea ammonium nitrate solution with a spoke wheel injector for field experiments. In both fertilization systems, the mixtures containing the Felina hybrid had higher clover abundance than mixtures with Perseus hybrid. We evaluated dry matter production, quality of forage and clover abundance in the sward.

Keywords: N application technique, dry matter yield, nitrogen, grass-clover mixture, CULTAN

Introduction

N injection is a fertilizer placement with fluids, and became popular in Germany as the CULTAN (Controlled Uptake Long Term Ammonium Nutrition) method starting around 1970. With regard to drinking water protection, it was shown that nitrate concentrations are frequently lower in seepage water after fluid injection compared to conventional broadcast fertilization. The CULTAN method uses a special injection technique to apply nitrogen solu-tions rich in ammonium ions into soil at a depth of 7-20 cm, where it is retained in the spots with high concentration of ammonia, so-called depots (Sommer, 2005, Kücke and Scherer, 2006). This process does not influence the function of rhizobia, which cannot uptake am-monium ions. The aim of our experiment was to compare the influence of different fertilisation techniques: 1. surface spreading, and 2. Injection, on dry matter production (DM), clover abundance and crude protein concentration (CP) between two grass-clover mixtures.

Materials and methods

In 2007 at the Jevíčko site (Czech Republic) an experiment was established in order to compare two systems of nutrition of grass-clover mixtures. The experimental site was at altitude 366 m above sea level, with annual average precipitation 545 mm, annual average temperature 7.4°C, soil type chernozem, and soil class loam of pH 6.6. The experiment consisted of two sowing cycles: 1st cycle: sown in 2007 and the harvest in 2008 and 2009; 2nd cycle: sown in 2008 and the harvest in 2009. Sowing was done without a cover crop [a plot size of 25 m² (20×1.25 m)] in a randomised block design with four replications. Prior to sowing, 30 kg ha^{-1} P as superphosphate (19.6% P) and 90 kg ha^{-1} K as KCl (50% K) were applied. Plots were sown with a mixture of red clover (*Trifolium pratense* L., Vltavín variety) and the loloid hybrid Perseus (*Lolium multiflorum* Lam.×*Festuca pratensis* Huds.) or the festucoid hybrid Felina (*Lolium multiflorum* Lam.×*Festuca arundinacea* Schreb.). The ratio of grass to clover was 70:30. Three levels of fertilization (without N fertilizer, 90 kg ha^{-1} N, 180 kg ha^{-1} N) were compared. N was applied in the form of calcium ammonium nitrate (27.5% N) on the soil surface and as urea ammonium nitrate (30% N), respectively, according to the CULTAN method using the GFI 3A machine (Maschinen- und Antriebstechnik, Güstrow, Germany). While 90 kg N were applied in the spring, 180 kg ha^{-1} N were applied in 3 applications: 90 kg ha^{-1} N in the spring, 60 kg ha^{-1} N after the first harvest and 30 kg ha^{-1} after the second harvest. Swards were cut three times. Plots were harvested with an MPZ-115 small-plot forage harvester with a tensometric weight VZT-3 (Cressto). An average mixed sample was taken from each plot. After drying at 60°C, dry matter yield was determined and the samples were homogenized in a laboratory knife mill Pulverisette 15 (Fritsch) equipped with normalised mesh with circle holes to sieve the particles < 1 mm. The analysis of samples for quality of forage was made using the FOSS NIR Systems 6500 instrument (FOSS NIRSystems, USA). Forage quality was predicted with the WinISI II software (Infrasoft International, USA). Clover content (projective cover) was measured as the percentage cover of red clover in plots (Šantrůček *et al*., 2007). Characteristics were statistically evaluated using a three-factor analysis of variance. The differences among average values were tested with the Tuckey's test. Values within the column marked with the same letter are not statistically different at the level of significance $P < 0.05$.

Results and discussion

The results of dry matter yield, clover abundance and average crude protein concentration of grass-clover mixture are given in Table 1.

The highest increase of DM in response to the fertilizer rate was observed in conventional fertilization for the first harvest year 2008 of the first sowing cycle with Perseus and Vltavín mixture (from 22.2 to 24.1 t ha^{-1}) and in CULTAN fertilization in the first harvest year 2008 of the first sowing cycle with Perseus and Vltavín mixture (from 20.96 to 23.04 t ha^{-1}). A similar tendency was obtained in the second harvest year of the first sowing cycle. Dry matter yield in the injection system was slightly higher as compared to the conventional fertilization. Kozlovský (2010) found similar results but this contradicts the results of Neuberg *et al*. (2010) obtained for pot experiments, who always obtained lower yields in treatments with fertilizer injection of grass-clover mixtures. The plants were more stressed after injection, because the higher root ratio was connected with the depot in the pot than field experiment. Comparing individual hybrids in our experiment, grass-clover mixtures containing the Felina hybrid seem to be more productive. Higher productivity was caused by higher clover abundance in the mixture with Felina hybrid and by higher dry matter yield in the second and the third harvest. Higher dry matter yield of the Felina hybrid, compared to mixtures with the Perseus hybrid, was observed in both fertilization systems. In the second harvest year of the first sowing cycle we observed an interannual decrease of the dry matter yield in all treatments and mixtures. In mixtures with the Perseus hybrid, this decrease was more significant.

We observed a trend of decreasing clover abundance in the mixture with increasing dosage of fertilizer applied conventionally. Fertilisation via CULTAN obviously did not influence the clover abundance. However, at the rate of 180 kg N ha^{-1} applied according to the CULTAN, a decrease of the clover ratio in the mixture was also observed. The highest clover abundance (83%) in the mixture was observed in CULTAN fertilization in the first harvest year of the second sowing cycle with Felina and Vltavín mixture. In both fertilization systems, the mixtures containing the Felina hybrid had higher clover abundance, compared to combination with the Perseus hybrid. This trend was more significant in the first harvest year of both sowing cycles. Due to faster seed emergence of Perseus compared with Felina seeds this led to higher competition of Perseus hybrid with the clover. CP concentration in grass-clover mixtures was balanced in both systems of fertilization, which is in agreement with the results of Neuberg *et al*. (2010). Nitrogen fertilization did not increase CP concentration. The highest CP concentration in a dependence on the fertilizer dosage was observed in CULTAN fertilization in the harvest year 2009 of the second sowing cycle with Felina and Vltavín mixture (from 170.9 to 184.1 g kg^{-1}). In the comparison of Perseus and Felina hybrids, the higher CP content in plants was observed in grass-clover mixtures with the Felina hybrid.

Table 1. Dry matter yield of grass-clover mixtures (t ha^{-1}), average clover abundance (%) and average crude protein concentration (g kg^{-1})

		Dry matter (t ha^{-1})			Clover abundance (%)			Crude protein (g kg^{-1})		
No.	Treatment	A1	A2	B2	A1	A2	B2	A1	A2	B2
1	K P 0	22.19^{cde}	6.00^{a}	11.95^{a}	39^{ab}	25^{a}	52^{a}	142.6^{a}	139.7^{a}	167.1^{a}
2	K P 90	20.46^{bcd}	7.30^{abc}	12.19^{a}	22^{a}	15^{a}	45^{abc}	137.4^{a}	139.8^{a}	152.7^{a}
3	K P 180	24.06^{e}	8.75^{bcd}	13.50^{a}	25^{ab}	15^{a}	40^{ab}	146.3^{a}	152.6^{a}	158.9^{a}
4	K F 0	19.60^{cde}	7.95^{abc}	12.50^{a}	79^{c}	24^{a}	82^{c}	167.9^{a}	141.3^{a}	181.8^{a}
5	K F 90	21.01^{bcd}	8.85^{bcd}	13.67^{a}	73^{c}	17^{a}	72^{abc}	167.4^{a}	144.0^{a}	176.6^{a}
6	K F 180	19.61^{abc}	10.33^{d}	15.11^{a}	71^{c}	11^{a}	81^{c}	160.7^{a}	148.6^{a}	162.5^{a}
7	C P 0	20.96^{bcd}	6.62^{ab}	12.72^{a}	42^{b}	35^{a}	50^{abc}	148.5^{a}	146.6^{a}	159.4^{a}
8	C P 90	22.30^{cde}	8.02^{abcd}	14.04^{a}	30^{ab}	31^{a}	50^{abc}	143.9^{a}	138.5^{a}	157.4^{a}
9	C P 180	23.04^{de}	8.49^{bcd}	13.90^{a}	26^{ab}	31^{a}	38^{a}	142.0^{a}	149.0^{a}	155.8^{a}
10	C F 0	18.87^{ab}	7.82^{abc}	13.61^{a}	80^{c}	21^{a}	83^{c}	157.5^{a}	140.7^{a}	170.9^{a}
11	C F 90	19.73^{abc}	8.62^{bcd}	14.32^{a}	75^{c}	20^{a}	79^{bc}	165.0^{a}	139.1^{a}	183.7^{a}
12	C F 180	17.31^{a}	9.09^{cd}	14.17^{a}	77^{c}	23^{a}	75^{abc}	164.8^{a}	143.5^{a}	184.1^{a}

K- conventional fertilization, C- Cultan method, P- Perseus+Vltavín, F- Felina+Vltavín, 0, 90, 180- dosage of kg ha^{-1} N, A- sowing 2007, B- sowing 2008, 1- harvest 2008, 2- harvest 2009. Values within the column marked with the same letter are not statistically different at the level of significance $P < 0.05$.

Conclusion

The clover abundance in mixtures was higher in the CULTAN treatments than in conventionally fertilized plots. In both fertilization systems, the mixtures containing the Felina hybrid had higher clover abundance than mixtures with Perseus hybrid. The highest increase of DM in dependence on the fertilizer rate was observed in conventional fertilization for the first harvest year of the first sowing cycle with Perseus and Vltavín mixture.

Acknowledgement

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Shrub invasion management by cattle grazing in the French Massif Central

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Abstract

Scotch broom (*Cytisus scoparius*) frequently leads to shrub invasion in laxly grazed pastoral landscapes of the French Massif Central. The control of young broom is particularly important in cattle-grazed pastures as they cannot overcome adult plants. A five-year experiment on a summer mountain pasture (62 ha, 1000 m elevation, 1.2 Livestock Units per hectare) located in the Auvergne (Central France) studied the impact of cattle grazing on young broom colonization. Broom seedling emergence, survival and dimensions were followed in the pasture under grazed and non-grazed conditions. Results showed that cattle grazing, at the stocking rate used, favoured broom seedling recruitment but had a negative effect on both survival and growth of the young plants. No grazing led to less broom emergence, but strong growth even when grazing was stopped for only one year. Managing this weed with cattle needs a quite high stocking rate soon after mechanical clearing.

Keywords: Scotch broom, shrub invasion, seedlings, cattle grazing, non-grazing

Introduction

Scotch broom (*Cytisus scoparius*) is a pioneer species, able to invade rapidly the extensive grasslands in upland areas of the French Massif Central. Management of this weed generally includes mechanical clearing and grazing in combination. The control of young broom populations is particularly important when clearing of invaded areas is followed by cattle grazing, as disturbed soil conditions favour seedling emergence (Paynter *et al*., 1998) and the grazing pressure of cattle is often not sufficient to overcome adult broom plants (Carrère *et al*., 1999). In order to improve the management of cleared areas and avoid recolonization we studied the impact of cattle grazing on young broom in comparison with a non-grazing system.

Materials and methods

The study took place on a summer mountain pasture for cattle in the Auvergne (62 ha, 1000 m asl) invaded by Scotch broom and mechanically cleared in spring 1999. Broom seedling recruitment (emergence and survival) and dimensions were then investigated for five years in 32 one-square-meter plots. Two cattle-grazed and two non-grazed plots were installed on each of the 8 vegetation facies of the pasture. The 8 sites were chosen to be representative of different previous adult broom density (medium to high) and seed bank in the soil (5,000 to 18,000 seeds m^{-2} on 15 cm). Five of the sites had an additional plot that was displaced each year, to measure the impact of one year of non-grazing. A stocking rate of 1.2 Livestock Units (LU) per hectare per season was applied, which was the optimum needed to maintain these types of grassland (Loiseau, 1991). Measurements were carried out at the beginning (mid-May) and the end (mid-October) of the continuous grazing season. The counting distinguished the emergent seedlings (presence of cotyledons) and the survivors (no more cotyledons but ligneous stems).

The five-year changes in broom populations under both treatments were analysed using the two repetitions' mean in each of the 8 sites. Statistical comparison for each year was performed with the Mann and Whitney U test as the distribution was not Gaussian. Global results based on the means of all sites are presented in this paper. The sites had different numbers of seedlings and survivors but the dynamics were similar.

Results

Figure 1 shows that seedling emergence mainly occurred in spring, with few germinations in autumn. Except in 1999, the number of spring seedlings was always significantly higher in grazed systems, especially in the early years after clearing. The maximum was reached in the second year for both treatments (grazed: 300 seedlings m^{-2}, non-grazed: 77 m^{-2}) and seedling number decreased afterwards. Grazed plots still had some spring germination after five years whilst non-grazed plots had almost no germination after two years.

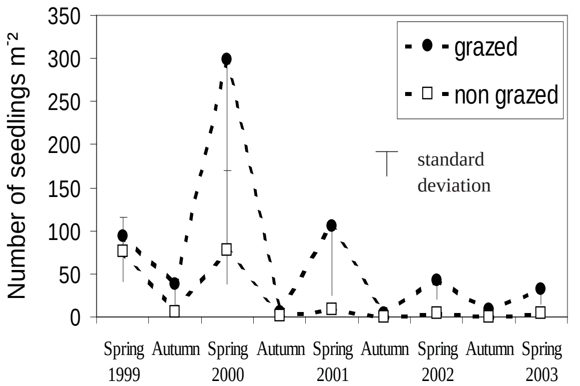

Figure 1. Broom seedling emergence

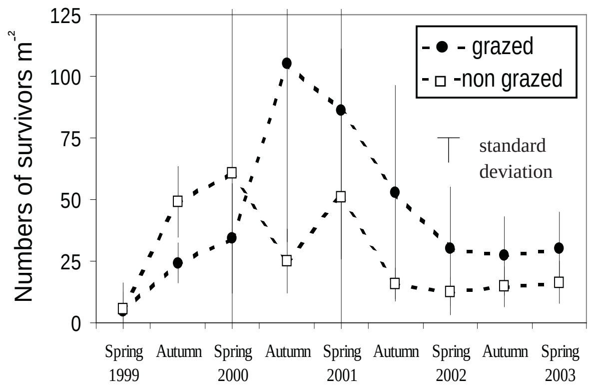

Figure 2. Young broom survival

When considering seedling survival (Figure 2) we noticed that both treatments had an impact on the number of survivors, as populations were lower in autumn than in spring for each year. The number of individuals was significantly higher for the non-grazed plots at the first autumn and then for the grazed plots in the second autumn (100 m^{-2}) which can be related to the spring seedling explosion on these plots in 2000 (Figure 1). Afterwards we observed a decrease in the survivor number for both situations with similar slopes and stable population after the fourth spring. Grazed systems always showed more individuals, with about thirty young broom plants per plot at the end of the experiment against fifteen for non-grazed systems, but the difference was not significant after the two first years.

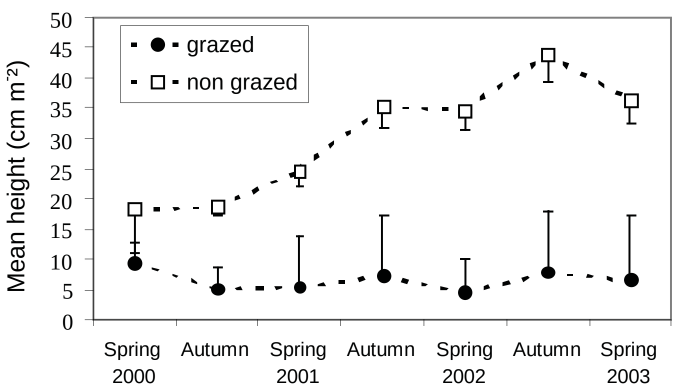

Figure 3. Growth of the young broom survivors under grazed and non-grazed conditions

Figure 3 shows that grazing maintained the brooms' height under 10 cm over five years, whereas the non-grazed treatment presented a continuous growth leading to a mean height of 35 cm in 2003 and much more voluminous brooms. The one-year non-grazed plots also had significant growth with a mean height always exceeding 10 cm (data not shown).

Discussion

One explanation for massive Scotch broom germination is the elevation of soil temperature due to solar radiation (Bossard, 1993). Grazing favours this by reducing vegetation biomass, resulting in more light on the soil and therefore higher soil temperature. In contrast, the litter accumulation observed in non-grazed systems creates shaded conditions less favourable to seedling emergence: two years of litter accumulation were enough to stop germination in our experiment. Survival was also affected as legumes such as broom need light for their growth and to be competitive against grasses (Williams, 1981).

Cattle grazing also had a strong effect on young broom with fewer survivors than in non-grazed systems in the first year after clearing. Even if the final number of individuals was quite similar after five years, grazing had a greater impact on broom survival as there was much more germination (Figure 1). This hypothesis is confirmed when comparing the annual survivors of grazed and one-year non-grazed plots. The number of individuals was the same in spring but always higher in autumn for non-grazed plots. Considering the height of broom plants, grazing maintained it in the grass layer so that brooms were in competition with grass and included in cattle's diet. When grazing was stopped, brooms immediately came out of this layer and had more light for their development. Three years after the end of the experiment, the still non-grazed plots were completely covered with 80 cm-high brooms.

Concerning the management of these areas, our results suggest that grazing should start directly after broom clearance. Although germination and survival will be limited by non-grazing due to competition for light, the few young surviving brooms will quickly grow into big shrubs that cattle will not overcome. Therefore, in order to be efficient, a clearing project needs to involve the farmers from the beginning. The stocking rate then has to be quite high to get the numerous seedlings that are favoured by grazing under control. This is generally not easy in under-grazed areas with a too-low stocking rate. Solutions require reduction of the cleared surface, or managing rotational grazing so as to achieve high stocking density at some periods in the season.

Conclusions

Cattle grazing at the stocking rate in our experiment favoured broom seedlings' recruitment but it controlled the population by having a negative effect on both survival and growth of the young broom plants. The balance obtained with cattle grazing is, however, delicate, as stopping grazing for one year is enough to bring the young broom plants out of the grass layer which enables broom invasion. Management of extensive areas with cattle needs to find ways of grazing or clearing (Poix and Orth, 2005) which permit high-enough stocking rates.

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The influence of nitrogen fertilizer application on the occurrence of couch grass

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Abstract

The occurrence of common couch grass (quackgrass: *Elytrigia repens* (L.) Desv. ex Nevski) in permanent grasslands was investigated during 2003-2009 by means of a small-plot trial. The experiment was carried out 390-402 m above sea level in the conditions of the Hruby Jesenik Mountains in the Czech Republic. The trial was managed with four levels of utilization: intensive (4 cuts per year), medium intensive (3 cuts per year), low intensive (2 cuts per year) and extensive (1 or 2 cuts per year). Four rates of fertilization were applied: nil-fertilization; $P_{30}K_{60}$; $N_{90}P_{30}K_{60}$; and $N_{180}P_{30}K_{60}$ (pure nutrients). Treatments without N fertilization showed the lowest ratio of couch in the swards (6.3%, and 5.8%, respectively; means of 2003-2009). The occurrence of couch in treatment $N_{180}P_{30}K_{60}$ was 5.4% in 2003 and 30.1% in 2009. Increase in couch grass occurred as a response to nitrogen fertilization, and it was most significant in extensively utilised grasslands.

Keywords: permanent grasslands, couch, N fertilization, cutting frequency

Introduction

Common couch grass (also called quackgrass: *Elytrigia repens* (L.) Desv. ex Nevski) is considered a primary noxious weed (Westra and Wyse, 1981). It is highly invasive in cultivated fields and pastures and it is one of the main factors reducing both grass yield and quality. Some cattle producers are discovering its value as forage for early season grazing and for winter feeding as hay. According to Werner and Rioux (1977) as cited in Malhi *et al*. (2003), couch can be used for pasture and hay, and is a preferred species for rangeland because its protein concentration is comparable to timothy at the same growth stage; its roots and rhizomes are also efficient soil binders on slopes, embankments and sandy soils, and it provides cover for wildlife. However, little information is available on how its occurrence changes in response to different grassland management treatments. The objective of this study was to determine the effects of different doses of N fertilizer (ammonium salt with limestone) and different intensities of grassland utilisation (cutting regime) on the occurrence of couch in permanent grassland under the conditions of the Czech Republic.

Materials and methods

A long-term small-plot trial was established in 2003 on permanent grassland sites in the locality of Rapotin (altitude 400 m a.s.l.; annual rainfall 693 mm; mean annual temperature 7.2°C). The locality is in the Hruby Jesenik Mts. geomorphological division of the Czech Republic. The soil is a sandy-loam, described as modal Cambisol with horizons Am-Bv-B/Cc-Cc (Ržonca *et al*., 2006). The grassland was used for cattle grazing before the trial was established. The vegetation at the beginning of the trial was classified as *Arrhenatherion*. The experimental

design was a randomised complete block with four replicates and a plot size of 12.5 m². The trial was managed with four levels of intensity of utilization:
1 = intensive (1st cut by 15 May, 4 cuts per year - cuts at 45-day intervals),
2 = medium intensive (1st cut between 16 and 31 May, 3 cuts per year at 60-day intervals),
3 = low intensive (1st cut between 1 and 15 June, 2 cuts per year at 90-day intervals) and
4 = extensive (1st cut between 16 and 30 June, 1 or 2 cuts per year, 2nd cut after 90 days).
Four levels of fertilization were investigated: A = nil-fertilization; B = $P_{30}K_{60}$; C = $N_{90}P_{30}K_{60}$; and D = $N_{180}P_{30}K_{60}$ (pure nutrients). Phosphorus was applied as superphosphate and potassium as potassium salt once in the spring. Ammonium salt with limestone was used as a nitrogen fertilizer and it was applied twice (in the spring and after the first cut). Before the first cut, the botanical composition was assessed by the method of reduced projective dominance (in %). The results were statistically evaluated by two-way ANOVA (effects of intensity of utilisation, fertilisation and their interactions) using software Statistica CZ v. 10.

Results and discussion

The results for the development of couch (in %) from 2003-2009 are given in Table 1. Grasslands without N fertilization (A and B treatments) showed the lowest ratio of couch in the swards (6.3%, and 5.8%, respectively; means of 2003-2009). In contrast, treatments C and D (with N fertilization) had large and significant effects on increase in percentage cover of couch. The highest dominance of couch in the swards was found in treatments fertilized with 180 kg N ha^{-1} (D treatments: N_{180}PK -20.3%; mean of 2003-2009). From the viewpoint of intensity of utilization or cutting frequency, increasing the number of cuts reduced the rate of couch in the swards by up to about 4.5%. The development of couch was significantly affected by the N-fertilization, confirming results of Oerlemans *et al*. (2005); an influence of cutting frequency, and an interaction between fertilization and cutting frequency, was also found (Table 2).
If we speculate on the reasons for our findings, the investigations of McIntyre and Cessna (1998) who studied the growth and development of the rhizome and lateral rhizome buds in couch may be relevant. These authors provided evidence that the C:N ratio may be an important morphogenetic factor in the mechanism controlling the path of bud and rhizome development. The effect of the N supply on growth of couch and its ability to compete by means of rhizome and lateral rhizome bud development may also be fundamental to our findings of couch dominance in permanent grasslands using different management strategies.
Couch has the ability to reproduce vegetatively (by means of rhizomes) and sexually, and luxury uptake of nutrients and possible allelochemic toxins may also make it a strong competitor (Bandeen and Buchholz, 1967). Producers might consider utilizing couch for hay or pasture if the production and quality could be maintained at a reasonable level. Hrabě and Buchgraber (2004) recommend that couch be tolerated in meadow stands for hay production at amounts of 12-15%. From this viewpoint and on the basis of our results attained in the trial conditions, we can conclude that this requirement could be met for the low intensive grassland management by the fertilization with the dose 90 kg ha^{-1} of nitrogen.

Conclusion

Our results showed that regular dosing with nitrogen, particularly under conditions of extensive grassland utilisation had a large significant influence on increasing couch dominance in the swards. Low intensive grassland utilization and the dose 90 kg ha^{-1} of nitrogen led to the maintenance of the occurrence of couch at the reasonable level up to 15%. These finding are

Table 1. Rate [%] of *Elytrigia repens* depending on cutting frequency and fertilization

	Year								
Treatment	2003	2004	2005	2006	2007	2008	2009	Mean	SD
1A	1.8	6.3	4.0	3.8	2.0	2.3	2.3	3.2	1.6
2A	2.8	7.0	3.3	3.8	5.0	8.8	2.3	4.7	2.4
3A	7.0	8.8	8.0	13.3	6.8	10.0	5.3	8.4	2.6
4A	7.0	10.3	9.0	12.0	9.8	8.8	6.5	9.0	1.9
1B	0.6	3.5	2.5	4.3	1.6	3.3	2.0	2.5	1.2
2B	5.6	8.0	2.5	5.0	4.0	3.8	3.5	4.6	1.8
3B	4.8	14.5	11.5	10.0	7.0	6.3	6.0	8.6	3.5
4B	10.5	10.0	8.3	8.3	4.5	5.5	5.3	7.5	2.4
1C	0.6	7.0	3.1	5.0	2.5	5.3	3.3	3.8	2.1
2C	4.8	8.3	9.0	13.0	5.3	5.0	7.0	7.5	2.9
3C	4.5	17.3	18.3	18.5	14.5	15.0	14.3	14.6	4.8
4C	8.5	20.8	26.8	36.0	30.5	27.3	18.3	24.0	9.0
1D	1.6	7.5	3.8	9.3	11.0	16.3	9.8	8.4	4.8
2D	2.0	8.3	10.3	21.0	22.8	22.5	22.5	15.6	8.6
3D	6.0	13.8	22.0	31.3	43.3	29.3	49.0	27.8	15.3
4D	12.0	25.0	29.5	32.0	41.0	28.0	39.0	29.5	9.6

Cutting frequency: 1 = 4 cuts/yr, 2 = 3 cuts/yr, 3 = 2 cuts/yr, 4 = 2 or 1 cut/yr; Fertilization: A = non-fertilization, B = $P_{30}K_{60}$, C = $N_{90}P_{30}K_{60}$, D = $N_{180}P_{30}K_{60}$ (pure nutrients); SD = standard deviation

Table 2. *P*-value of the analysis of variance of the parameter rate of *Elytrigia repens*

	Year							
Effect	2003	2004	2005	2006	2007	2008	2009	Mean
cutting frequency	0.00001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
fertilization	0.90509	0.00400	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
cuting fr.*fert.	0.74349	0.05475	0.00736	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

important for the appropriate grassland management and maintenance of the optimal botanical composition of permanent grasslands.

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Phedimus stoloniferus: a problematic alien species detected in Swiss grasslands

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Abstract

Phedimus stoloniferus (S.G. Gmelin) 't Hart is a succulent plant native to the Caucasus region, where it thrives in open woodlands. Recently, we detected this species in Switzerland. It is an aggressive neophyte that out-competes native grassland species, strongly hampering agricultural use of invaded grasslands. *P. stoloniferus* easily propagates through its stolons, which can still become established after being detached from the mother plant for many days. A survey to assess habitats colonised by *P. stoloniferus* showed that the species invaded a wide range of grassland and woodland habitats in the northern Prealps between 400 and 1000 m a.s.l. Thus it could become a threat to agricultural production and conservation of biodiversity in large areas of Europe. In field experiments, we tested different herbicides as well as alternative control strategies. However, even repeated herbicide applications did not totally eliminate *P. stoloniferus*, which recovered from axillary buds and recolonised the sward. Successful eradication was only achieved by covering the affected area with black plastic for four months, a control strategy with very limited applicability. Therefore at present, early detection and prevention of its propagation in new areas is the only control option.

Keywords: invasive neophyte, habitat, range, control method, herbicide

Introduction

In 2006, a dairy farmer from the Northern Swiss Prealps sought advice because of an unknown plant causing major problems in his grassland. The species was not yet described in the Swiss Flora, and therefore we sought expertise from the Botanical Garden of Zurich, where it was identified as *Phedimus stoloniferus* (S.G.Gmelin) 't Hart (Stutz *et al*., 2008), a *Crassulaceae* native of Caucasus, North-Iran, North-Persia and Anatolia. In its native range it mainly colonises open woodland habitats at altitudes from 600 to 2150 m a.s.l. (Acar, 2003; Eggli, 2003). At infested Swiss farms this succulent species negatively affects forage production in three ways: firstly, the species produces a very tight network of stolons that prevents forage species to produce high yields. Secondly, it increases the risk of sliding when mechanically harvesting forage on slopes. Thirdly, the thick water-filled leaves barely dry during the hay making process, thereby impeding proper storage. It is therefore important to develop strategies for the control of this alien species in infested grassland areas and to prevent further infestation. To meet these goals, both knowledge about the occurrence and ecology of *P. stoloniferus* in Switzerland, and testing of measures for its control are urgently needed. The objectives of this study were to assess the types of habitats currently colonised by this species and to develop a control strategy.

Materials and methods

Survey: Locations with existing *P. stoloniferus* populations were found through interviews with farmers and botanists of the affected region and by inspecting the habitats adjacent to the sites where the presence of the species was confirmed. Our results thus include a range of habitats currently colonised by *P. stoloniferus*, but do not represent a complete list of habitats that could potentially be invaded. We recorded the topography of the sites, the cover of all plant species present in 25 m² plots, and analysed soil pH (in H_2O) in the 0-10 cm soil layer. Field experiments: From preliminary experiments with a range of herbicides and alternative control methods (flaming, black plastic sheets), three growth regulator herbicides (Metsulfuron-methyl, MCPB and Dicamba+MCPP+MCPA) were selected because they seemed to be the most effective control measure. They were either applied in two successive applications of two different herbicides or three successive applications of the same herbicide. This gave a total of 10 herbicide treatments, applied in a randomized complete block design with three replicates, which were applied in a fertilized permanent grassland (plot size 4 m²) located at 900 m a.s.l. and mown four times yearly. Herbicide applications were performed between the end of April and the beginning of July, with a 5-week interval between applications. The cover of green biomass of *P. stoloniferus* was assessed by visual estimation.

Results and discussion

Survey: Despite of moderate searching effort, 44 sites with *P. stoloniferus* were found in an area of approximately 200 km². They were situated between 413 and 1002 m a.s.l. with an exposure ranging from North to South. The sites were mainly agriculturally managed grasslands, but *P. stoloniferus* was also found in forests close to the forest margin and on slopes adjacent to roads. Correspondingly, the light condition of the sites ranged from shady to well lit, as indicated by the mean Landolt indicator value of the plant community (Landolt, 1977; Figure 1). The range of moisture and nutrient availability was narrower: the sites where *P. stoloniferus* was present were all moderately moist and relatively nutrient rich. Nevertheless, at one site the species was found growing on a stone heap. The soil pH of the colonised habitats ranged from 4.4 to 7.3 (Figure 1). Three intensively managed grasslands were so strongly infested that the cover of *P. stoloniferus* was estimated to be more than 75%. Therefore, *P. stoloniferus* is able to colonize a wide range of habitat types and out-competes native grassland species. Because this corresponds to environmental conditions found in many grassland regions, the problem could potentially spread to a large area in Europe.

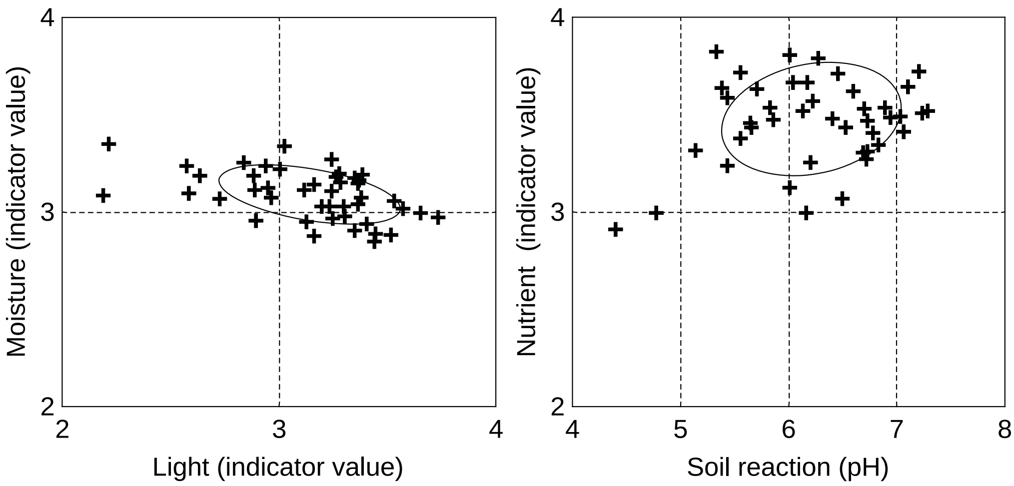

Figure 1. Range of light, moisture, nutrient and soil pH conditions of the 44 sites where *P. stoloniferus* was found. For light, moisture and nutrients, the cover-weighted mean Landolt indicator values of the communities in the 1-5 unit scale1 (Landolt, 1977) are shown. Soil pH was measured from 0-10 cm soil samples (in H_2O). Ellipses include 50% of data.

1 Light (L): 2 = shade, 3 = semi-shade, 4 = well lit; Moisture (F): 2 = moderately dry, 3 = moderately moist, 4 = very moist; Nutrient (N): 2 = infertile, 3 = medium infertile to medium fertile, 4 = fertile.

Field experiments: Previous experiments using a range of herbicides have shown that a single herbicide application does not eliminate *P. stoloniferus*. The current study shows that after three applications of Dicamba+MCPP+MCPA, no green biomass of *P. stoloniferus* was found in the treated plots (Figure 2), but 15.5 weeks after the last herbicide application, *P. stoloniferus* was recovering from axillary buds even in this treatment. After only 12 weeks, cover of *P. stoloniferus* rebounded to 33% in the treatment Metsulfuron-methyl/MCPB and up to 15% in treatments where herbicide applications had initially reduced cover to less than 5% (compare week 3.5 and 15.5, Figure 2). The cover of *P. stoloniferus* also increased from week 3.5 to 15.5 in the plots without herbicide application, which may be explained by reduced grass growth in the summer. Successful eradication was achieved by covering the affected area with black plastic sheets for four months during the growing season (data not shown), which of course is only feasible on very limited surfaces.

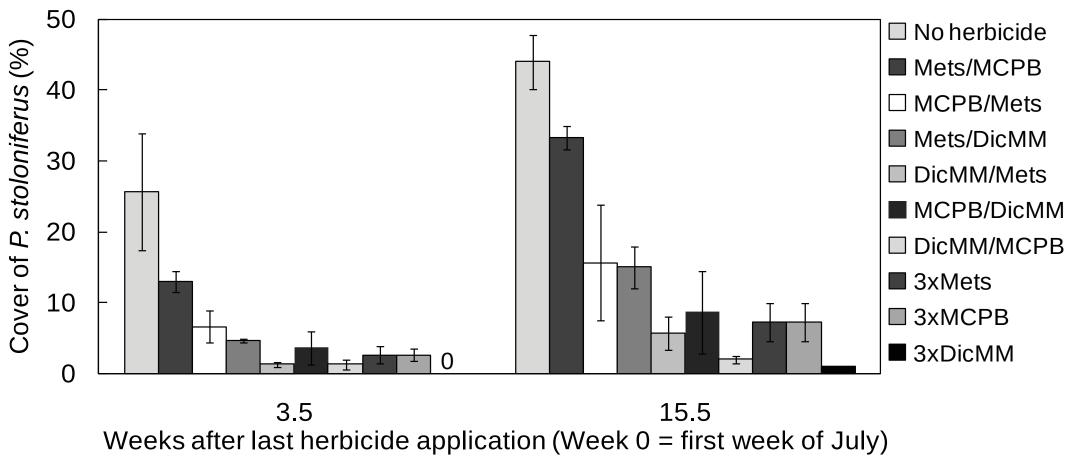

Figure 2. Percentage of the plot area covered by green biomass of *P. stoloniferus* after successive application of either 2 different herbicides or 3 times the same herbicide, with 5-week intervals between applications, in an infested permanent meadow. Shown are means ± SE (n = 3) at 3.5 and 15.5 weeks after the last herbicide application. Mets = Metsulfuron-methyl; DicMM = Dicamba+MCPP+MCPA.

Conclusions

P. stoloniferus can colonise different habitat types in the Swiss Prealps and thrives at least in a range of moderate conditions from the colline to the montane zone. Once established it is very difficult to eradicate because small amounts of surviving plant parts (stolons) are able to rapidly re-colonize the sward: even repeated application of the most effective herbicide tested was not successful. We conclude that *P. stoloniferus* has the potential to become invasive in many regions, not only in Switzerland, and cause tremendous problems for forage production. It is therefore important to prevent its spread into new areas and eradicate the species from newly colonised plots before it covers more than a few square meters.

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Forage as a primary source of mycotoxins

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Abstract

The objective of the present paper was to assess the content of mycotoxins entering the food chain from fodder. The paper includes results of three years of observation of mycotoxins assessed in fresh herbage. The evaluated species were *Lolium perenne*, *Festulolium pabulare*, *Festulolium braunii* and mixtures of these species with *Festuca rubra* and a mixture of these species with *Poa pratensis*. The content of the following mycotoxins was established by ELISA method: deoxynivalenol (DON), fumonisin (FUM), aflatoxin (AFL) and zearalenone (ZEA). DON and ZEA were detected both in summer and in autumn. The lowest concentrations were found in June (DON 32.5 ppb, ZEA < LOQ) and the highest in October (DON 53 ppb, ZEA 173 ppb). AFL and FUM were below the limit of quantification (< LOQ).

Keywords: perennial grasses, zearalenone, deoxynivalenol, ELISA

Introduction

Microorganisms in the phyllosphere of grasses are influenced substantially by changes in grassland management, particularly by transition from intensive management to extensification due to reduced cutting frequencies and lower fertilizer applications (Behrendt *et al*., 1997). In late autumn, the vegetation of pasture plants gradually decreases and weather conditions stimulate the development of microscopic fungi (Giesler *et al*., 1996) which, in consequence, may lead to the accumulation of mycotoxins (Opitz von Boberfeld *et al*., 2006). These metabolites can cause economic losses in animal production and decrease meat quality (Opitz von Boberfeld, 1996). The issue of moulds is very urgent, mainly in connection with forages from grass stands used at the end of the growing season. There are considerable differences amongst species. Mould-resistant species include *Festuca arundinacea* and its hybrids (Opitz von Boberfeld and Banzhaf, 2006). The goal of the present paper is to assess the safety, i.e. concentration of mycotoxins, of selected grasses (*Lolium perenne*, *Festulolium pabulare*, *Festulolium braunii*) and their mixtures with *Festuca rubra* and/or *Poa pratensis* during the growing season.

Material and methods

A small-plot experiment, established in 2007, was conducted at the Research Station of Fodder Crops in Vatín, Czech Republic (49°31'N, 15°58'E), at 560 m a.s.l. In 1970-2000, mean annual precipitation was 617 mm and mean annual temperature was 6.9°C.
A split-plot design was used with plots of 1.5×10 m in size, each variant in three replications. The experiment was a completely randomized design. The following species and mixtures were used: *Lolium perenne* (cv. Kenatur), *Festuca pabulare* (cv. Felina), *Festuca braunii* (cv. Perseus), mixtures of these species with *Festuca rubra* (cv. Gondolin) and/or *Poa pratensis* (cv. Slezanka). The share of *F. rubra* and/or *P. pratensis* in the mixture was 15%. Pure stands of each species were sown at a rate of 30 kg seed ha^{-1} and each mixture was sown at 37.5 kg ha^{-1}. The first evaluated factor was species or mixture, the second evaluated factor was harvest

date. For summer grass, stands with double cut in June and July were used. Subsequently, autumn harvest dates were October and/or November or December.
The ELISA method was applied to estimate contents of the mycotoxins deoxynivalenol (DON), zearalenone (ZEA), fumonisin (FUM) and aflatoxin (AFL).
Data were processed by the STATISTICA.CZ Version 8.0 program (Czech Republic). Results are expressed as means (x) and standard errors of the mean (s.e.). The obtained results were further analysed using ANOVA.

Results and discussion

The concentrations of DON in summer ranged from 33.0 to 51.7 ppb in the evaluated species (Table 1). A higher ($P < 0.05$) content of DON was found in June than in July. The content of ZEA in *L. perenne* and *F. pabulare* was below the limit of quantification (< LOQ). The highest concentration of ZEA was determined in mixtures (102.1 ppb and 112.5 ppb, respectively). The differences among species were not significant because of higher standard errors of the means. The contents of AFL and FUM were zero or below the limit of quantification. This finding is valid for both summer and autumn samples. DON concentration decreased during autumn ($P < 0.05$) (Table 2). A difference among the years of observation ($P < 0.05$) is also evident. The concentration of ZEA was lowest in *F. braunii*. Content of ZEA decreased from October to December ($P < 0.01$) similarly like DON content. The reason for the low production of mycotoxins could be explained by falling temperatures and as a consequence mycotoxins are not produced. Warm weather during autumn is another basic cause for mycotoxin production. The effect of not only biotic but also abiotic factors on the production of mycotoxins was reported by DeNijs *et al*. (1996) and Engels and Krämer (1996). The content of ZEA was considerably higher in October (173.0 ppb) than in summer (< LOQ and 122 ppb, respectively). According to D'Mello (2003), the zearalenone concentration ranging from 0.2 to 1.0 mg kg^{-1} is toxic even to rodents. Forage with a zearalenone content higher than 0.5 mg kg^{-1} is not recommended for feeding (Marasas *et al*., 1979).

Table 1. The influence of species, harvest date and year on the content (ppb) of deoxynivalenon (DON) and zearalenone (ZEA) in summer

Factor	DON			ZEA		
	x		s.e.	*x*		s.e.
Species						
Lolium perenne	78.1		17.1	< LOQ		0.0
Festulolium pabulare	65.3		16.9	< LOQ		0.0
Festulolium braunii	35.1		13.6	91.0		90.9
Mixture with *Festuca rubra*	38.9		18.6	112.5		112.4
Mixture with *Poa pratensis*	42.4		25.2	102.1		102.0
Level of significance		0.433			0.732	
Harvest date						
June	32.5		12.3	< LOQ		0.0
End of July	71.4		7.7	122.0		62.5
Level of significance		0.015			0.066	
Year						
2008	54.6		11.6	122		62.6
2009	49.3		12.6	< LOQ		0.0
Level of significance		0.762			0.066	

< LOQ = below the limit of quantification

Table 2. The influence of species, harvest date and year on the content (ppb) of deoxynivalenol (DON) and zearalenone (ZEA) in autumn

Factor	DON		ZEA	
	x	s.e.	*x*	s.e.
Species				
Lolium perenne	41.4	11.1	56.7	51.0
Festulolium pabulare	36.2	12.1	16.3	7.4
Festulolium braunii	33.0	13.1	60.7	60.7
Mixture with *Festuca rubra*	51.7	15.7	78.0	77.9
Mixture with *Poa pratensis*	47.6	16.5	92.4	80.3
Level of significance	0.867		0.926	
Harvest date				
October	53.0	9.2	173.0	66.2
November	51.7	12.0	3.7	3.6
December	21.4	6.1	5.8	3.8
Level of significance	0.041		0.005	
Year				
2008	26	9.3	111	49.1
2009	58	4.7	10	3.9
Level of significance	0.005		0.049	

Conclusions

During the growing season, grass forages can be contaminated by mycotoxins. Especially in July and in October high concentrations of deoxynivalenol (DON) and zearalenone (ZEA) could be determined. Thus, the risk of food chain contamination by mycotoxins is increased. Differences among the particular grass species in their content of mycotoxins were not found to be statistically significant. However, the lowest content of ZEA was measured in Festulolium pabulare.

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Influence of growth stage of permanent grassland on dry matter yield, nutritive value, feed intake and milk yield of dairy cows during the whole period of vegetation

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Abstract

The impact of growth stage of permanent grassland on dry matter (DM) yield, cell wall content, sheep *in vivo* digestibility, *in situ* ruminal degradability as well as feed intake and yield of dairy cows was investigated for three consecutive years covering all three growths of the total vegetation period. Both the influence of growth as well as vegetation week were statistically significant ($P \leq 0.05$) in all essential criteria. Regarding the parameters DM yield, cell wall content, feed intake and milk yield a significant interaction between growth and vegetation week was found, but this was not the case with digestibility and ruminal degradability. Hence there was a very close correlation between cell wall content and digestibility in the growth 1, but the relationship became weaker in growth 2 and especially in growth 3. On average of three growths, the DM yield increased from 1,808 to 4,812 kg ha^{-1} during 7 weeks of vegetation, the NDF content rose from 542 to 608 g kg^{-1} DM and the digestibility of OM decreased from 77.3 to 63.8%. The forage intake was reduced from 12.9 to 11.3 kg DM and theoretical milk production from forage decreased from 13.4 to 6.7 kg.

Keywords: Meadow forage, growth stage, digestibility, feed intake, milk yield

Introduction

In meadow forage the growth stage of the various species is of outstanding influence on the nutritive value. The growth stage determines the proportion and the composition of the cell wall carbohydrates. Whereas the rumen microbes can degrade the fibre carbohydrates (cellulose, hemicellulose) to a certain degree depending on lignification, lignin itself is indigestible and the most significant factor limiting the availability of plant cell walls to herbivores (Van Soest, 1994). The digestibility is reduced by both the cross-linking of core lignin with hemicellulose and by penetrating the cellulose fibrils. In the present paper the impact of growth stage of permanent grassland on DM yield, nutrient and cell wall content, *in vivo* digestibility (with sheep), *in situ* ruminal degradability (nylon bag technique; Ørskov and McDonald model, 1979) as well as feed intake and yield of dairy cows was investigated for three consecutive years covering all three growths during the vegetation period per year.

Materials and methods

The botanical composition of the grassland was 51% grasses, 21% legumes and 28% herbs. The forage was cut daily and directly fed to wethers and dairy cows in order to measure digestibility (continuous method), feed intake and milk yield potential of the forage. The experimental period of each growth lasted for 7 weeks. The chemical analyses were carried out according to conventional methods (Goering and Van Soest, 1970; VDLUFA, 1976; Mertens, 2000). The statistical model considered the fixed effects of year, growth number, week of vegetation and their interactions (Proc GLM of SAS, 2010).

Table 1. Experimental results (DM yield, nutrient and carbohydrate content, digestibility *in vivo*, degradability *in situ*, feed intake and milk yield)

Growth	1st growth							2nd growth							3rd growth						
Experimental week	1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Yield (kg DM ha^{-1})	1,692	2,579	3,439	4,302	4,842	5,361	5,782	1,764	2,586	3,201	3,860	4,179	4,686	4,916	1,968	2,502	3,068	3,302	3,625	3,629	3,739
Content of nutrients, cell walls and non-fibre-carbohydrates																					
Crude protein (g kg^{-1} DM)	202	181	160	146	127	117	129	216	197	178	161	155	139	148	206	202	190	186	179	166	160
Crude fibre (g kg^{-1} DM)	222	250	283	314	315	333	326	252	269	282	295	300	308	323	272	266	273	273	274	272	268
NDF (g kg^{-1} DM)	521	562	572	620	615	633	623	537	545	555	596	603	619	620	568	561	575	592	564	572	558
ADF (g kg^{-1} DM)	272	304	332	373	371	396	401	307	319	333	362	368	369	369	312	311	309	352	323	336	322
ADL (g kg^{-1} DM)	29	30	33	40	44	47	50	42	44	48	48	53	52	52	36	32	37	44	40	43	42
NFC (g kg^{-1} DM)	147	134	146	118	146	138	138	91	113	128	117	116	126	102	89	111	107	95	130	123	144
Digestibility, energy content and protein value																					
Organic matter (%)	78.2	78.1	72.6	70.4	68.5	64.9	60.8	75.8	74.8	72.3	70.8	68.4	67.3	62.9	78.0	75.9	74.6	73.4	70.7	68.3	67.7
NDF (%)	81.1	80.6	73.0	70.9	66.4	63.2	56.5	78.7	76.1	73.5	71.8	68.9	68.3	63.7	82.5	79.5	77.6	77.7	72.1	70.3	67.8
ADF (%)	76.8	77.2	71.2	69.6	65.1	62.9	56.9	74.0	72.3	69.8	69.0	65.7	63.8	59.1	77.7	75.2	71.9	73.9	67.8	66.3	63.1
Energy (MJ NEL kg^{-1} DM)	6.44	6.44	5.89	5.66	5.48	5.12	4.78	6.05	5.95	5.71	5.65	5.39	5.33	4.84	6.31	6.17	6.00	5.90	5.65	5.34	5.30
Protein value (uCP, g kg^{-1} DM)	146	143	133	128	122	115	111	143	139	133	130	125	122	116	146	143	139	137	132	125	123
Ruminal N-balance, g kg^{-1} DM)	9.0	6.0	4.3	3.0	0.9	0.4	2.8	11.7	9.3	7.2	5.0	4.9	2.7	5.2	9.6	9.4	8.2	7.8	7.5	6.6	5.9
Degradability																					
a (% of DM)	31.5	31.2	28.3	28.4	26.2	27.5	25.3	27.6	26.8	26.9	26.0	26.6	25.7	21.7	26.3	24.6	24.6	27.0	24.6	27.1	27.2
b (% of DM)	54.5	53.8	53.5	51.7	52.7	47.3	47.0	52.8	53.2	51.8	52.8	51.8	48.0	50.5	53.6	56.4	55.9	54.9	54.8	52.1	47.9
c (% h^{-1})	8.61	5.78	6.20	5.37	4.62	4.22	4.25	7.33	7.07	5.63	4.82	5.39	3.89	4.72	6.68	5.30	4.45	4.24	4.87	4.82	5.92
Potential deg. (a + b) (%)	86.0	84.9	81.8	80.1	78.9	74.9	72.3	80.4	80.0	78.6	78.8	78.4	73.7	72.2	79.9	81.0	80.5	81.9	79.4	79.2	75.0
Effective deg. k_p = 0.02 (%)	74.2	70.6	67.7	65.2	61.6	59.2	57.1	67.6	67.2	64.0	62.7	63.3	56.7	56.1	66.1	63.8	61.9	62.6	62.2	62.7	60.8
Effective deg. k_p = 0.05 (%)	63.4	59.4	56.5	54.0	49.4	48.6	46.7	56.5	56.3	52.7	51.0	51.9	45.7	44.6	54.8	50.8	48.7	49.7	49.5	50.6	49.4
Effective deg. k_p = 0.08 (%)	56.5	53.1	50.2	47.8	43.1	43.3	41.5	49.9	49.7	46.4	44.8	45.7	40.3	38.6	48.3	43.7	42.0	43.2	42.8	44.2	43.2
Feed intake and milk yield																					
Forage (kg DM d^{-1})	13.34	12.70	12.86	12.06	12.32	11.52	10.66	12.44	12.87	12.53	12.48	12.48	11.61	11.20	12.80	12.95	13.03	12.78	13.01	12.48	12.02
Concentrate (kg DM d^{-1})	5.45	5.61	5.39	5.37	5.66	5.63	5.40	6.03	5.68	5.83	5.74	5.76	5.84	5.57	6.34	6.09	5.93	5.30	5.86	5.98	5.69
NDF intake (g kg^{-1} LW)	13.2	13.2	13.2	13.2	13.5	12.9	11.8	12.8	13.1	13.0	13.5	13.7	12.8	12.5	14.0	13.8	14.0	13.8	13.5	13.2	12.3
Energy (MJ NEL d^{-1})	129.1	125.9	120.3	113.1	115.2	107.3	98.5	123.0	122.0	118.8	117.1	114.8	110.3	101.6	129.9	127.5	125.2	117.9	121.3	116.4	111.0
Milk yield (kg d^{-1})	25.6	25.0	23.8	22.4	21.3	19.5	18.1	24.4	24.6	23.6	22.1	21.3	20.2	19.3	25.0	24.6	24.8	23.1	22.5	21.3	20.3
ECM yield (kg d^{-1})	25.9	25.0	24.1	22.9	21.4	19.7	18.1	23.9	25.0	23.6	21.9	20.9	20.2	19.1	25.6	25.4	25.5	23.9	23.5	22.5	21.2
Milk fat content (%)	4.21	4.10	4.23	4.31	4.20	4.21	4.14	3.97	4.19	4.14	4.08	4.07	4.13	4.10	4.27	4.35	4.31	4.31	4.41	4.45	4.39
Milk protein content (%)	3.28	3.31	3.31	3.25	3.23	3.28	3.29	3.28	3.33	3.27	3.24	3.25	3.28	3.28	3.38	3.38	3.35	3.44	3.45	3.52	3.57
Milk prod. pot. Forage (kg d^{-1})	15.1	13.6	12.3	10.1	10.0	7.7	5.4	11.8	12.3	10.9	10.6	9.8	8.1	6.1	13.4	13.2	12.8	12.1	11.7	9.8	8.7
Milk prod. pot. Total DM (kg d^{-1})	28.8	27.8	25.9	23.6	24.3	21.8	19.0	26.9	26.6	25.5	25.0	24.3	22.8	20.1	29.3	28.4	27.7	25.5	26.4	24.8	23.0

Results and discussion

Both the influence of growth number as well as week of vegetation was statistically significant in all essential criteria ($P \leq 0.05$). The mean results of the three experimental years regarding the interaction growth number × week of vegetation are presented in Table 1. Concerning the parameters of DM yield, cell wall composition (NDF, ADF, ADL), feed intake and milk yield a significant interaction between growth number and week of vegetation was found ($P \leq 0.05$), but this was not the case with digestibility and ruminal degradability.

On average over weeks of vegetation, the DM yield decreased with number of growth (4000, 3599, 3119 kg DM ha^{-1} in growth 1, 2 and 3). As a mean over all growths, the DM yield increased from 1808 to 4812 kg ha^{-1} during 7 weeks of vegetation, but increase of yield was much higher in growth 1 than in growth 2 and especially in growth 3. The daily growth decreased from 138 to 43 kg DM ha^{-1} in growth 1, from 123 to 38 kg DM ha^{-1} in growth 2 and from 97 to 0 kg DM ha^{-1} in growth 3. Similar growth characteristics and levels of DM yield on comparable sites have been reported by Caputa (1966) and Gruber *et al*. (2000). The growth characteristics for ryegrass (*Lolium perenne*) were also modelled by Taube (1990). Obviously the yield and the growth characteristics in (permanent) grassland reflect mainly the light incidence and temperature.

On average over all growths, the NDF content increased from 542 to 608 g kg^{-1} DM and the digestibility of OM decreased from 77.3 to 63.8%. But cell wall content and digestibility as well as degradability developed in a quite different manner in the various growths. The cell wall content (crude fibre, NDF, ADF) increased very intensively during the 7 weeks of vegetation in the 1^{st} and 2^{nd} growth (approx. 530 to 620 g NDF kg^{-1} DM), but was nearly the same in all 7 weeks of 3^{rd} growth (on average 570 g NDF kg^{-1} DM). Regarding ADL, the 2^{nd} growth showed a significantly ($P \leq 0.05$) higher content than the two other growths (39, 48, 39 g ADL kg^{-1} DM) and its proportion to NDF was constantly high (8%) during the whole 2^{nd} growth. This higher ADL level in 2^{nd} growth is caused by higher temperatures during summer season (Van Soest *et al*., 1978). The increase of cell wall content during vegetation is well documented in various feed tables (e.g. INRA, 1989 and 2007; DLG, 1997; NRC, 2001). On the other hand, digestibility and degradability decreased in all 3 growths in a similar manner, on average from 77.3 to 63.8% during 7 weeks. This means that there was a very close correlation between cell wall content and digestibility in the 1^{st} growth, but the relationship became weaker in 2^{nd} growth and especially in 3^{rd} growth. Similar to digestibility, the forage intake was reduced from 12.9 to 11.3 kg DM and theoretical milk production from forage (according to NEL supply) decreased from 13.4 to 6.7 kg.

The impact of growth stage of meadow forage on digestibility and nutritive value in the broader sense is well documented in literature and was intensively studied all over the world in the past decades (Van Soest, 1967 and 1994; Burns, 2008). The decrease of digestibility during vegetation is on the one hand caused by dramatic morphological changes, i.e. stem to leaf-ratio, and on the other hand by the extensive lignification of the plant cell walls (Jung and Fahey, 1995). This lignification constrains the physical access of hydrolytic enzymes to cell walls due to steric hindrance and - as its consequence - the cell wall degradation (Jung and Deetz, 1993). It is concluded that the 1^{st} growth should be harvested in due time in order to achieve a nutritive feed quality satisfying for economic animal performance. A more detailed description of procedures, results and list of references can be found in Gruber *et al*. (2010).

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Using phenological progression and phenological complementarity to reveal potential for late grassland harvest

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Abstract

Farmers often face the problem of which grasslands enable harvest later in the season without a substantial decline in fodder quality. As decline is particularly driven by plant phenology, there arises a question which long-term management produces vegetation with a slower phenological progression and/or supports occurrence of later developing species (i.e. phenological complementarity). We used an experiment in dry broad-leaved grassland in the White Carpathian Mountains (Czech Republic) with three treatments: sheep grazing, mowing in mid-July and fallow. Species cover and phenophase were recorded in permanent plots at the beginning of May, June and July during two seasons. Phenological complementarity appeared only in the grazed plots. Community-weighted means of plant traits revealed that grazed and mown plots were characterised by earlier flowering and lower leaf dry matter content than fallow plots. Consistently, community phenological progression was the fastest in the mown plots and the slowest in the fallow plots. Mown plots accelerated the development earlier than grazed plots which was apparent from a significantly higher cover proportion of non-sterile species in June. We concluded that long-term grazed swards offer a greater potential for a single late harvest than mown grasslands, as fodder quality is expected to decline more slowly.

Keywords: asynchrony of growth, fallow, grazing, late harvest, mowing, phenophase

Introduction

Especially in mountainous and less-favoured areas, farmers' timing of grassland use has to accommodate new agri-environmental scheme rules and also weather conditions. Thus, farmers often face the problem of which grasslands allow for harvest later in the season without a substantial decline in fodder quality (Martin *et al*., 2009). Decline of fodder quality is particularly driven by the speed of species phenological progression (PP) (Duru *et al*., 2008). Therefore, which factors control the overall community PP is a challenging question. Grassland communities with higher community-weighted means (CWM) of leaf dry matter content (LDMC) flower later (Ansquer *et al*., 2009). However, no study has explicitly answered the question of how community PP is modified by long-term management. The aim of our study was to test experimentally which long-term management supports a vegetation composition that produces slower community PP and/or enables later developing species to coexist within a community. Both these processes may retard fodder quality decline and widen the 'time window' for harvesting (Martin *et al*., 2009; Mládek *et al*., 2011).

Materials and methods

During the 2009 and 2010, community PP and complementarity were investigated in plots of a long-term management experiment which was set up in 2004 in dry broad-leaved grassland. The site is located near the town of Brumov-Bylnice (49°05′58″N, 18°01′59″E; 370 m above sea level; mean annual temperature 7.9°C, mean annual precipitation 760 mm) in the White Carpathians Mountains, Czech Republic. Three management treatments (rotational sheep grazing from April with two cycles per year, mowing in mid-July, and fallow) were applied, each treatment in five 5×5 m experimental plots arranged in blocks (scheme in Mládek *et al*., 2011). We monitored a permanent subplot 1 m² in size within each experimental plot. The subplots in the grazed treatments were protected each year from grazing until all observations were completed and were then only grazed in autumn. In each plot, cover (in %) and phenophase of all species were recorded at the beginning of May, June and July. We distinguished five phenophases (*sensu* Martínková *et al*., 2005): sterile plant (1), plant with flower buds (2), flowering plant (3), plant with immature fruits (4), and plant with mature fruits (5). The phenophase for a species was assigned the highest of values attained by at least 30% of individuals in a subplot. Index of phenological complementarity (Stevens and Carson, 2001) was used to describe the asynchrony of growth: if peak cover of all species occurs at the same time, then the index value is << 0; if some dominant species display their peak cover in spring and others reach their peak cover in summer, then the value is > 0.

Results and discussion

Comparison of phenological complementarity (Figure 1A) showed that in both years mown plots had the lowest index values, indicating the most synchronous community development. Indeed, the seven most abundant species in the mown plots reached their peak cover in May or June, whereas four out of seven species in the grazed plots peaked in May (grasses) and three species in July (dicotyledons) (data not shown). Later developing species may substantially improve overall fodder digestibility due to positive effects of high nitrogen concentration tissues on the digestion process (Niderkorn and Baumont, 2009). Remarkably, vegetation under the influence of long-term grazing displayed complementarity only in the first year of observation. This might be attributed to the protection of the monitored permanent plots from early spring grazing, enabling early developing species to gain competitive advantage and possibly suppressing the occurrence of later developing species the next year. Further, analyses of variance for the CWM of functional traits according to database values (Biolflor database: onset of flowering, $P = 0.04$; LEDA traitbase: LDMC, $P = 0.04$) and post-hoc Fisher's LSD test revealed that grazed and mown plots were similar, but in contrast to the fallow plots they were associated with communities with earlier flowering and lower LDMC. Therefore, according

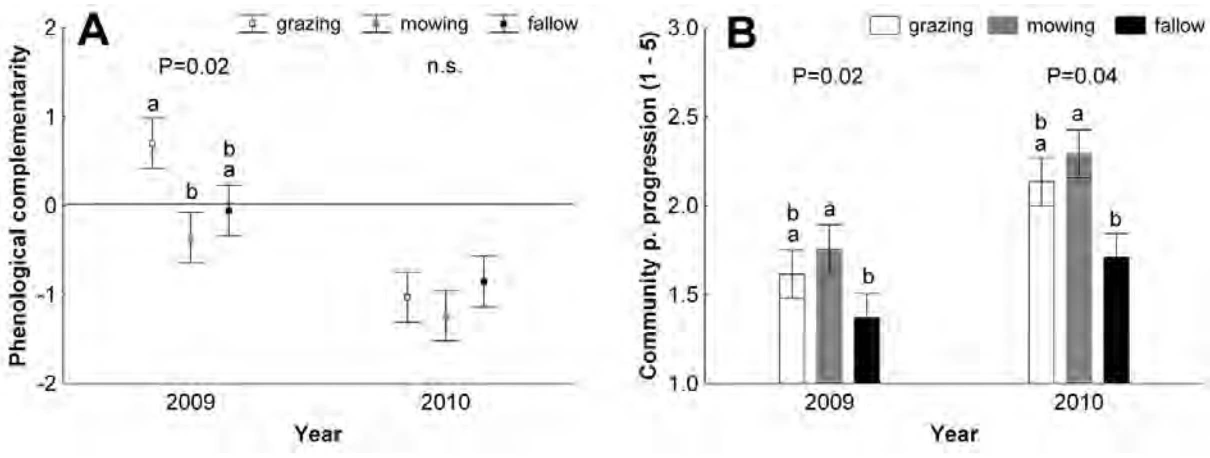

Figure 1. Index of phenological complementarity (A), above zero values indicate high seasonal asynchrony of species peak cover. In community phenological progression (B) the cover weighted mean of species phenophases is presented (values from 1 [sterile plant] to 5 [plant with mature fruits]) as averages over all three sampling dates. One-way ANOVA for each year separately; error bars represent SE; means with same letter are not significantly different (Fisher's LSD test, $P < 0.05$).

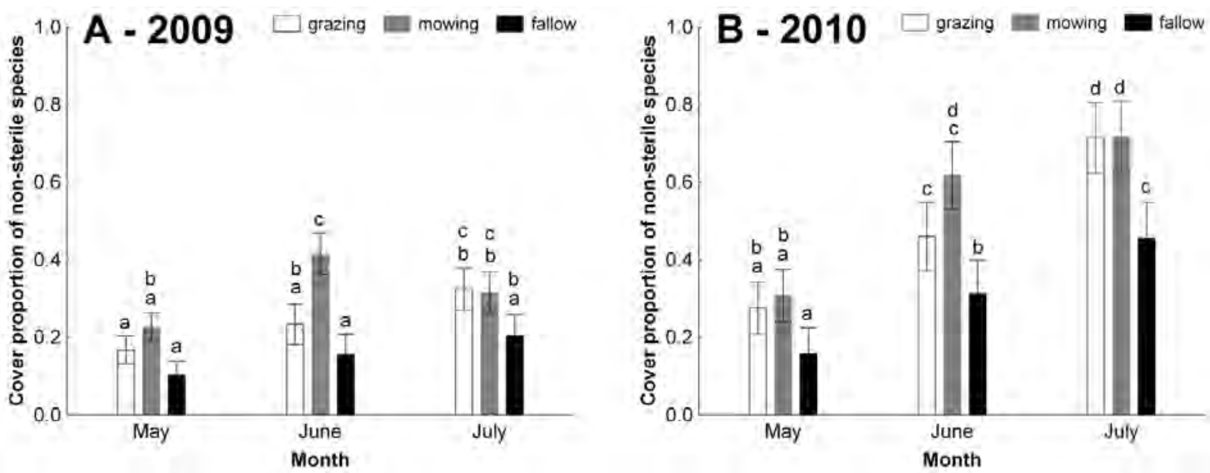

Figure 2. Seasonal development of cover proportions of non-sterile species (from 2 [plant with flower buds] to 5 [plant with mature fruits]). Repeated measures ANOVA; error bars represent SE; means with the same letter are not significantly different (Fisher's LSD test, $P < 0.05$).

to the results of Ansquer *et al*. (2009), in grazed and mown plots a parallel community PP may be expected, which should be faster than in fallow plots. In fact, community PP averaged over all three sampling dates was in both years the fastest in the mown plots and the slowest in the fallow plots (Figure 1B). Community PP of grazed plots was in both years slower than that of mown plots, but not significantly. In addition, we analysed the seasonal development of the cover proportions of non-sterile species (Figure 2A, 2B). Notably, the vegetation of the mown plots accelerated the development earlier (in June) than that of grazed plots (in July).

Conclusion

We showed, consistent with Ansquer *et al*. (2009), that community PP is slower in grassland with a higher LDMC (here fallow plots). However, in the case of a similar LDMC late harvest should be less unprofitable in long-term grazed than in mown grassland, because the former manifests a slower community PP and supports later developing species.

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Effect of TMR composition on milk fatty acids profile of dairy cows grazing different day-time periods

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Abstract

An experiment with sixteen Holstein cows blocked and randomly assigned to four treatments in a 4×4 factorial arrangement was conducted in order to evaluate the influence of type of silage included in the Total Mixed Ration (TMR) of dairy cows grazing 12 hours during day or night period. Treatments applied were two TMRs, offered *ad libitum*, with maize silage or grass silage, and two different day-time grazing periods: day or night. Silage type had no effect on the fatty acid profile. However, the day-time had a great effect on the fatty acid profile. When cows grazed for 12 hours with natural light, milk excretion showed higher proportion of CLA (2.46 *vs.* 1.64 g $100g^{-1}$ FA at day and night grazing periods respectively, $P < 0.05$), while the proportion of stearic acid was lower ($P < 0.05$) when grazed during the day (7.64 g $100g^{-1}$ FA) than the night (10.60 g $100g^{-1}$ FA). The SFA:UFA ratio was higher than WHO dietary recommendations regarding essential fatty acids intake, in cows grazing at night (2.11) than cows grazing at day, which showed a healthier ratio (1.51).

Keywords: grazing, total mixed ration, dairy cows, milk, fatty acids profile

Introduction

Milk fat has a high proportion of saturated fatty acid (SFA); about 20 g kg^{-1} of total milk fatty acids (FA) are polyunsaturated (PUFA), including n-3 fatty acids and conjugated linoleic acid (CLA), which help the human health. Moreover, the stearic acid of milk has little effect on plasma cholesterol. The diet of dairy cows plays an important role in the degree of unsaturation of milk fat. Grazing cows produce milk with a FA profile more favourable to human health, with high proportions of CLA, vaccenic acid (VA) and linoleic acid than non-grazing cows (Dewhurst *et al*., 2006). Cows grazing during the night, between evening and morning milking, saved almost 1.5 kg of TMR per day without affecting milk production and composition (Hernández-Ortega *et al*., 2010). Using pasture during the grazing season, as part of the diet, could reduce feed costs and produce healthier milk. The aim of this work was to compare the milk fatty acid profile of cows fed TMR *ad libitum*, based on grass or maize silage, and grazing high-quality pasture for 12 hours during day or night period.

Materials and methods

Four treatments were studied. These were GSD: feeding a grass silage-based TMR with day grazing; GSN: feeding a grass silage-based TMR with night grazing; MSD: feeding a maize silage-based TMR with day grazing; and MSN: feeding a maize silage-based TMR with night grazing. Sixteen Holstein cows (648 ± 20 kg live weight; 31.2 ± 2.01 L milk d^{-1}) in the first third of lactation were blocked in four groups and randomly assigned to each treatment. Two TMRs, offered *ad libitum*, were designed including grass (GS) or maize (MS) silages as conserved forages, cereal straw, alfalfa, and concentrate. Cows on day grazing (GSD and MSD) were moved to a fresh paddock after morning milking and kept indoors at night, while cows on night grazing (GSN and MSN) were moved to a fresh paddock after evening milking and kept indoors in the morning. Rotational grazing occurred in an area of 4.75 ha divided into 4 paddocks with *Trifolium repens* and *Lolium perenne* and presence of *Agrostis capillaris*, *Bromus erectus*, *Poa annua*, *Poa trivialis* and *Dactylis glomerata*. After fourteen days of adaptation, the TMR intake and milk production were recorded daily during the experimental period (seven days). TMR intake and milk production at both milkings were sampled daily. Pastures were sampled the first and last days in each trial. Feedstuffs and pasture were dried at 60ºC for 24 h for dry matter analysis (DM), ground (0.75 mm) and analysed by near infrared reflectance spectroscopy for organic matter, crude protein (CP), neutral detergent fibre (NDF), acid detergent fibre and starch. The contents of fat and protein of milk samples were analysed by MilkoScan FT6000 and milk fatty acids by gas-liquid chromatography as described by Christie (1982) with the modifications of Chouinard *et al*. (1999). Statistical analysis was performed in SAS (1999) using the GLM procedure for a 4×4 Latin square design.

Results and discussion

Both TMRs had similar protein content, around 142 g kg^{-1} DM. The pasture had a high nutritive value with 215 g CP kg^{-1} DM, 454 g NDF kg^{-1} DM, and 1.67 Mcal NEL kg^{-1} DM. Milk protein (31.9 g kg^{-1}) and lactose (49.7 g kg^{-1}) concentrations were not affected by the feeding strategies; however, the milk fat content tended to be higher for GS than MS (33.6 *vs*. 32.3 g kg^{-1} respectively, $P = 0.08$), likely due to lower concentration of NDF in MS treatment (403 *vs*. 434 g kg^{-1} for MS and MS respectively, $P > 0.05$). TMR dry matter intake was higher in cows grazing during day-time than cows grazing at night (14.1 *vs*. 12.6 kg d^{-1} respectively, $P < 0.05$). However, milk production (31.4 kg d^{-1}) and milk composition (33.0 g fat kg^{-1} and 31.9 g protein kg^{-1}) were not affected by the treatments.
The fatty acid profiles of milk of the experimental treatments are shown in Table 1. Grass or maize silage had no effect on the fatty acid profile. However, the day-time had an effect on the concentration of some fatty acids. Cows grazing for 12 hours with natural light showed higher a proportion of rumenic acid in milk (2.46 *vs*. 1.64 g 100 g^{-1} FA at day and night grazing respectively, $P < 0.05$), while the proportion of stearic acid was lower ($P < 0.05$) when grazing during the day (7.64 g 100g^{-1} FA) than during the night (10.60 g 100g^{-1} FA). The SFA:UFA ratio in milk of cows grazing at night (2.11) was above the current dietary limit (WHO, 2003), while for day grazing it was 1.51.

Conclusion

Cows grazing between morning and evening milking with natural light excreted more rumenic acid and had a healthier SFA:UFA ratio than dairy cows grazing during the night.

Acknowledgements

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Table 1. Fatty acid profile (g 100 g^{-1} FA) of milk of dairy cows under different feeding strategies.

Grazing (G)	Day grazing		Night grazing			Significance[1]		
Silage (S)	MSD	GSD	MSN	GSN	MSE	S	G	S×G
Caproic acid	1.76	1.92	2.45	1.78	0.076	NS	NS	**
Caprylic acid	1.01	1.10	1.40	0.94	0.085	NS	NS	NS
Capric acid	2.02	2.41	3.20	1.90	0.287	NS	NS	NS
Lauric acid	3.22	3.51	4.19	3.05	0.348	NS	NS	NS
Myristic acid	12.07	12.50	12.84	11.47	0.427	NS	NS	NS
Myristoleic acid	1.40	1.15	0.89	0.86	0.124	NS	NS	NS
Pentadecanoic acid	1.41	1.38	1.28	1.25	0.054	NS	NS	NS
Palmitic acid	35.24	33.44	31.92	34.31	0.602	NS	NS	NS
Palmitoleic acid	1.47	1.49	0.83	1.14	0.113	NS	*	NS
Palmitoelaidic acid	0.08	0.11	0.11	0.06	0.026	NS	NS	NS
Heptadecanoic acid	0.55	0.61	0.52	0.54	0.032	NS	NS	NS
Stearic acid	8.05	7.22	10.59	10.60	0.620	NS	NS	NS
Oleic acid	23.93	22.43	22.99	24.56	0.852	NS	NS	NS
Vaccenic acid	0.86	0.94	0.75	0.83	0.055	NS	NS	NS
Trans vaccenic acid	1.92	2.90	2.11	1.97	0.296	NS	NS	NS
Elaidic acid	0.25	0.50	0.17	0.14	0.067	NS	NS	NS
Rumenic acid	1.95	2.97	1.63	1.65	0.161	NS	*	NS
Linolelaidic acid	0.17	0.10	0.00	0.05	0.040	NS	NS	NS
Linoleic acid	2.11	2.56	2.07	2.21	0.129	NS	NS	NS
Linolenic acid	0.31	0.48	0.33	0.37	0.026	0.07	NS	NS
Nonadecanoic acid	0.05	0.14	0.21	0.11	0.029	NS	NS	NS
Arachidonic acid	0.10	0.10	0.09	0.10	0.028	NS	NS	NS

MSD: TMR with maize silage and day grazing; GSD: TMR with grass silage and day grazing; MSN: TMR with maize silage and night grazing; GSN: TMR with grass silage and night grazing; [1]Significant statistical probabilities *$P < 0.05$; NS: Non Significant; S: effect of type of silage in TMR; G: effect of time of grazing; S×G: Interaction

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Improvement of air temperature interpolation in mountainous regions for grassland-specific spatial analysis of growth dynamics

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Abstract

A simple temperature sum model (TSM) has been adapted for the purpose of estimating the growth dynamics of grassland in a complex terrain. It requires time series of daily mean temperatures and model parameters calibrated and optimized on phenological observations. By means of geostatistical methods time series of daily mean temperature are interpolated to a high resolution Digital Elevation Model (DEM). In order to include the effect of slope, aspect and the sky view factors on temperature, modelled daily global radiation sums on the grid are assimilated into the interpolation procedure of temperature. Feeding the data sets into the phenological model, the entry dates of the desired grassland phases can now be calculated at each grid element of the DEM.

Keywords: phenology, complex terrain, spatial interpolation, climate change

Introduction

Spatial models for analysing grassland growth, the dominant crop in mountainous regions, need continuous surfaces of model parameters to cope with the topography. The most important of these is temperature as it is the driving force for growth. This study presents methods for improving standard spatial interpolation of temperature and their application on grassland growth phases, adjusted to the conditions of a complex terrain. As an example the phase of flowering of *Dactylis glomerata* is estimated for Austria by using TSM as a basis of interpolated daily temperature grids.

Materials and methods

The daily temperature grids are the critical input to the proposed TSM. Following the approach 'first interpolate, then calculate' the performance of daily temperature surfaces affects the quality of the TSM results enormously and is a key requirement especially for the application in complex terrain. The interpolation has to consider the lapse rates, their ambiguous behaviour in the context of temperature inversions and the apparent difference between south- and north-facing areas (Lhotellier, 2007). The monthly lapse rates differ in lowland/valleys and in mountains because of inversions in autumn, winter and spring. Therefore, the study region is split into two altitudinal ranges with a transition zone between them, where adjusted geo-regressions with height reduced kriging (Goovaerts, 2000) are applied separately. The regression is built on monthly averages of temperature at weather stations and applied on a DEM with a resolution of 250 meters. The residuals of daily mean temperature are interpolated with ordinary kriging and then combined with the monthly grid of the height reduced fraction of temperature. The three-layer method considers the slightly different elevation regressions

of temperature in both altitudinal ranges and thus approximates the effect of inversions. The transition layer reflects the elevation range in which the real inversion height varies.
The temperature difference of south- and north-facing slopes are derived from the correlation between monthly long-term average of diurnal temperature range and radiation. By using the Solar Analyst tool in ArcGIS only the geometrical aspect of radiation was considered to cover the topographic impact on temperature (Fu and Rich, 2002). The algorithms are applied on a DEM. Before combining the diurnal temperature range with radiation data, they had to be spatially interpolated by using the three-layer method as proposed for the daily mean temperature values above (cross validation shows an R^2 of 0.82, slope of 0.99, and intercept of 0.05). The shift of mean daily temperature values due to topographical effects on daily global radiation sums is expressed by daily grids of temperature-correction values.These values are combined with the geostatistically interpolated surface of daily mean temperatures. Finally, a 'focal statistics' tool smooths the grids (3×3 cells). The developed algorithms are implemented in Visual C# and include several tools of ArcGIS software library.
To show the effect of the temperature interpolation improvements of the above proposed interpolation method on growth we selected the phenological phase '*Dactylis glomerata*: Flowering'. The spatial algorithms of temperature summation are built on three optimized parameters, which are the commencement date of temperature summation, the temperature threshold and the temperature sum at the entry date of the phenological phase as it was introduced by Réaumur (1735). In order to find out the optimum set of parameters we iterate over a wide range of each parameter and compare the estimated entry dates with 632 spatio-temporally smoothed phenological observations for the years 1990 to 2008 from 45 meteorological stations. The optimum parameter set is identified by the least Root Mean Squared Error (RMSE) of this comparison over all stations and years with 5.07 days and is used for spatial processing.

Results and discussion

The temperature interpolation was validated by using independent observations from 652 stations of the National Hydrological Service on a daily base for 2003. We found a very strong correlation of interpolated and observed data with an R^2 of 0.97, a slope of 0.97, an intercept of 0.71, and a Mean Absolute Error of 1.21°C. The optimal parameter triple for the TSM was found with the 92^{nd} day of the year as the commencement date of summation, 3°C as the temperature threshold and 449°C as the temperature sum at the entry date. The regression analysis of estimated entry dates of flowering of *Dactylis glomerata* from gridded results and the spatio-temporal smoothed phenological observations shows an R^2 of 0.71, a slope of 0.89, an intercept of 16.24, and a Mean Absolute Error of 4.28 days.
The spatial result presented in Figure 1 shows a detail of the flowering dates of *Dactylis glomerata* in the alpine valley 'Ennstal' for the year 1999. Additionally, the exact values on the defined transect through the valley are displayed in Figure 2. This curve shows the effect of north and south exposed areas very clearly, especially at the small hill in the centre of the valley. The entry dates on south-facing areas are slightly earlier than at the valley floor or at the north-facing slopes. Therefore, the implementation of the effects of slope and aspect into temperature interpolation procedures could be helpful for studies based on high resolution DEMs and could serve as a starting point for more sophisticated spatial models.

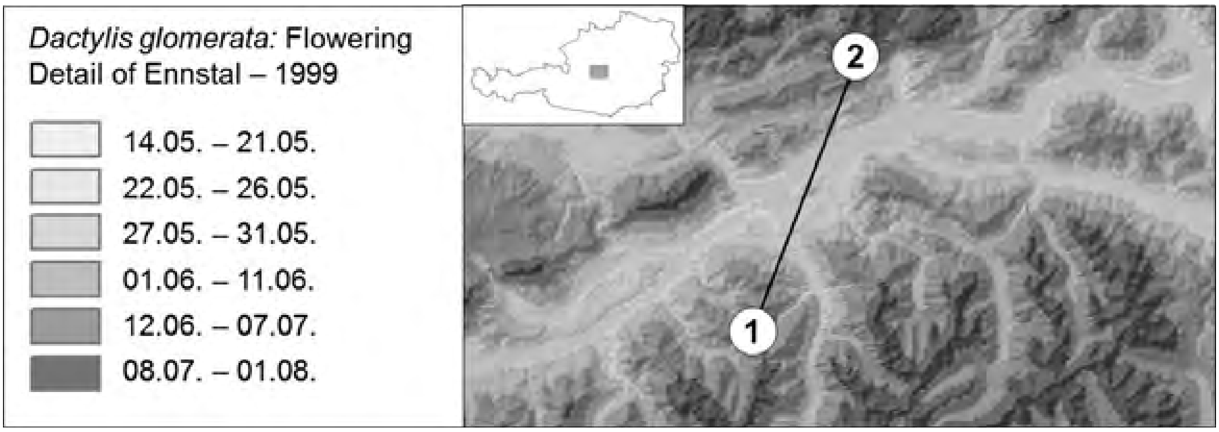

Figure 1. Continuous surface of entry dates of flowering of Dactylis glomerata on the base of TSM in detail for Ennstal (Styria) in 1999 (transect from South ① to North ② in Figure 2)

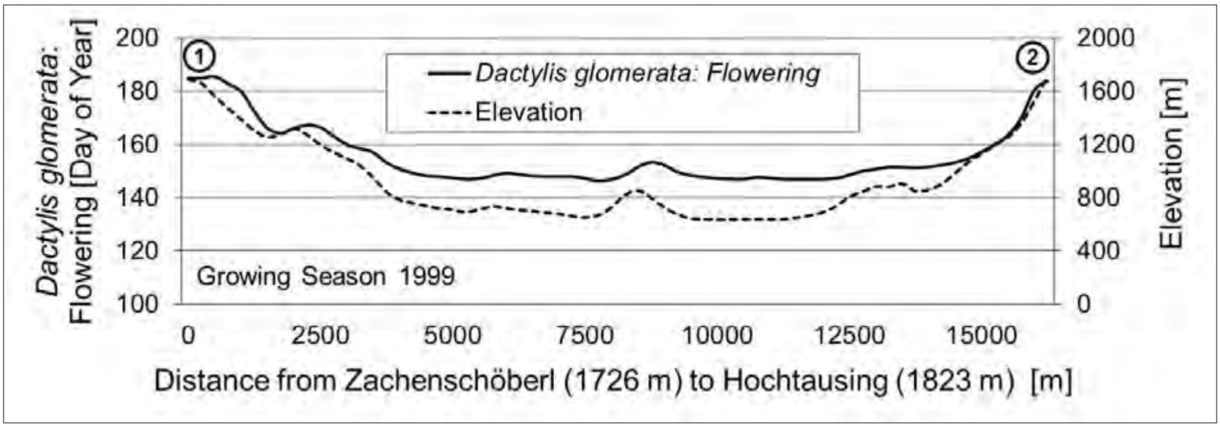

Figure 2. Raster values of entry dates of flowering of Dactylis glomerata along an example transect (defined in Figure 1) through the Ennstal from South ① to North ② in 1999

Conclusion

The spatial analysis of grassland growth dynamics based on temperature interpolation excluding the effect of slope and aspect represents a very strong simplification. This approach cannot describe the growth in spatial detail but can only provide a first guess of the spatial distribution of phenological entry dates in a complex terrain. Our approach is particularly adjusted for the requirements of a complex terrain. Alternatively, temperature time series (e.g. possible future climate scenarios) can be fed into the modelling system in order to assess the effect of climate variability and change on grassland growth and yield.

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Effects of intensity of fertilisation and cutting frequency on yield and forage quality of permanent grassland in the Czech Republic from 2003 to 2010

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Abstract

At six sites in the Czech Republic we evaluated long-term small-plot trials for 2 factors of utilisation from 2003 to 2010: 4 cutting frequencies (four - I_1, three - I_2, two - I_3 and one or two cuts - I_4) and four levels of fertilizer application (zero fertilizer, PK, N_{90}PK, N_{180}PK). The average dry matter (DM) production of grasslands, over years and sites, was 6.90 t ha^{-1}. DM production increased significantly (P < 0.01) when 4 cuts (6.35 t ha^{-1}) and 3 cuts (6.75 t ha^{-1}) were taken compared with 2 (7.09 t ha^{-1}) or 1-2 cuts (7.41 t ha^{-1}). Nitrogen fertilizer application, on average over eight years, significantly increased DM production in comparison with zero fertilised (5.14 t ha^{-1}) and PK fertilised (5.55 t ha^{-1}) treatments to 7.82 t ha^{-1} DM when N_{90}PK and 9.10 t ha^{-1} DM when N_{180}PK. Intensive (intensity 1, I_1) utilisation of grasslands in comparison with extensive (intensity 4, I_4) utilisation significantly (P < 0.01) increases CP concentration from 120.3 (I_4) to 168.1 (I_1) g kg^{-1} DM, NEL concentration (from 4.98 to 5.64 MJ kg^{-1} DM) and it significantly decreased (P < 0.01) fibre concentration from 286.8 to 218.5 g kg^{-1} DM. Level of fertilisation, especially graded N-fertilisation in comparison with the control and PK fertilisation, significantly (P < 0.01) increased CP concentration from 141.4 to 148.9 g kg^{-1} DM.

Keywords: permanent grassland, yield, forage quality, cutting frequency, nitrogen fertilization

Introduction

Permanent grasslands are a valuable part of agricultural soil and landscape resources in all European countries. Their conservation and maintenance in natural and cultural conditions are priorities of the Common Agricultural Policy and of EU member states as well.

Permanent grasslands cover an area of 974,000 ha in the Czech Republic. However, the number of livestock decreased from 1,236,000 heads of cows in 1990 to 552,000 in 2010 (Kvapilík and Kohoutek, 2011), out of which 384,000 dairy cows and 168,000 suckler cows. Livestock numbers of cattle, sheep, goats and horses, which reached about 4 million heads in 1990, decreased to about 1.6 million heads by 2010. As a result of low number of livestock a significant part of permanent grasslands is not utilised for forage production. Therefore it is necessary to select convenient methods of management and utilisation of permanent grasslands to use fully their potential, which must be taken into account when the principles of the EU common agricultural policy will be discussed for the period after 2013. Gruber *et al*. (2000) also state that the increase of cutting frequency improved the voluntary intake of voluminous fodder (10.4, 13.0, 15.2 kg DM) as well as intake of daily feedstuffs (herbage+concentrates) at 2, 3 and 4 cuts respectively. Effect of feedstuffs on dairy production was correspondingly 11.4, 17.2 and 23.0 kg milk (FCM) per cow per day.

Material and methods

Long-term small-plot trials were performed on permanent grasslands at the sites at Jevíčko, Vatín, Zubří, Liberec, Rapotín and Hladké Životice in 2003, each consisting of 16 treatments, in 4 replications, with a 10 m² harvest-plot size. The vegetation of grasslands on the experimental stands was classified as Arrhenatherion.

Four intensities of utilisation:
I_1 = (1st cut by May 15th, 4 cuts per year with cuts at 45-day intervals),
I_2 = (1st cut between 16th and 31st May, 3 cuts per year at 60-day intervals),
I_3 = (1st cut between 1st and 15th June, 2 cuts per year at 90-day intervals) and
I_4 = (1st cut between 16th and 30th June, 1 or 2 cuts per year, second cut after 90 days).

Four levels of fertilizer application:
F_0 = no fertilisation, $F_{PK} = P_{30}K_{60}N_0$; $F_{PKN90} = P_{30}K_{60}+N_{90}$, $F_{PKN180} = P_{30}K_{60}+N_{180}$.
Phosphorus was applied as superphosphate, potassium as potash salt and nitrogen as calcium ammonium nitrate. For all sites the total annual dry matter (DM) production was measured. The quality of forage DM was evaluated by NIR Systems 6500 fitted with a spinning sample module, in reflectance range 1100-2500 nm, band width 2 nm, measured in small ring cups, duplicate samples scanned twice. The parameters measured were: crude protein (CP), fibre (CF), NEL (net energy of lactation), NEF (net energy of fattening), PDIE (ingested digestive protein allowed by energy), PDIN (ingested digestive protein allowed by nitrogen) using software WinISI II, vers. 1.50. Our paper evaluates averages in harvest years 2003-2010. The measured results were statistically evaluated with two-factor analysis of variance with one observation in the sub-class; the differences between the averages were tested with the Tuckey test ($DT_{0.05}$, $DT_{0.01}$).

Results and discussion

Overall annual average DM production of grasslands (Figure 1) was 6.90 t ha^{-1} for sixteen treatment combinations for six sites over eight years (2003 to 2010). DM production increased significantly ($P < 0.01$) when 4 (6.35 t ha^{-1}) and 3 cuts (6.75 t ha^{-1}) were taken incomparison with 2 (7.09 t ha^{-1}) resp. 1-2 cuts (7.41 t ha^{-1}). Gruber *et al*. (2000) report similar results in long-term trials in Gumpenstein (Austria): a 2-, 3- and 4-cutting frequency resulted in DM yields of 8.65, 8.05 and 6.51 t ha^{-1}. The highest yield of energy was acquired in a 3-cut utilisation. The effect of N-fertilizer application over eight years was a significantly increased ($P < 0.01$) DM production compared to zero fertilizer application; resp. PK-fertilised treatments from 5.14, resp. 5.55 t ha^{-1} DM to 7.82 t ha^{-1} DM when N-fertilised with 90 kg ha^{-1} and 9.10 t ha^{-1} DM when N-fertilised with 180 kg ha^{-1}.
Forage quality (Figure 1) was significantly influenced by two factors in all treatments/years. The intensive utilisation (I_1) in comparison with the extensive one (I_4) significantly ($P < 0.01$) increased CP concentration from 120.3 to 168.1 g kg^{-1} DM, NEL concentration (from 4.98 to 5.64 MJ kg^{-1} DM), NEV concentration (from 4.69 to 5.51 MJ kg^{-1} DM), PDIE concentration

(from 73.8 to 84.0 g kg^{-1} DM), and PDIN concentration (from 71.8 to 96.3 g kg^{-1} DM), and it significantly ($P < 0.01$) decreased the fibre concentration from 286.8 to 218.5 g kg^{-1} DM. The level of fertilizer application, especially graded N-fertilisation in comparison with zero fertilizer application control (F_0) and PK fertilised (F_{PK}) treatments, significantly ($P < 0.01$) increased CP concentration (141.4 versus 148.9 g kg^{-1} DM), NEL concentration (5.46 versus 5.24 MJ kg^{-1} DM) and NEV concentration (5.29 versus 4.99 MJ kg^{-1} DM). The concentration of fibre from N-fertilised treatments moderately increased from 237.6 g kg^{-1} DM to 263.5 g kg^{-1} DM. The system where grassland is cut four times per year is also the most favourable practice from an ecological resource management perspective (Kohoutek and Pozdíšek, 2007), enabling decreased import of grain onto the 500,000 ha of grassland by 762,000 t annually.

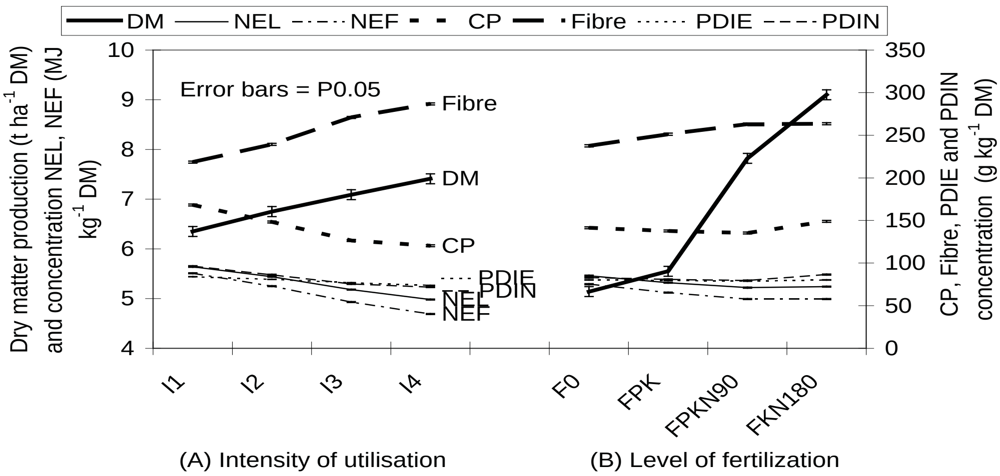

Figure 1. Dry matter production and forage quality of grasslands in relation to: (A) cutting frequency (average of fertilizer applications) and (B) level of fertilization (average of cutting frequencies) as a global average over six sites and eight years (from 2003 to 2010)

Conclusion

During extensive utilisation of grasslands by cattle it is necessary to manage and utilise these grasslands so that the quality of produced fodder was optimal and could be converted by animals to a maximal possible extent. For every agricultural system it is necessary to optimize stocking by herbivores with respect to production potential of grasslands and to reflect this into specific agri-environmental programmes for each geographical and climatic situation.

Acknowledgements

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Effect of daily herbage allowance on sward quality and milk performance of grazing dairy cows

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Abstract

The aim of this study was to analyse milk production of two herds (72 spring- and autumn-calving Holstein-Friesian dairy cows) in response to two levels of daily herbage allowance (DHA): high (H, 30 kg DM cow^{-1} day^{-1}) and low (L, 25 kg DM cow^{-1} day^{-1}); determining two stocking rates (low and high), imposed during spring/summer, in rotationally grazed (H, 4 *vs*. L, 5 rotations) mixed perennial ryegrass and white clover swards. Milk yield and total DM intake were similar in both treatments. Pasture DM intake was slightly lower with low DHA, but more grazing days were achieved. Increasing stocking rate (SR) reduced DHA and post-grazing sward height but increased herbage utilization enough to obtain higher milk yield due to improved sward quality (higher crude protein content, lower acid and neutral detergent fibre). Milk protein and fat contents were higher at low DHA. Thus, increasing SR, despite decreasing DHA, can improve sward and milk quality without reducing milk yield per cow.

Keywords: rotational grazing, stocking rate, grass nutritive value, intake, milk quality

Introduction

Sward structural characteristics influence grass nutritive value and condition of pasture quality. Delagarde *et al*. (2004) established a quadratic relationship between daily herbage allowance (DHA) and pasture intake (PDMI): increasing DHA resulted in higher PDMI up to a maximum, and thereafter decreased. To achieve maximum PDMI, DHA should be 3 to 5 times higher than animal demand. In practice, to avoid low herbage utilization and sward deterioration, it is recommended to use DHA of not more than twice the maximum expected consumption, i.e. ~ 25 kg^{-1} DM cow^{-1} day^{-1} for high yielding grazing dairy cows supplemented at the peak of lactation (Bargo *et al*., 2003).

Through pasture management it is possible to control the nutritional composition of grass during the grazing season. For instance, Vázquez-Yáñez *et al*. (2004) found that crude protein (CP) content was higher in paddocks heavily grazed by high yielding dairy cows, while fibres (acid, ADF and neutral detergent, NDF) were higher in swards grazed by lax or low performance dairy cows. Lower milk yield (MY) is associated with low sward quality.

Sustainable milk production systems based on grazing pastures should play a major role in the humid grassland area of the NW Spain. The high concentrate inputs of intensive dairy systems can be reduced and/or supplemented with silage during the peak yield to reduce feeding costs of production. If management decisions can maintain a good sward quality, such a strategic use of concentrate can help Galician dairy farmers to increase spring stocking rates (SR), reducing the DHA but without compromising the individual milk output per cow.

Materials and methods

The study was conducted in a humid grassland, with seventy-two spring and autumn calving Holstein-Friesian dairy cows from the experimental herd of the Agrarian Research Centre of Mabegondo (CIAM), La Coruña, Spain (43º15’N; 81º18’W). Two herds of dairy cows (n = 44+28) grazed rotationally independent areas of perennial ryegrass-white clover mixed swards during five months, from spring to summer, to investigate the effect of two DHA: high (H, 30 kg DM cow^{-1} day^{-1}) *vs.* low (L, 25 kg DM cow^{-1} day^{-1}) determining two SR: low (L, 3.9 cow^{-1} ha^{-1}) *vs.* high (H, 4.8 cow^{-1} ha^{-1}), respectively. All cows had a silage mixture, 60% grass and 40% maize, fed *ad libitum* (33% DM) and 6 kg DM cow^{-1} day^{-1} of concentrate, from calving. The trial started when cows were turned out to grazing on 16March and both groups had the concentrate amount reduced to 4 kg DM cow^{-1} day^{-1}. All supplementation was suppressed from the end of the second grazing rotation to early August when summer drought started. Sward chemical composition (CP and fibres content), PDMI (by pre- and post-grazing sampling), and *in vitro* digestibility were determined during this grazing period. Daily milk yields were registered and protein, fat and milk urea content were determined weekly. Production and chemical composition data were analysed by SPSS version 15.0 using a mixed model with treatment diets as fixed effects and dairy cows as random effects. Least square means (LSM) and standard error of the means (SEM) were calculated for each dependent variable. Mean differences were compared using a Tukey's multiple comparison test and statistical significance were declared at $P < 0.05$ for the main effects.

Results and discussion

Milk production of dairy cows decreased during the spring rotations (from 1 to 5) as lactation advanced (Figure 1b), with no significant differences between the two DHA imposed (L, 22.4 *vs.* H, 22.1 kg cow^{-1} day^{-1}). At the same time, PDMI (Figure 1a) and utilization of pasture increased in both treatments, as concentrate at pasture was reduced and dairy cows depended more on grass. A slightly higher PDMI was found in H, 14.1 with 4 grazing rotations than in L, 13.7 kg DM cow^{-1} day^{-1} with 5 rotations, and fewer grazing days (H, 126 *vs.* L, 135 days).

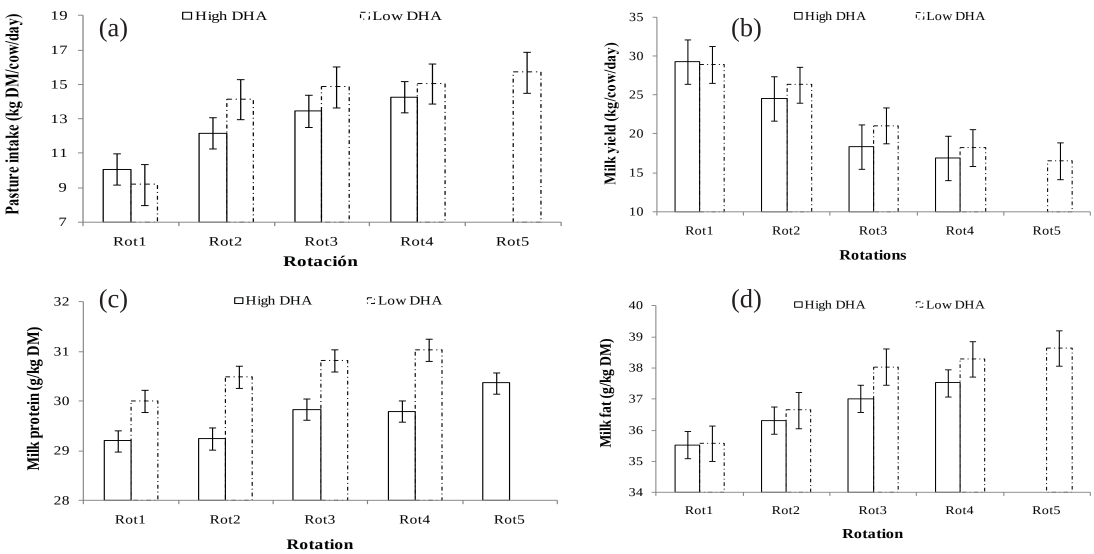

Figure 1. (a) Pasture DM intake, (b) milk yield, (c) milk protein and (d) milk fat of Holstein-Friesian cows grazing swards at two daily herbage allowances (high and low) in spring.

DHA affected sward chemical composition. Swards grazed at low DHA had higher CP content (Figure 2a), with higher proportion of leaves and lower proportion of senescent material. DM content of pastures at the end of the grazing season was lower at low than at high DHA (L, 18.4 *vs.* H, 20.3 g kg^{-1}). Average CP content decreased across all the grazing rotations (Table 1), with higher content in the low DHA (L, 149 *vs.* H, 131 g kg^{-1} DM) and this could be related to higher protein content of milk (L, 30.4 *vs.* H, 29.6 g kg^{-1} DM) (Figure 1c). Milk fat content (Figure 1d) was also higher at low than high DHA (L, 37.4 *vs.* H, 36.5 g kg^{-1} DM). On average, ADF (Figure 2b) and NDF (Figure 2c) were lower ($P < 0.05$) in the low DHA swards, with higher ($P < 0.05$) WSC and digestibility *in vitro* of organic matter (Figure 2d). Higher sward quality was thus achieved at low DHA with high SR.

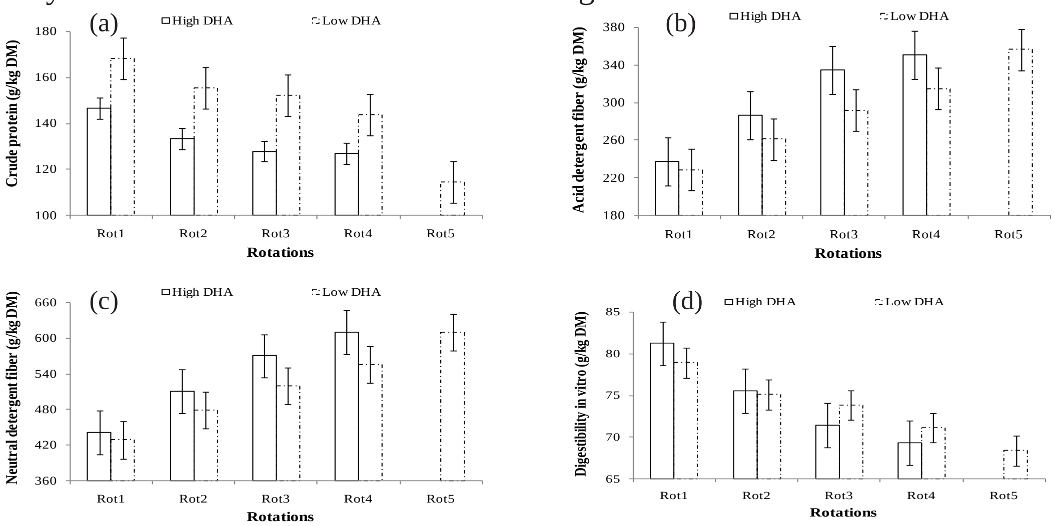

Figure 2. Evolution of (a) crude protein, (b) acid and (c) neutral detergent fibres and (d) *in vitro* digestibility of grazed swards at two daily herbage allowances (high and low) in spring.

Table 1. Chemical composition of grazed swards at two herbage allowances from rotations.

	DHA[1]		Rotations[2]					
Sward variables[3]	H	L	1	2	3	4	5	SEM[4]
DM (g kg^{-1})	20.3^{a}	18.4^{b}	16.4^{c}	17.0^{d}	18.8^{b}	21.3^{a}	26.2^{e}	1.0
CP (g kg^{-1} DM)	131.2^{a}	149.1^{b}	159.5^{c}	146.4^{b}	141.7^{b}	137.9^{a}	105.8^{d}	5.6
ADF (g kg^{-1} DM)	312.3^{a}	283.5^{b}	231.4^{c}	272.9^{b}	312.1^{a}	331.0^{d}	369.4^{e}	8.1
NDF (g kg^{-1} DM)	546.1^{a}	508.6^{b}	433.3^{c}	493.8^{b}	543.7^{a}	581.9^{d}	626.0^{e}	10.6
WSC (g kg^{-1} DM)	148.9^{a}	166.7^{b}	225.6^{c}	177.5^{b}	140.3^{a}	124.1^{d}	92.6^{e}	8.2
IVOMD (g kg^{-1} DM)	730.3^{a}	746.8^{b}	802.9^{c}	754.1^{b}	727.7^{a}	703.0^{d}	677.5^{e}	7.5

[1]DHA (Daily Herbage Allowance): H (high, 30 kg DM cow^{-1} day^{-1}) and L (low, 25 kg DM cow^{-1} day^{-1}); [2]Rotations: 1 to 5 (1, March-April; 2, April-May; 3, May-June; 4, June-July and 5, July-August); [3]Sward variables: DM (Dry Matter), CP (Crude Protein), ADF and NDF (Acid and Neutral Detergent Fibre), WSC (Water Soluble Carbohydrates), IVOMD (Digestibility *in vitro* of Organic Matter); [4]SEM: Standard Error of the Mean; [a-e] Values in the same row with distinct superscript are significantly different ($P < 0.05$).

Conclusions

High herbage utilization was achieved by low daily herbage allowance resulting in higher sward quality, due to lower DM and fibres, and higher CP, carbohydrates and digestibility as the grazing season advanced. Thus, it was possible to raise the stocking rate of supplemented cows without penalizing yield and quality of milk across lactation.

Acknowledgements

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Milk composition and fatty acid profile of grazing dairy cows supplemented with oilseed concentrates

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Abstract

The diet of ruminants influences their milk composition and fatty acid (FA) profile. The effect of supplementation at pasture with two sources of forage (grass+silage (S) compared to 'all grazing' grass (G)), and two types of concentrate (C, cottonseed and L, linseed) differing in FA profile of the two oilseed components, was examined in four groups (SC, SL, GC and GL) of autumn-calving Holstein-Friesian cows (n = 50). Milk yield and composition were determined across the main grazing season. The 'all grazing' treatments produced more milk, with higher urea content, than the silage-supplemented grazing treatments, despite lower protein and fat. The forage source had a greater effect on milk FA profile than the type of concentrate used. The group of cows grazing all day had lower levels of short- and medium-chain FA than those at grass-plus-silage. Higher content of long-chain (mono- and poly-unsaturated) FA was observed in milk from cows grazing all day. Daily intake of fresh grass was a decisive factor for the highest conjugated linoleic acid (CLA) content. The addition of cottonseed in the concentrate showed higher levels of long chain and mono-unsaturated FA than the use of linseed. High reliance on grass at farm level would be a good tool to increase the CLA content in milk fat and get more added-value with an improved milk FA profile.

Keywords: grazing supplementation, cottonseed, linseed, milk quality, CLA

Introduction

Fatty acid profiles in sustainable milk production systems should be taken into account by farmers and dairies as grazing has proved to be a good tool to increase milk quality. Elgersma *et al*. (2004) showed that the content of conjugated linoleic acid (CLA) in milk fat from 12 cows at pasture varied from 12.4 to 27.8 g kg^{-1} and went down to 4.0-8.6 g kg^{-1}, after four days transition to a maize silage diet. In humid regions of Galicia (NW Spain), Gonzalez-Rodríguez *et al*. (2010) found that the levels of CLA under pasture grazing were 11.7 g kg^{-1} of FA, dropping to 4.8 g kg^{-1} in milk fat when forage feeding was just silage. Both experiments highlighted that the highest concentrations of CLA and unsaturated fatty acids (UFA) are observed in milk production systems based on long periods of pasture feeding. Cows grazing grass all day had higher proportions of UFA and more CLA content than cows fed just on silage, which showed an increased proportion of saturated fatty acids (SFA). When grazing was supplemented with silage, the level of CLA in milk fat decreased significantly ($P < 0.05$) to 8.4 g kg^{-1}, compared to cows at full spring grazing. In both situations, with all-grazing or silage-plus-grazing, some seasonality in milk FA profile has been described. In spring-early summer, CLA levels were three times higher in milk fat when cows were grazing all day than when feeding on silage, whereas at the end of summer and in autumn these differences were reduced by half. In a previous work, Roca-Fernández *et al*. (2010) studied the milk FA profile of dairy cows comparing two types of concentrate (barley *vs*. cottonseed) in the stable, and obtained better milk performance with cottonseed. The aim of this new study was to investigate the effect of using two sources of forage, grass+silage compared to all-grazing, and two types of concentrate, cottonseed and linseed, on milk FA profile of supplemented grazing dairy cows.

Materials and methods

Fifty autumn-calving Holstein-Friesian dairy cows from the experimental herd of the Agrarian Research Centre of Mabegondo (CIAM) were rotationally grazing four-year-old perennial ryegrass swards with very little white clover content, with an average crude protein ranging content from 18% to 12%. After the peak of lactation (35 L cow^{-1} day^{-1}), on 20 March, cows were randomly assigned to one of four grazing treatments in a 2×2 factorial design, feeding 6.5 kg DM cow^{-1} day^{-1} of concentrate differing in FA profile of the oilseed components (C, cottonseed and L, linseed). Two of these herds (n = 12+11) were all-day grazing grass (G) while the other two (n = 14+13) received a limited amount of silage feeding (S), 20 kg cow^{-1} day^{-1} (50% grass and maize mixture, 33% dry matter DM), trying to cover half of the forage DM intake, and grazing for only half day. The four groups (SC, SL, GC and GL) grazed separately in four farmlets from spring to summer in 2008. Daily milk yield (MY) and weekly milk chemical composition (protein, fat and urea) were recorded and milk FA profile and the CLA (C18:2 *cis*-9 *trans*-11) content after milk fat extraction, were determined by gas chromatography, sampling five cows per treatment. Short (SCFA, C4:0 to C10:0), medium (MCFA, C12:0 to C16:0) and long-chain fatty acids (LCFA, C18:0 to C18:3) and, the ratio between saturated (SFA, C4:0 to C18:0) and unsaturated fatty acids (UFA, C18:1 to C18:3) were determined. The proportions of mono- (MUFA, C18:1) and polyunsaturated (PUFA, C18:2 to C18:3) of the total UFA were calculated. The data analysis was performed by ANOVA with treatment diets as fixed effects and dairy cows as random effects. Significant differences were declared at $P < 0.05$. SEM represents the stand error of the mean.

Results and discussion

The all-grazing treatments (GC and GL) produced more milk ($P < 0.05$) and had higher milk urea content ($P < 0.001$) than the grass+silage treatments (SC and SL), despite lower ($P < 0.001$) milk protein and fat content (Table 1). No differences were found between treatments in body weight and body condition score of dairy cows. The type of concentrate used at grazing influenced MY ($P < 0.05$), being MY higher with cottonseed. An interaction ($P < 0.01$) between forage source and concentrate type was found for milk protein. Milk fat was lower ($P < 0.05$) with cottonseed, as in early results (Roca-Fernández *et al.*, 2010).

Table 1. Dairy cows' milk performance of two forage feeding sources (grass and silage (S) and all grass (G)) with two types of concentrate (C, cottonseed and L, linseed).

Forage source (For.)	Silage+Grazing		All Grazing			Significance		
Concentrate type (Conc.)	Cotton	Line	Cotton	Line	SEM	Forage	Conc.	For.*Conc.
Body weight (kg)	627^a	622^a	616^a	614^a	5.44	NS	NS	NS
Body condition score (1-5)	3.49^a	3.48^a	3.46^a	3.45^a	0.03	NS	NS	NS
Milk yield (kg cow^{-1} day^{-1})	20.9^{ac}	20.6^a	22.3^b	21.1^c	3.68	*	*	NS
Milk protein (g kg^{-1})	32.3^a	32.0^a	30.1^b	31.3^b	0.24	***	NS	**
Milk fat (g kg^{-1})	38.6^a	39.9^b	35.7^c	37.0^d	0.49	***	*	NS
Milk urea content (mg kg^{-1})	254^a	262^a	302^b	318^b	13.0	***	NS	NS

[a-d] Within a row means with different superscripts differs. *** $P < 0.001$; ** $P < 0.01$; * $P < 0.05$; NS = Not significant.

The short- and medium-chain FA in the milk fat were lower ($P < 0.001$) while the long chain FA, MUFA and PUFA, linoleic acid, CLA and linolenic acid were higher ($P < 0.001$) when Holstein-Friesian cows had forage at full grazing compared with the cows supplemented with silage (Table 2). The type of concentrate also affected the milk FA profile to a lesser extent. The cottonseed concentrate proved to have a beneficial effect on milk FA due to lower ratio SFA/UFA ($P < 0.001$) and long-chain FA ($P < 0.05$), and higher long chain FA ($P < 0.01$), MUFA ($P < 0.001$), linoleic acid ($P < 0.05$) and CLA ($P < 0.01$) than the linseed concentrate (especially in the GC treatment). There were interactions between the forage feeding system and the type of concentrate for medium-chain FA ($P<0.05$), ratio SFA/UFA ($P < 0.05$), polyunsaturated FA ($P < 0.05$), linolenic acid ($P < 0.05$) and also for CLA ($P < 0.01$) but not for short- and long-chain FA, monounsaturated FA and linolenic acid. The feeding system, considering different forage sources from each region, should be carefully checked, paying attention to the animal feeding patterns and the characteristics of forage species. In our trial, the ingestion of fresh grass was a decisive factor for the CLA content. Type of concentrate showed a lower effect on FA profile, but better milk quality was observed with cottonseed.

Table 2. Milk fatty acids (FA) profile of two forage feeding systems (S, grass+silage; G, all grass) with two types of concentrate (C, cottonseed; and L, linseed).

Forage source (For.)	Silage+Grazing		All Grazing			Significance		
Concentrate type (Conc.)	Cotton	Line	Cotton	Line	SEM	Forage	Conc.	For.*Conc.
SCFA (short chain)	11.8^{ac}	12.4^{a}	10.3^{b}	11.2^{c}	0.44	***	NS	NS
MCFA (medium chain)	43.4^{a}	43.3^{a}	38.9^{b}	41.8^{c}	0.64	***	*	*
LCFA (long chain)	34.8^{a}	33.8^{b}	39.3^{c}	36.5^{d}	0.66	***	**	NS
Ratio SFA/UFA	2.59^{a}	2.68^{a}	2.10^{b}	2.45^{c}	0.06	***	***	*
MUFA (monounsaturated)	21.9^{a}	21.1^{b}	24.9^{c}	22.6^{d}	0.39	***	***	NS
PUFA (polyunsaturated)	3.21^{a}	3.27^{a}	3.79^{b}	3.49^{c}	0.08	***	NS	*
Linoleic acid, $_{C18:2}$	2.74^{a}	2.74^{a}	3.22^{b}	2.88^{a}	0.08	***	*	*
CLA, $_{C18:2\ cis\ 9\text{-}trans\ 11}$	0.84^{a}	0.85^{a}	1.24^{b}	0.97^{c}	0.05	***	**	**
Linolenic acid, $_{C18:3}$	0.47^{a}	0.54^{b}	0.56^{bc}	0.61^{c}	0.03	***	*	NS

[a-d] Within a row means with different superscripts differ. ***, $P < 0.001$; **, $P < 0.01$; *, $P < 0.05$; NS = Not significant.

Conclusions

The amount of fresh forage in the ration of dairy cows had higher influence on the milk FA profile than the type of concentrate fed. All-day grazing dairy cows showed a more beneficial FA profile, with higher levels of LCFA, MUFA, PUFA and CLA and lower levels of SCFA, MCFA and ratio SFA/UFA than cows supplemented with silage during the grazing season. The type of concentrate influenced the milk FA profile of bovine milk to a lesser extent. Using cottonseed gave better performance than linseed, mainly on cows with all-day grazing.

Acknowledgements

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Effects of feed quality of mountain pastures and cultivated pastures on lamb meat quality in Norway

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Abstract

Norwegian lamb meat production is mainly based on free grazing in mountainous pastures during the summer. Prior to slaughter in the autumn, some lambs not big enough for slaughter are finished on, e.g., cultivated pastures. This study looked at the feed quality of different forages, and the effect on lamb meat quality. Lambs grazed on mountain pastures at Kvaløya in Northern Norway (69°N) and Sør-Fron in Mid Norway (58°N) in 2007, and a subgroup at each location was finished on cultivated pastures for 6 weeks prior to slaughter in September. The fibre content was significantly higher in the cultivated pasture in Mid Norway compared to the mountain pasture, while no differences between pastures in Northern Norway were found. In Mid Norway the content of polyunsaturated fatty acid (18:3) was significantly higher in meat from lambs grazing the mountain pasture compared to lamb grazing the cultivated pasture. For Northern Norway, the opposite pattern was observed. The higher 18:3 content may be attributable to lower fibre content at the mountain pasture in Mid Norway. In our study, there appears to be an effect of fibre content on the fatty acid composition in lamb meat.

Keywords: fatty acids, lamb meat, NDF

Introduction

In Norway, most of the sheep meat produced is based on lambs slaughtered directly from unimproved mountain range pastures in the autumn. To reach the recommended carcass weight, lambs below 40 kg live weight (LW) are finished on cultivated lowland pastures. The levels of poly-unsaturated fatty acids (PUFA), in particular the omega-3 PUFA, are considered to be positive in the human diet but the nutritional value of fat in lamb meat is discussed amongst nutritionists. However, feeding systems have shown effects on the fatty acid composition in lamb meat and as high levels of linoleic acid (C18:2*n-6*) is related to concentrate feeding (Aurousseau *et al*., 2007), high levels of α-linolenic acid (C18:3*n-3*) is related to grazing. Green plants contain high levels of C18:3*n-3* but factors such as the rate of fattening in the lamb, the age of the lamb and the level of bio-hydrogenation in the rumen, all play a role in the total level of C18:3*n-3* found in the meat. Unsaturated FAs ingested by ruminant animals are hydrogenated to their saturated counterparts in the rumen. However, the rate of hydrogenation depends on the composition of rumen bacteria, and the composition of the rumen bacteria depends on the feed fed to the animals. The level of neutral detergent fibre (NDF) is one of several important factors affecting the bacteria composition in the rumen. Other factors may be antioxidants in the feed plants such as vitamin E and polyphenoloxidase (PPO). In the present study we examined the effects of pastures on the level of PUFA in lamb meat.

Materials and methods

Two locations, Kvaløya in Northern Norway (69°N18°E) and Sør-Fron in Mid Norway (61°N 9°E), were selected for the study. The experiment was undertaken in 2007. In Northern Norway, the experimental lambs grazed on cultivated pastures for 39 days and in Mid Norway for 42 days before being slaughtered. Lambs from a control group at each location were sent directly to the abattoirs after being gathered from the mountain pastures (Lind *et al*., 2009).

The mountain pastures ranged from 0 to 800 m, and 700 to 1000 m above sea level for Northern and Mid Norway, respectively. In the mountain pasture in Northern Norway *Avenella flexuosa*, *Anthoxanthum odoratum*, *Nardus stricta*, *Vaccinium myrtillus*, *Empetrum nigrum*, *Salix* genus and ferns were the most dominating species, representing more than 80% of the biomass. In Mid Norway, *A. flexuosa*, *Agrostis capillaris*, *Deschampsia cespitosa*, *A. odoratum* and the herbaceous species of *Geranium sylvaticum*, *Betulanana* and *V. myrtillus* were the most dominating species, representing approximately 85% of the biomass (Lind *et al*., 2009). The cultivated pastures were given chemical fertilizer four weeks prior to the grazing start. The cultivated pastures were dominated by the grasses *A. capillaris* (39%) and *Elymus repens* (45%) in Northern and Mid Norway, respectively. Other grasses in the cultivated pastures were *Poa pratensis*, *Phleum pratense*, *Festuca pratensis* and *D. cespitosa*. The grasses represented about 90% of all species. Grass samples from the cultivated pastures were collected throughout the finishing periods. The samples were scanned with a NIR spectrophotometer (Foss NIRSystem model 6500, Silver Spring, MD, USA) to determine the nutritional value (energy-, protein- and fibre content).

Traditionally managed Norwegian Crossbred sheep were used in the study. In Northern Norway 40 twin lambs with a minimum LW of 32 kg were randomly separated from the flock and brought to the cultivated pasture for the finishing period. Out of these 40 lambs, 35 of both sexes weighing more than 40 kg LW were slaughtered. As a control group, 35 lambs from the main flock grazing in the mountains, with similar LW, litter size, sex and age were selected and sent directly off the mountain pasture to the local abattoir, together with the experimental lambs. After slaughtering, 20 carcasses from each pasture type were selected for determination of fatty acid composition. The same procedure was followed in Mid Norway and included 72 male twin-lambs. Fatty acid composition was determined using one-way ANOVA analysis with pasture as fixed effect and single animals as experimental units.

Results and discussion

We did not find any significant differences in the NDF content between pastures in Northern Norway (Table 1). The NDF content in the cultivated pasture in Mid Norway was significantly higher than the NDF content found on the mountain pasture. Meat from lambs grazing the cultivated pastures at both locations had a higher content of palmitic acid (C16:0) while no differences in the content of stearic (C18:0) and oleic acid (C18:1*n-9*) were found. In Northern Norway, lambs grazing the cultivated pasture had a lower content of C18:2*n-6* and a higher content of C18:3*n-3* compared to meat from lambs grazing the mountain pasture. In Mid Norway, lambs grazing the mountain pasture had a higher content of both the PUFAs compared to lambs grazing the cultivated pasture (Table 1).

Ruminants fed with a high level of NDF in the feed-ratio will cause a high growth and activity of the rumen bacteria *Butyrivibrio fibrisolvens*, a bacterium that degrades the fibre content in the rumen. It is also found that this bacterium is important in the bio-hydrogenation of PUFA to saturated fatty acids (Chiofalo *et al*., 2010). Our study showed that meat from lambs grazing pastures with a high content of NDF had a lower content of PUFA in the subcutaneous fat. In Chiofalo *et al*. (2010) where sheep grazed ryegrass (*Lolium multiflorum*), white clover (*Trifolium subterraneum*) or a mixture of the species, a higher activity of cellulolytic bacteria for the bio-hydrogenation process was determined. Lambs grazing *L. multiflorum* had a lower level of omega-3 fatty acids than lambs grazing *T. subterraneum* as a consequence of the reduction of C18:2*n-6* to C18:0. The level of NDF in *L. multiflorum* was significantly higher than in *T. subterraneum*. Similar results were found by Fraser *et al*. (2004) where lambs grazing red clover (*Trifolium pratense*) had a higher level of PUFA in the meat than that of lambs grazing perennial ryegrass (*Lolium perenne*). In both studies the ryegrass species had a higher level of NDF than the clover species, although factors such as higher levels of vitamin E and PPO in red clover also may have influenced the level of PUFA in the meat. In our case the cultivated pasture had the highest content of NDF compared to the mountain pasture in Mid Norway. This could be explained by the fact that the cultivated pasture in Mid Norway to a large extent consisted of *E. repens*. This is a species that matures early in the autumn and therefore a high level of NDF could be expected. In contrast, the mountain pasture in Mid Norway had a large variety of species and some, e.g. *A. flexuosa* that is preferred by sheep, develops later in the autumn. However, NDF is not the only factor for PUFA in meat, as shown in our results from Northern Norway with similar NDF produced significant effect on C18:2*n-6* and C18:3*n-3*. One possible explanation of the results from Northern Norway could be due to high biodiversity in both pastures and other factors than NDF, such as specific antioxidants in different plant species may have influenced the level of C18:2*n-6* and C18:3*n-3*. Specific antioxidants may also have played a role in addition to NDF, for the highly biodiverse mountain pasture in Mid Norway.

Table 1. Least square means of fatty acids (% of total fat) in subcutaneous fat in lambs and content of NDF (% of DM) of different pastures in Northern and Mid Norway.

	Northern Norway				Mid Norway			
	Cultivated pasture	Mountain pasture	SEM	*P*-value	Cultivated pasture	Mountain pasture	SEM	*P*-value
C16:0	27.2	25.5	0.40	***	28.7	27.7	0.29	**
C18:0	21.2	22.1	0.92	NS	18.9	18.9	0.68	NS
C18:1	37.5	37.4	0.63	NS	36.7	38.5	0.78	NS
C18:2*n-6*	1.8	2.6	0.15	***	1.5	2.0	0.09	***
C18:3*n-3*	1.9	1.5	0.11	**	1.4	1.6	0.07	**
NDF % of DM	53.9	51.5	1.0	NS	65.2	53.5	2.1	***

NS - non significant; ** $P < 0.01$; *** $P < 0.001$; SEM - Standard Error Mean

Our results suggest that feeds with a high level of NDF can be one of many factors that may influence the level of PUFA in lamb meat. Producers of lamb meat should pay attention to the finishing system to aim for a healthy lamb meat.

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Voluntary intake of grasslands under different management by heifers from suckler cow breeding system

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Abstract

This paper presents the results on the voluntary dry matter intake (VDMI) of silages made from grasslands managed with four different intensities of utilisation (intensive, medium intensive, low intensive, extensive). The experiment was conducted on 6 heifers from a suckler-cow breeding system using feeding troughs. The voluntary intake (VI) was found to be influenced by intensity of grassland management: increasing intensity of use increased theVDMI. Mean values for treatments ranged from 15.31 to 23.65 g DM kg^{-1} BW. There were highly significant differences between intensive and low intensive treatments; intensive and extensive treatments; medium intensive and low intensive treatments; and medium intensive and extensive treatments. The difference between intensive and medium intensive treatments was not significant. A negative correlation was found between dry matter (DM) intake and concentration of crude fibre, as well as a positive correlation between DM intake and energy value.

Key words: voluntary intake, feeding value, grassland, silage, suckler cows

Introduction

Permanent grasslands constitute an important source of high quality forage in livestock nutrition. However, the feeding value and voluntary intake (VI) of the forage are decisive factors for meeting the nutritional requirements of different animal categories and their feeding management. The aim of this study was to determine the voluntary dry matter intake (VDMI) of silages from grasslands under different grassland management in heifers from a suckler-cow breeding system.

Material and methods

Feeding trials were conducted using silages made from the cuts of different grassland treatments. For the trials, 6 heifers were used (300-355 kg LW) - crossbreeds of Czech Fleckvieh with meat breeds from a suckler-cow rearing system using feeding trough equipment (RIC Insentec B.V.). There were 9 feeding trials lasting from November 2008 to April 2009.
The experimental grasslands were managed as follows: fertilized intensive (4 cuts per yr, from 15 May followed by cuts at 45d-intervals); fertilized medium intensive (3 cuts per yr - from 30 May followed by cuts at 60d intervals); fertilized low intensive (2 cuts per yr - from 15 June, next cut after 90d) and unfertilized extensive (2 cuts per year - first on 15June with the next cut after 90d). The dose of mineral fertilisers was $N_{90}P_{30}K_{60}$ (pure nutrients). Before each cut, the botanical composition and vegetation stage were evaluated. The grass silage was made by cutting grass and leaving it to dry naturally in the field, after which the dry matter content was about 37%. After wilting, the mowed fodder was compressed into round bales using a baling press with chopping equipment. The fermentation process lasted 3 months to ensure optimal silage quality. Each trial was divided into a habituation period (one week) and a testing period (two weeks). The animals were offered grass silage *ad-libitum*. The content

of basic nutrients (crude protein - CP, crude fibre - CF, ash, fat, neutral detergent fibre - NDF and acid detergent fibre - ADF) in silages was analysed according the Czech State Standard (CSS) 46 7092 'Method for Feed Testing'. The *in vitro* organic matter digestibility (DOM) was determined by the method of Tilley and Terry (1963) modified according to Resch (1991). The energy and protein value was predicted by means of the regression equation (Pozdíšek *et al*., 2000). Evaluation of the nutritive value in system NE (net energy), PDI (officially used in the Czech Republic) corresponded with INRA (Jarrige *et al*., 1989). The data were processed using descriptive statistics and General Linear Models with fixed effects for heifers, method of utilization and between effect (day in test) and its interactions with fixed effects using the SAS® 2007 software package. The post-hoc analysis was performed using Tukey´s HSD test at the level of significance $P < 0.05$.

Results and discussion

The botanical composition of grasslands (Table 1) was comparable for the intensive and medium-intensive treatment. The dominant species were *Dactylis glomerata*, *Poa pratensis*, *Lolium perenne*, *Trifolium repens* and *Taraxacum* sect. Ruderalia. Increase in the species *Trifolium pratense* (up to 33%) and simultaneous decrease in the percentage of forbs (up to 16%) was observed in the second cuts. The weed species *Crepis biennis* slightly increased in dominance (up to 15%) in the second and the third cut, which resulted in slight decrease in the feed value and subsequently in VI as well. The low-intensive and extensive treatments showed a low percentage of legumes (4-5%) and high percentage of forbs (31-53%). The species with low nutritional value (e.g. *Urtica dioica*, *Aegopodium podagraria*, *Anthriscus sylvestris*) were more dominant in those grasslands (2-8%). Mládek *et al*. (2006) confirmed that these weed species decrease the VI and feed value of silages.

Table 1. Botanical composition of grasslands and nutrient content of silages.

		G	L	F	DM	CP	Fat	CF	NFE	Ash	ADF	NDF
TR	Cut		%		g				g kg^{-1} DM			
IN	1	57	12	31	294	134	36	237	476	117	257	439
IN	2	48	33	19	354	152	32	242	459	116	325	449
IN	3	45	29	26	443	100	29	288	480	103	350	566
MI	1	69	10	21	353	104	29	285	476	106	342	523
MI	2	57	27	16	543	116	29	262	478	115	324	484
LI	1	65	4	31	304	105	27	359	396	114	419	608
LI	2	53	5	42	382	110	22	282	425	162	409	574
E	1	71	4	25	346	104	26	339	431	101	387	630
E	2	42	5	53	381	113	26	297	443	121	375	552

TR = treatment: IN = intensive, MI = medium intensive, LI = low intensive, E = extensive, G = grasses, L = legumes, F = forbs, NFE = nitrogen free extract

Increase in the concentration of CF together with decrease in the concentration of CP and other nutrients were found in connection with reduced intensity of utilisation. The same tendencies were reported by Buchgraber (2005) and Pozdíšek *et al*. (2008). The third cut of the intensive treatment was delayed due to unfavourable weather. This caused advancement of the vegetation stage by harvest, which resulted in higher concentration of CF and lower concentration of CP. The VDMI of silages (Table 2) ranged from 22.76-23.64 g kg^{-1} BW for the intensive treatment; 20.03-20.40 g kg^{-1} BW for the medium-intensive treatment; 16.12-18.47 g kg^{-1} BW for the low intensive treatment, and 15.31-17.19 g kg^{-1} BW for the extensive treatment. Kirzsan and Randby (2007) found VIs of grass silages (220-240 g kg^{-1} of DM concentration;

325-383 g kg^{-1} DM of ADF concentration) at the level of 17.90-26.50 g kg^{-1} BW in heifers (mean 150 kg BW). Our results are in line with Gruber *et al.* (2000) who studied the VI of grasslands under the same type of management in dairy cows.

Table 2. Nutrient content and voluntary intake of silages by different grassland management.

TR	Cut	DOM %	BW kg	NEL MJ	PDIN g	PDIE g	PDIN/PDIE g	Voluntary dry matter intake Mean g	SD kg^{-1} BW	CV %
IN	1	72.3	329.8	5.76	86	87	0.99	23.64	2.13	9.00
IN	2	71.8	346.2	5.71	97	89	1.09	22.94	0.92	4.01
IN	3	64.8	299.3	5.14	64	78	0.83	22.76	1.22	5.36
MI	1	65.4	339.3	5.18	67	79	0.85	20.03	1.41	7.03
MI	2	68.6	312.8	5.43	75	83	0.91	20.40	0.93	4.58
LI	1	58.2	302.7	4.45	67	73	0.93	16.12	0.22	1.35
LI	2	68.6	324.8	5.15	71	79	0.90	18.47	1.50	8.14
E	1	59.4	355.3	4.63	66	74	0.89	17.19	0.99	5.78
E	2	65.1	318.7	5.06	73	79	0.92	15.31	0.30	1.96

TR = treatment: IN = intensive, MI = medium intensive, LI = low intensive, E = extensive; BW = mean body weight of heifers in group; SD = standard deviation; CV = coefficient of variation.

Conclusions

The quantity and quality of fodder can be altered through grassland management i.e. the number of cuts and fertilisation. Second, the VDMI by cattle is affected by the intensity of grassland management. Further study of the VI in different cattle categories fed on grasslands is needed.

Acknowledgement

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Feasibility and economic advantage of conserving grassland forages as wrapped bale silage in a mountain environment of Italy

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Abstract

In the European mountain environment 40% of dairy farms were abandoned in the last 20 years. In order to remain profitable, the farms still operating must reduce feed-input costs by maximizing the utilization of local forage resources from native grassland. Two trials were conducted at Sauze d'Oulx (Torino, Italy) with the aims of comparing two conservation systems (baled silage *vs.* field-cured hay) and of determining the effects of harvesting herbage for baled silage at two stages of maturity on nutritional quality, forage production costs and milk income over feed cost in comparison with field-cured hay. Total harvest costs were higher for bale silage than for hay (66 *vs.* 80 € Mg^{-1} DM), and only an earlier cutting date than in traditional haymaking could increase baled forage quality, thus enhancing milk production and income over feed costs of winter feeding.

Keywords: bale silage, mountain meadow, forage quality, milk yield, costs

Introduction

In the European Alps 40% of all farm holdings were abandoned within the past 20 years and almost 70% of the farms still operating are run as a secondary source of income. In Italy, mountain dairy farms base their feeding system on extensive grazing in the summer period (3 to 4 months) and on supplemental confinement feeding over a large part of the year (8 to 9 months). Field-cured hay is currently the main system for forage conservation, and is normally harvested at a late stage of maturity. Due to high mechanical losses and frequent rain damage, the resulting hays may be poor in quality, and consequently the winter milk production needs to be supported with concentrates purchased from outside the production areas (Borreani *et al*., 2007). Wrapped bale silage has proved to be a good alternative to haymaking on small-to-medium farms in the lowlands; it can easily be mechanized and harvested with the same equipment that is used for field-cured hay, with the only addition of a plastic wrapper. The aims of this study were to compare two conservation systems of permanent mountain meadows (baled silage after 30 h of wilting and field-cured hay) and to determine the effects of harvesting herbage for baled silage at two stages of maturity on nutritional quality, forage production costs, and income over feed cost (IOFC) for cows fed baled silage in comparison with field-cured hay.

Material and methods

Two trials (I and II) were conducted at Sauze d'Oulx (Torino, Italy). In Trial I, bale silage (LS) and hay (LH) were produced later in the growing season, as for the local hay production. In Trial II, wrapped bales were made at an earlier harvesting time (ES) in order to improve the quality of conserved forage and to increase the potential dry matter DM intake (DMI), whereas field-cured hay (LH) was harvested at the same stage of maturity as in Trial I. In both trials, the forages were harvested from alternate windrows, half as baled silage and half as field-cured hay. The forage was baled in round bales (1200 mm diameter) and the silage bales were individually wrapped using six layers of polyethylene stretch film. In both trials, a herd of 40 Aosta Red Pied dairy cows was divided into two groups, balanced for parity, body weight, stage of lactation, and individual daily milk yield in a two-period crossover design (10 d for adaptation to the ration and 9 d for data collection). In Trial I, the diets included LS or LH fed *ad libitum* and 5.4 kg DM of grain, mineral and vitamin mix. In Trial II, diets included ES fed *ad libitum* and 3.5 kg DM per cow of grain, mineral and vitamin mix, or LH fed *ad libitum* and 5.1 kg DM per cow of grain, mineral and vitamin mix. The experimental diets were balanced for energy, protein, and minerals according to NRC requirements for 506-kg cows. Herbage samples were taken immediately before cutting. Silages and hays were sampled during the feeding trial by coring the bale from its side to a depth of about 450 mm. Samples were analysed for DM content, crude protein (CP, Kjeldahl N x 6.25), ash by ignition to 550°C, NDF, ADF and ADL, gross energy (GE) using an adiabatic calorimeter bomb, enzymatic organic matter digestibility (OMD) and net energy for lactation (NEL). Individual daily milk yields were recorded eight times (on days 2, 4, 6, and 8 of each experimental period) from both the morning and afternoon milkings, and fat and protein content were determined by Milk-O-Scan. The forage harvest costs for LH, LS and ES were evaluated using standard contractor charges and material costs (based on 2010 costs), for all the operations and materials, respectively. The budget did not include the costs of producing the crop, land charge/rent, or the storage costs. Data were analysed, within each trial, using the ANOVA procedure of SPSS. The Duncan range test ($P < 0.05$) was used to interpret any significant differences among the mean values of Table 1.

Result and discussion

The conservation process reduced forage quality compared to that of fresh herbage, both for hay and silage (Table 1). In Trial II the baled-silage system resulted in higher quality forage due to the earlier cut and shorter wilting period than hay. Fermentation of baled silage was restricted by the DM content higher than 50% and resulted in pH of 5.72 and 5.13, lactic acid concentration of 0.78 and 1.38% of DM, and ammonia-N of 4.74 and 5.06% of total nitrogen for Trial I and II, respectively. The operating costs in the field were higher for hay than for baled silage due to the greater number of tedding treatments (3 to 4 *vs.* 1), in both trials (Table 2). Otherwise, the stretch film, wrapping operation and plastic disposal accounted for about 44% of the total production costs in the baled silage system and, as a consequence, the total harvesting cost was lower for hay than for baled silages, in both trials. The forage intake and the total DMI were similar in Trial I, while they were higher in ES treatment than LH treatment in Trial II. In Trial I the 3.5% fat-corrected milk (FCM) yield was higher in LH treatment than in LS treatment. In Trial II cows on the ES treatment produced more milk (1.7 kg d^{-1}) and more 3.5% FCM (1.1 kg d^{-1}) than cows on the LH treatment. Concentration of milk fat was higher in LH diets in Trial I, whereas milk protein was not different between diets in both trials. In Trial II, total daily feed costs were about 10% lower and milk value 8% higher when cows were fed ES than LH, whereas milk value was slightly higher (5%) for LH treatment in Trial I. As a consequence ES allowed a 0.72 €/day per cow more IOFC than LH, in Trial II; whereas, due to its higher production costs LS resulted in an IOFC 0.36 € lower than LH, in Trial I. Extrapolating figures from Trial II to a mountain dairy herd of about 100 milking cows, and hypothesizing supplementation with baled silage instead of field-cured hay for 220 days per year would potentially increase IOFC by more than 15000 € annually. It is concluded that the round bale silage preservation system offers potential to minimize harvest losses and increasing forage quality compared to conventional field-cured hay, since less handling and a shorter drying time than haymaking can greatly reduce mechanical shattering and the risk of rain damage. However, baled silage should not be considered as a replacement for conventional field-cured hay, and it needs to be coupled with earlier cutting schedules than haymaking to be effective in improving the quality of conserved forages, and thus offering the opportunity of increasing the economic profitability of indoor-feeding over winter.

Table 1. Nutrient composition of herbage at cutting and of baled silage (S) and hay (H) produced at Sauze d'Oulx (Italy) in the two trials.

	Trial I					Trial II				
	Herbage at cut		Conserved forage			Herbage at cut		Conserved forage		
	LS	LH	LS	LH	*SE*	ES	LH	ES	LH	*SE*
DM, %	29.4^{c}	29.7^{c}	53.6^{b}	90.7^{a}	7.69	20.6^{d}	30.3^{c}	52.2^{b}	91.5^{a}	6.08
CP, % of DM	8.5^{a}	8.5^{a}	7.9^{b}	7.7^{b}	0.62	12.5^{a}	8.6^{c}	10.7^{b}	8.4^{c}	1.51
NPN, % of TN	19.2^{b}	19.0^{b}	43.2^{a}	21.8^{b}	3.13	27.6^{ab}	21.6^{b}	32.6^{a}	23.3^{b}	0.46
NDF, % of DM	57.0^{b}	60.3^{b}	61.9^{ab}	65.5^{a}	0.97	52.1^{c}	64.5^{a}	57.0^{b}	64.7^{a}	1.46
ADF, % of DM	36.0^{b}	37.9^{b}	42.1^{a}	42.8^{a}	0.59	34.2^{c}	38.9^{b}	38.6^{b}	42.2^{a}	0.73
ADL, % of DM	4.6^{c}	5.5^{b}	5.9^{b}	6.5^{a}	0.12	5.1^{b}	5.6a^{b}	5.9^{ab}	6.5^{a}	0.16
OMD, % of OM	64.6^{b}	64.4^{b}	59.5^{a}	58.7^{a}	0.32	68.7^{a}	63.2^{b}	63.6^{b}	59.4^{c}	0.85
NEL, MJ kg^{-1} DM	5.45^{b}	5.49^{b}	4.98^{a}	4.65^{a}	0.11	6.00^{a}	5.44^{b}	5.88^{a}	4.67^{c}	0.10

LH = late hay, LS = late baled silage, ES = early baled silage, *SE* = Standard error.

Table 2. Harvest costs of baled silages cut at two stages of maturity (LS and ES) and of the hay (LH), and costs and returns of the feeding study in two trials at Sauze d'Oulx (Italy).

	Trial I			Trial II		
	LS	LH	*P*-value	ES	LH	*P*-value
Mowing, tedding, raking and baling (€ Mg^{-1} DM)	41	61	**	46	63	**
Hauling and storing (€ Mg^{-1} DM)	2	2	NS	2	2	NS
Wrapping (€ Mg^{-1} DM)	14	0	***	17	0	***
Stretch film (€ Mg^{-1} DM)	14	0	***	15	0	***
Plastic net (€ Mg^{-1} DM)	2	3	NS	2	2	NS
Plastic disposal (€ Mg^{-1} DM)	2	0	**	2	0	**
Total harvest costs (€ Mg^{-1} DM)	76	66	**	84	67	***
Forage DMI (kg d^{-1})	9.8	9.9	NS	12.5	10.3	***
Total DMI (kg d^{-1})	15.2	15.3	NS	16.0	15.4	**
Milk yield (kg d^{-1})	12.6	12.8	NS	14.9	13.2	**
3.5% fat-corrected milk (kg d^{-1})	11.7	12.3	*	13.8	12.7	***
Milk fat (%)	3.38	3.64	*	3.55	3.64	NS
Milk protein (%)	3.19	3.30	NS	3.23	3.17	NS
Forage costs (€ cow^{-1})	0.74	0.65	NS	1.05	0.70	**
Total feed costs (€ cow^{-1})	2.68	2.60	NS	2.31	2.54	*
Milk value (€ cow^{-1})†	5.27	5.54	*	6.21	5.72	**
Income over feed cost (€ cow^{-1})	2.58	2.94	*	3.90	3.18	**

† Based on 3.5% fat-corrected milk price of 45 € t^{-1}.

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Calibration of the C-Dax Pasture Meter in a Danish grazing system

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Abstract

Dairy farmers that prefer grazing as a primary source of grass in the summer diet for their herds need a good estimation of grass on offer and intake. The C-Dax Pasture Meter (PM)®, which was developed in New Zealand (NZ), might be a relevant decision tool. The PM consists of a series of light and optical sensors at 20mm intervals. The software that is provided includes an equation to calculate the kilograms of dry matter (DM) ha^{-1} and this can be calibrated using grass height or the difference in height before and after harvest. Grassland and grazing management in Denmark (DK) is quite different from NZ, and therefore the usefulness of the machine for use in DK was tested. In order to do this a series of calibrations was undertaken in 2009 and 2010 at a research facility. The tests lead to the conclusion that harvested DM per ha can be accurately related to grass height measured by the C-Dax Pasture meter. DM ha^{-1} estimation showed different accuracy for high and low grass height.

Keywords: Pasture Meter, grass height, dry matter, Danish calibration

Introduction

Grazing is only practised by around 25% of the conventional dairy farmers in Denmark (DK) (Kristensen *et al*., 2010). Only 15% of conventional farmers are practising grazing if a minimum intake per day per cow of 2 kg DM from pasture grass is used to define 'grazing'. Even for organic dairy cows, high levels of pasture DM intake per cow per day are declining, despite that they are required, by law, to graze (Kramer, 2006). Organic farms comprise approx. 12% of all dairy farms in DK and the average organic herd size is 135 milking cows. When farmers were asked why grazing is perceived as problematic, primary reasons mentioned are fear for reduced milk yield and lack of pasture adjacent to the barn (Oudshoorn, 2009). Fear for reduced milk yields comes from uncertainty of feed intake from pasture, which, in turn, leads to abundant feeding of supplementary feed in the barn. A solution to breaking this perpetuating cycle is to enable accurate estimates of DM intake during grazing. This can be done with an easily obtainable and accurate measure of pasture DM ha^{-1} before and after grazing. Clipping plots or harvesting by machine is accurate but laborious and not practical for farmers. The rising plate meter has been used as a research tool, but is also inconvenient and time consuming (Umemura *et al*., 2009). A trailer pasture meter, based on light optical sensors and embedded software that computes DM from measured grass height has been developed in New Zealand (NZ) and is being used when cattle are rounded up for milking. Tests were undertaken for calibration under Danish grazing management as part of a larger, joint institutional grazing research project.

Materials and methods

Calibration of the PM was performed in August and September 2009 and from May to September in 2010 at the research facilities of the Faculty of Agricultural Sciences, Aarhus University. In 2009 grass height and harvested plots of 15 m² were compared. In 2010, grass height and harvested plots of 38 m² were compared. In 2010, ten days before starting measurements, the harvest area under investigation was fenced. Harvesting and PM measurement took place 4 times in each fenced grazing pasture (harvest area) in 4 successive parcels in the 4 plots (replicates), with 7-10 days intervals, moving systematically and successively (all first plots, followed by all second plots etc), through the fenced harvest area. Seven to ten days before finishing one harvest area, the next (harvest area B, etc) was fenced, to secure re-growth before sampling. In 2009 the grass mixture contained equal parts of diploid and tetraploid ryegrass; in 2010 the grass mixture contained 15% white clover, 58% tetraploid ryegrass, 27% late diploid ryegrass (all % of seeds). No fertilizer was applied during the grazing seasons in 2009 or 2010. The height measurements using the PM preceded the DM harvest using a Haldrup® experimental green mass harvester with a cutting width of 1.5 m. After harvest, the stubble height was measured by the PM. The PM measures with a sampling frequency of 200 Hz, summing data for each second of registration. Height measurement data were log transformed as necessary to normalize distribution. Data were analysed using regression of transformed height data or difference on dry matter in the R statistical LM package (R Development Core Team, 2010).

Results and discussion

One concern was that the stubble left by the harvester was not the same as accounted for by the PM. If the harvester and PM are synchronized, the difference in height before and after harvesting should result in a regression with an intercept not significantly different from 0 (Figure 1). The equation in Figure 1 predicts that for each 5 mm difference in grass height measured before and after harvest, 10 kg DM ha^{-1} would be available in the field, which is a negligible amount in terms of grass production. The conclusion was that no correction between harvester and the PM was needed (Figure 2).

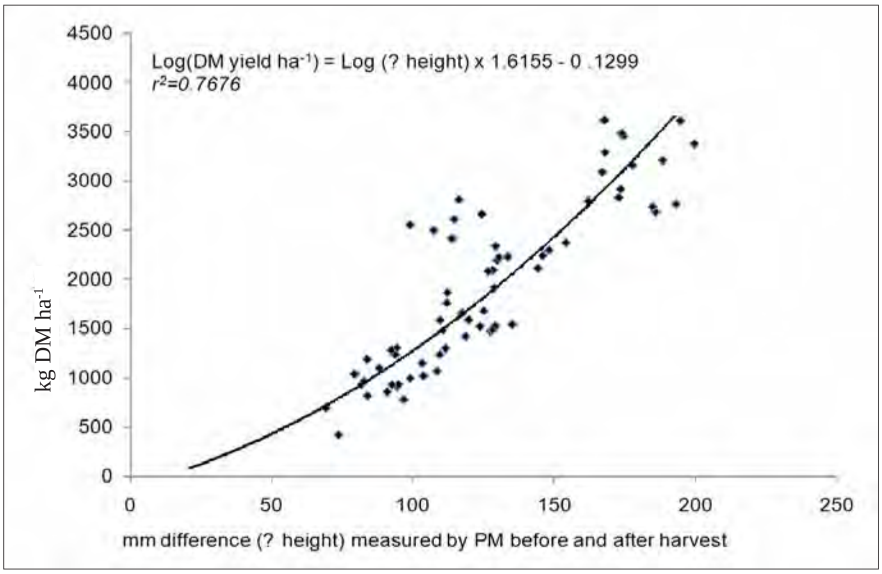

Figure 1. Dry matter (kg ha^{-1}) expressed as a function of height difference (mm) measured by the pasture meter before and after harvesting.

It was expected, but shown to be incorrect, that a common growth curve (S- shaped curve; Gompertz growth curve) would give the best fit. The significant ($P < 0.05$) and best fitting regressions (largest r^2) were significantly different for 2009 (linear) and 2010 (log-linear) data ($P < 0.05$) (Figure 2). This could be expected as the pasture vegetation was different (a grass sward *vs.* clover grass mixture). Sample influence analyses showed that 4 samples from 2010 had a determining effect on the significant difference between the years (circled data in Figure 2). However, there is no reason to question the validity of these samples. The regressions are most valid for pasture heights within a practical grazing interval. Low grass height was conspicuously absent in the data (Figure 2). Practical grazing management in DK would primarily occur in pastures over 70 mm, but less than 180 mm, so future tests should concentrate on lower grass height.

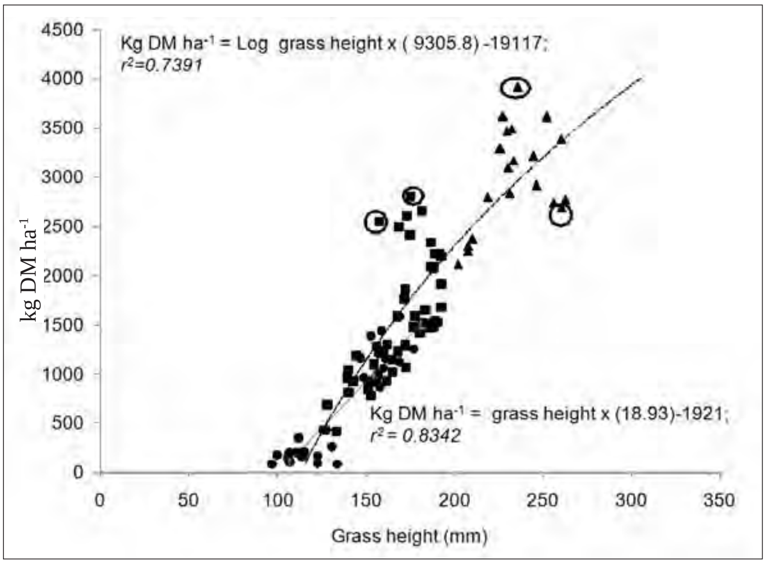

Figure 2. Relationship between grass height (mm) measured by Pasture Meter and harvested dry matter (kg ha^{-1}). • 2009; ■ 2010 (< 200 mm); ▲2010 (> 200 mm).

Conclusion

The Pasture Meter provides information that can be accurately related to harvested dry matter per ha and a single calibration equation seems probable within the height of pasture most commonly used in Denmark and a given grass-clover mixture. However, more data should be collected, particularly in the range of pasture height most used in Danish permanent grazing management.

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Variation of fatty acid composition of forage from natural pasture located at different altitudes during the first growth cycle

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Abstract

Milk produced from cows on highland pastures contains more fatty acid (FA) with properties beneficial to human health, such as conjugated linoleic acid (CLA) and polyunsaturated FA (PUFA). These FA are mainly derived from partial biohydrogenation of PUFA in the diet. The main objective of this research was to study the variability of forage FA profile over the period of the first growth cycle of permanent meadows at different altitudes. Permanent grasslands located at four different altitudes, 350, 1400, 1800 and 2200 m a.s.l., were studied. The first growth cycle of grasslands was sampled two times, in early and late stage of maturity, and analysed for botanical composition, dry matter (DM) yield and FA content. The results showed that altitude affects the botanical composition, DM yield and FA concentration of forage. Furthermore, the α-linolenic acid decreased with advancing maturity.

Keywords: forage, milk, fatty acid composition, mountain grassland

Introduction

Among the mountainous regions in Europe, the Alps are one of the richest areas for plant species, and their grasslands are an important feed resource for mountain dairy systems (Van Dorland *et al*., 2008). Animal products obtained in such systems contain high levels of fatty acids (FA) beneficial to human health, such as conjugated linoleic acid (CLA) and polyunsaturated FA (PUFA) of the omega-3 group (Dewhurst *et al*., 2006). Collomb *et al*. (2002) reported that the concentration of these beneficial FA in milk fat increases with altitude and suggested that they could be related to a higher percentage of herbs in the dairy cow ration. The concentration of healthy FA in milk and dairy products is mainly due to PUFA concentrations in the diet. The forages, despite their low lipid concentration, are an important source of PUFA for dairy cows. Sources of variation in the FA concentration of forage are plant species, leaf-to-stem ratio, regrowth interval, stage of maturity, weather and fertilizer regime (Dewhurst *et al*., 2006). The aim of this research was to study the variation of FA composition over the first growth cycle of permanent grasslands located at different altitudes in north-west Italy.

Material and methods

Forage from permanent grasslands located at four different altitudes in the Alps of north-west Italy was sampled during the first growth cycle. Grasslands were located in the lowland at 350 m above sea level (L0), and in the highland at 1500 (H1), 1800 (H2) and 2200 (H3) m above sea level, and they represented the predominant grassland types of the studied area. The experimental design was a randomized complete block design, with three blocks and two plots per block at each altitude. Forage samples from each of the grasslands were taken during the early stage of maturity (approximately one month after the beginning of the growing season), when grazing would typically begin, and in the advanced stage of maturity, after 40 days from the previous sampling. The forage samples were split into three sub-samples for determination of botanical composition, dry matter (DM) content, and chemical analyses. The sub-samples for chemical analyses were analysed for crude protein (CP), neutral detergent fibre (NDF), acid detergent fibre (ADF), lipid extraction, and for determination of the FA methyl esters by gas chromatography as described by Revello-Chion *et al*. (2011). The CP, NDF, ADF and FA concentrations of grasslands were subjected to ANOVA using GLM of the SPSS software (v 16.0), considering the fixed effect 'growth stage' and 'altitude', and their interaction.

Results and discussion

The growing season for the alpine vegetation is related to the altitude, which has effects on the botanical composition, phenology and nutritive value of permanent grasslands. The lowland grassland (L0) was dominated by Poaceae (68% of total DM) and presented a lower number of plant species (n = 9). The number of species increased with altitude and was 30, 31, and 54 for H1, H2 and H3, respectively. The increase of altitude led to an increase of contribution of botanical species belonging to other families, which accounted for 32%, 52%, 68%, and 73% of total DM for L0, H1, H2 and H3, respectively. The DM yield and CP were affected by altitude, stage of maturity and their interaction, whereas the NDF and ADF contents increased from the early to the late stage of maturity (Table 1). The total fatty acids (TFA) were affected by altitude, stage of maturity and their interaction (Table 2). The highland grasslands contained more TFA than lowland grassland (L0), and TFA were affected by stages of maturity. The α-linolenic acid (C18:3 n-3) was the main FA of the forages and its content followed the trend of TFA through altitude and stage of maturity. Significant decreases of α-linolenic acid content were found with advancing stage of maturity in L0, H1, and H2 grasslands, whereas it was almost constant in H3 grassland. The oleic acid (C18:1 n-9) increased with the advancing of the stage of maturity, except for H3 grassland. The linoleic acid (C18:2 n-6) was not influenced by altitude and stage of maturity. The role of plant maturity on forage FA concentration and composition has previously been described for other environments (Dewhurst *et al*., 2006). Climatic conditions, species and sward management also have effects on FA concentration (Dewhurst *et al*., 2006). The length of growing season and the botanical composition of permanent grasslands changed with increasing altitude. This could have influenced the FA concentration and evolution of permanent grasslands, due to differences in the FA composition of individual species and also due to species variation in phenology (Van Dorland *et al*., 2008).

Conclusions

The present study showed difference of FA contents in grasslands located at different altitudes and, consequently, their availability in the diets of ruminant based on pasture. This could contribute to explaining the differences observed in FA composition of milk produced from lowland and highland pastures.

Acknowledgements

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Table 1. Dry matter (DM) yield, crude protein (CP) concentration, neutral detergent fibre (NDF) and acid detergent fibre (ADF) concentrations of grasslands located at different altitudes during the first growth cycle

Altitude	Stage	DM yield ($Mg\ ha^{-1}$)	CP ($g\ kg^{-1}$ DM)	NDF ($g\ kg^{-1}$ DM)	ADF ($g\ kg^{-1}$ DM)
L0 (350 m)	Early	1.43	164	376	255
	Late	6.51	122	560	370
H1 (1500 m)	Early	1.33	174	382	259
	Late	4.62	102	477	368
H2 (1800 m)	Early	0.55	133	434	252
	Late	1.88	101	500	350
H3 (2200 m)	Early	0.50	155	464	307
	Late	1.88	118	528	347
SEM		0.402	6.73	15.9	12.5
Significance					
Altitude (A)		***	**	NS	NS
Stage (S)		***	***	***	***
Interaction A×S		**	**	NS	NS

SEM = Standard error of the mean, NS = not significant, ** = $P < 0.01$, *** = $P < 0.001$

Table 2. Individual and total fatty acids (TFA) concentrations ($g\ kg^{-1}$ DM) of the grasslands located at different altitude throughout the first growth cycle

Altitude	Stage	C16:0	C18:0	C18:1 n-9	C18:2 n-6	C18:3 n-3	TFA
L0 (350 m)	Early	1.63	0.123	0.338	2.53	8.04	12.87
	Late	1.73	0.231	1.283	4.89	5.18	13.77
H1 (1500 m)	Early	3.85	0.395	0.496	4.46	18.67	27.87
	Late	2.75	0.569	3.352	3.58	9.89	20.57
H2 (1800 m)	Early	2.44	0.274	0.813	3.35	12.07	19.33
	Late	2.34	0.365	1.592	4.29	8.43	17.29
H3 (2200 m)	Early	2.70	0.347	1.489	4.26	11.63	20.97
	Late	2.67	0.277	1.089	4.77	12.32	21.52
SEM		0.139	0.027	0.204	0.186	0.789	0.945
Significance							
Altitude (A)		***	***	NS	NS	***	***
Stage (S)		NS	*	**	NS	***	**
Interaction A×S		*	NS	*	NS	***	***

SEM = Standard error of the mean, NS = not significant, * = $P < 0.05$; ** = $P < 0.01$; *** = $P < 0.001$

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The effects of different conserved forages on fatty acid profile and terpene composition of cow milk in Alpine dairy production

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Abstract

Farming systems in mountainous areas are generally based on local forage resources and the milk produced is transformed to high quality cheeses. Most of the milk is produced when animal diets are based on conserved forages, locally produced or purchased from lowlands. The aim of this study was to compare the effects of different winter cow diets based on local and non-local forage resources on the fatty acid (FA) profile and terpene composition of milk in a mountainous area. Forty-five Aosta Red Pied cows were fairly allocated into three groups and fed different diets based on local hay (H), local haylage (S), and hay purchased from the lowlands (LoH), respectively. Diets were supplemented with concentrate to balance the requirements of energy, protein and minerals. The high proportion of forage in diets allowed the obtaining of milk with relatively good contents of conjugated linoleic acids (CLA) and unsaturated FA. Furthermore, the S-based diet did not lead to any change of the milk FA profile compared to H, thus allowing a better self-sufficiency of mountainous dairy farms.

Keywords: conserved forage, milk, fatty acid composition, hay, haylage, mountain

Introduction

Farming systems in mountainous areas are generally based on local forage resources and the milk produced is transformed to typical and/or Protected Denomination of Origin (PDO) cheeses. Differences in diet composition, such as forage type and forage-to-concentrate ratio, have a major impact on fatty acid (FA) composition and terpene profile of milk and dairy products (Engel *et al*., 2007). Several authors have noted that the contents of terpenes and FA beneficial to human health are higher in animal products produced in mountainous systems during the summer season, when cow diets are based on pasture (Leiber *et al*., 2005; Engel *et al*., 2007). However, most of the milk and cheese is produced in winter and early spring periods, when animal diets are based on conserved forages, mainly hay locally produced or purchased from the lowlands. Harvesting forage as haylage in wrapped round bales is an alternative method to produce conserved forage locally and allows for improving the nutritive quality of forage (Borreani *et al*., 2007). The aim of this study was to evaluate the effects of different winter cow diets based on local and non-local forage resources on milk FA composition and terpene profile in a mountainous area.

Material and methods

The experiment was conducted at the ‚Stazione Sperimentale Alpina‘ experimental farm in Sauze d’Oulx (1850 m above sea level, 45°02’N, 6°53’E). Forty-five Aosta Red Pied cows were fairly allocated into three groups according to body weight (499 ± 18 kg), dry matter intake (DMI; 15.5 ± 0.11 kg d^{-1}), and parity (4.3 ± 0.4). During a two-month period, cows of the three groups were fed different diets based on local hay (H), local haylage (S) and hay purchased from the lowlands (LoH). The contribution of forages to the dietary DM was similar throughout the diets and its average value was 68% of DMI. Diets were supplemented with ground barley and pea grains, and a mineral and vitamin mix to balance for the cows' requirements of energy, protein and minerals. The H and S were produced on native permanent grasslands located at 1500-1600 m a.s.l., where Poaceae accounted for more than 75% of total DM. The LoH, made on a *Dactylis glomerata* L. meadow, was purchased in the lowland. Forage, concentrate and milk samples were taken six times (every 10 days) on the same sampling dates. Forage and concentrate samples were freeze dried and ground. Milk samples of each group were taken from stirred bulk tank after two milkings, then centrifuged and cream was extracted. The ground diet component and milk cream samples were analysed for the FA methyl esters by gas chromatography. Milk cream samples were also analysed for terpene compounds by gas chromatograph-electron impact mass spectrometer and results were expressed in arbitrary area units. Data of milk FA composition were analysed using one-way ANOVA (SPSS 16.0) and Duncan's multiple range test ($P < 0.05$) was used to interpret any significant differences among the mean values. Terpene values were log10 transformed to obtain log-normal distributed data and analysed for their statistical significance via a Kruskal-Wallis non-parametric independent group comparison (SPSS 16.0).

Results and discussion

Table 1 summarises the total fat content and the FA composition of forages and concentrates which constituted the diets of three cow groups. The LoH presented higher content of total fat compared to H and S. The $C_{18:3\ n\text{-}3}$ and $C_{18:2\ n\text{-}6}$ were the main FA of forages, followed by $C_{16:0}$. Furthermore, S forage presented 10.82 g 100 g^{-1} FA of $C_{18:4\ n\text{-}3}$. In both concentrates more than 69% of FA was represented by sum of $C_{18:2\ n\text{-}6}$ and $C_{18:1\ n\text{-}9}$. Milk FA composition was affected by diets (Table 2). The $C_{16:0}$, the most present FA in milk, was higher in LoH and S than H milk. The monounsaturated FA (MUFA) and the $C_{18:1\ n\text{-}9}$ were higher in H than in LoH milk. The $C_{18:0}$, $C_{18:1\ n\text{-}7}$ and $C_{18:2\ n\text{-}6}$ were higher in H and S than LoH milk. The different forages fed to the three cow groups did not affect the $C_{18:3\ n\text{-}3}$, conjugated linoleic acid (CLA) and polyunsaturated FA (PUFA) contents of milk. However, these FA presented a relatively higher content when compared to milk produced in lowland and intensive dairy farms (Engel *et al.*, 2007). Five terpenes were also detected in milk from H diets, whereas only four were found in S and LoH milks. The main terpenes were D-limonene and α-pinene.

Table 1. Total fat content (g kg^{-1} DM) and fatty acid (FA) composition (g 100 g^{-1} FA) of local hay (H), local haylage (S), lowland hay (LoH) and concentrates.

	H	S	LoH	Barley	Pea
Total fat	14.8	18.4	21.4	16.8	11.9
$C_{16:0}$	13.47	8.87	15.65	19.50	10.31
$C_{18:0}$	1.39	1.19	2.87	1.67	3.16
$C_{18:1\ n\text{-}9}$	5.54	5.68	6.02	16.00	25.39
$C_{18:2\ n\text{-}6}$	19.04	15.53	18.12	53.64	46.55
$C_{18:3\ n\text{-}3}$	34.08	25.91	34.57	6.51	10.60
$C_{18:4\ n\text{-}3}$	1.39	10.82	1.25	0.00	0.00
Others	25.09	31.99	20.62	2.68	3.99

Conclusions

Table 2. Fatty acid (g 100 g^{-1} FA) and terpene composition (arbitrary area units) of milk from cows fed diets based on local hay (H), local haylage (S) and lowland hay (LoH).

	H	S	LoH	SEM	*P*-value
Fatty acids					
$C_{4:0}$	4.63^{a}	3.44^{b}	3.37^{b}	0.137	<0.001
$C_{6:0}$	2.88^{a}	2.37^{b}	2.27^{b}	0.070	<0.001
$C_{8:0}$	1.64^{a}	1.54^{ab}	1.44^{b}	0.035	0.045
$C_{10:0}$	3.24	3.48	3.30	0.074	0.532
$C_{12:0}$	3.48	3.83	3.73	0.078	0.304
$C_{14:0}$	11.96	12.93	12.82	0.165	0.059
$C_{14:1}$	1.08	1.14	1.18	0.022	0.183
$C_{15:0}$	1.40^{b}	1.39^{b}	1.72^{a}	0.043	<0.001
$C_{16:0}$	31.11^{a}	32.84^{b}	33.26^{b}	0.285	0.002
$C_{16:1}$	1.51^{b}	1.37^{c}	1.66^{a}	0.033	<0.001
$C_{17:0}$	0.67^{a}	0.64^{a}	0.88^{b}	0.031	<0.001
$C_{18:0}$	7.46^{a}	7.40^{a}	6.27^{b}	0.203	0.007
$C_{18:1\ n\text{-}9}$	18.78^{a}	17.77^{ab}	17.17^{b}	0.271	0.044
$C_{18:1\ n\text{-}7}$	1.98^{a}	1.90^{a}	1.45^{b}	0.089	0.012
$C_{18:2\ n\text{-}6}$	1.80^{a}	1.78^{a}	1.66^{b}	0.023	0.006
$C_{18:3\ n\text{-}3}$	0.69	0.68	0.74	0.014	0.118
CLA	0.80	0.95	0.83	0.030	0.179
Unidentified	4.88^{b}	4.55^{b}	6.24^{a}	0.204	<0.001
SFA	68.48	69.86	69.35	0.292	0.276
MUFA	23.34^{a}	22.19^{ab}	21.46^{b}	0.309	0.035
PUFA	3.30	3.41	3.23	0.035	0.111
Terpenes					
D-limonene	32622	23939	14358	-	0.700
α-pinene	94998	46403	23083	-	0.181
Camphene	218	120	-	-	-
β-pinene	19098	2299	423	-	0.202
Δ-3-carene	367	-	149	-	-

CLA = Conjugated Linoleic Acid; SFA = Saturated Fatty Acid; MUFA = Monounsaturated Fatty Acid; PUFA = Polyunsaturated Fatty Acid; SEM = Standard error of the mean; Means followed by different letters within the same row are significantly different according to the Duncan's multiple range test at 0.05 level of probability.

The data showed that winter diets in the mountain environment could be based on different forage resources with only small changes to the FA profile of the milk. Furthermore, forages conserved as baled silages were comparable to hays, and could allow farmers to choose the most cost-effective conservation method.

Acknowledgements

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Ranking stability and indicators for predicting the yield and quality of perennial ryegrass cultivars throughout the growing season

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Abstract

National variety evaluation schemes for perennial ryegrass (*Lolium perenne* L.) cultivars are based on yield and quality assessments. For these schemes, assessing the relative performance of cultivars is the principal objective. As genotype × environment interactions occur, evaluations are carried out over several years. Fifteen cultivars were assessed for DM yield, buffering capacity, crude protein, digestibility and water soluble carbohydrates across four harvest years. The potential to predict the four-year mean 'reference' ranking of cultivars from seasonal growth periods was examined. Silage 1 period was almost as good a predictor as the annual totals for BC, DMD and WSC, with DM yield and CP least predictable by any seasonal period. The design of a minimalist variety selection tool was discussed.

Keywords: perennial ryegrass, cultivars, ranking, quality, yield

Introduction

Perennial ryegrass (*Lolium perenne* L.) swards account for the majority of permanent grassland in temperate climates throughout most of Europe. National variety evaluation schemes for perennial ryegrass evaluate cultivars based on yield, persistence and, to a lesser degree, quality attributes. For the purposes of evaluation schemes the relative performance of cultivars is more important than the absolute performance as this is only relevant to the test site and conditions. The goal of any evaluation scheme is to assess the phenotypic merit of a cultivar; however, this is confounded by genotype × environment interactions. Crossover interactions between cultivars are common in variety evaluation schemes with the implication that a cultivar that is superior in one environment may not maintain this superiority in another (Conaghan *et al*., 2008). This paper compares the seasonal ranking of cultivars for dry matter (DM) yield and four quality attributes with a four-year mean 'reference' ranking. The objectives were to assess the ranking stability among agronomic attributes and the degree to which individual seasonal periods are predictors of the over-years 'reference' rank.

Materials and Methods

Four sowings of 15 perennial ryegrass cultivars (Table 1) were harvested in the second year after sowing from replicated field trials in Backweston, Ireland. Trial management and yield analysis were as described by Grogan and Gilliland (2010). A c.300 g sub-sample was taken from each plot and analysed for 4 quality attributes (*in vitro* dry matter digestibility (DMD), water soluble carbohydrates (WSC), crude protein (CP) and buffering capacity (BC)) using near infrared reflectance spectroscopy as described by Burns *et al*. (2011). The 'reference' ranking was calculated as the total DM yield across all years and quality calculated as a weighted average, by yield, across all years and harvests. The ranking was in descending order from highest to lowest value for all attributes. Comparison of the 'relative' DM yield and quality rankings was calculated using Spearman rank correlation. The data were divided into four seasonal growth periods within a year (Spring, Silage 1, Silage 2 and Rest of Year (ROY)) as described by Grogan and Gilliland (2010). Rank order was assessed in descending order at each seasonal growth period for DM yield and quality and these were compared to the 'reference' ranking using Spearman rank correlation for the respective attribute.

Table 1. 'Reference' ranking of 15 perennial ryegrass cultivars across 4 harvest years for dry matter yield and 4 quality attributes (1 = highest, 15 = lowest).

Cultivar	Maturity	Ploidy	DM Yield	BC	CP	DMD	WSC
Abercraigs	Late	Tetraploid	9	1	6	9	7
Cancan	Late	Diploid	12	7	14	12	8
Cashel	Intermediate	Diploid	10	14	8	15	14
Fornax	Intermediate	Tetraploid	6	15	11	8	2
Gilford	Late	Diploid	13	5	5	7	6
Greengold	Intermediate	Tetraploid	2	10	9	4	4
Magician	Intermediate	Tetraploid	1	11	15	10	9
Millennium	Late	Tetraploid	8	3	3	2	11
Navan	Late	Tetraploid	4	8	12	3	3
Orion	Late	Tetraploid	7	6	4	5	5
Portstewart	Late	Diploid	14	2	2	6	10
Premium	Intermediate	Diploid	11	13	7	13	12
Sarsfield	Late	Tetraploid	3	9	10	1	1
Spelga	Intermediate	Diploid	5	12	13	14	15
Tyrone	Late	Diploid	15	4	1	11	13

Results and discussion

The 'reference' ranking (Table 1) provides the best estimate from this data set for the genuine phenotypic merit of a cultivar and would be comparable to those used for the recommendation of cultivars. The 'reference' rankings of the four quality and DM yield attributes had variable relationships amongst each other with few significant correlations (Table 2). DMD and WSC had the highest rank correlation (R = 0.711) and Humphreys (1989) found a relationship in the latter part of the growing season. CP and WSC are known to have an inverse relationship (Humphreys, 1989). This was not apparent in our analysis; however, further interpretation of the seasonal relationships may reveal some degree of this effect masked by our use of a yield-weighted average across the season.

Comparison of rank order was applied to assess whether a minimal selection tool could be developed that required sampling of only part of the growing season. This would help identify those cultivars worthy of more intense testing and those that could be discarded at an early stage in the testing process. Individual seasonal growth periods were predictors of the 'reference' rankings to varying degrees (Table 3). The highest correlations with the 'reference' rankings were between the annual values for DM yield, DMD, WSC and BC, though these ranged between R = 0.35-0.96. CP was the least predictable of the quality attributes with no consistency across years for any seasonal period. The Silage 1 period was almost as good a predictor of the reference ranking as the annual totals for BC, DMD and WSC, with R.O.Y. being next best for DMD and WSC. The DM yield 'reference' ranking was not consistently predictable by any seasonal period as differences between individual years were greater than for the quality attributes. This indicated that the genotype × climatic interactions were greater for DM yield and CP than for BC, DMD and WSC. Nonetheless there were varying degrees

Table 2. Spearman rank correlation matrix of DM yield and four quality attributes

Yield				
DMD	0.357			
WSC	0.450	0.711**		
CP	-0.639*	0.211	-0.214	
BC	-0.446	0.393	0.007	0.625*
	Yield	DMD	WSC	CP

* P < 0.05; ** P < 0.01

of crossover interactions throughout the seasonal growth periods and also throughout all four years for all attributes and none provided as precise a cultivar ranking as using all four years of data. This does not mean that a minimal selection tool is not possible as the requirement was for an early indicator to select the top performing cultivars and exclude those with poor potential from further investment in testing activity. The 15 cultivars were assessed across four years and any environmental influences were due to variation in weather rather than to edaphic or management factors.

Table 3. Spearman rank correl. of individual seasonal growth periods with the 'reference' ranking

	DM yield							
	2003	2006+	2007	2008	2003	2006+	2007	2008
Spring	0.414	-	0.389	0.511*				
Silage 1	0.554*	0.289	0.639*	-0.243				
Silage 2	0.564*	-0.007	0.582*	0.475				
R.O.Y.	0.493*	-0.111	0.654**	-0.004				
Annual	0.789**	0.357	0.846**	0.611*				
	DMD				WSC			
Spring	0.511*	-	0.057	0.089	0.707**	-	0.421	0.414
Silage 1	0.821**	0.739**	0.711**	0.793**	0.718**	0.521*	0.750**	0.636*
Silage 2	-0.357	-0.189	0.521*	0.329	0.332	0.193	0.450	0.243
R.O.Y.	0.332	0.775**	0.818**	0.843**	0.107	0.564*	0.625*	0.607*
Annual	0.775**	0.818**	0.925**	0.907**	0.796**	0.571*	0.875**	0.825**
	CP				BC			
Spring	-0.089	-	0.586*	0.307	0.368	-	0.864**	0.379
Silage 1	-0.364	0.396	0.425	0.282	0.557*	0.782**	0.411	0.750**
Silage 2	0.082	0.186	0.186	0.136	0.346	0.282	-0.639**	0.039
R.O.Y.	0.571*	-0.200	0.875**	0.114	0.850**	0.025	0.300	0.182
Annual	-0.130	0.457	0.400	0.471*	0.746**	0.960**	0.450	0.800**

R.O.Y. - Rest of Year, + No spring cut in 2006, *$P < 0.05$; ** $P < 0.01$

Conclusion

Expected effects of genotype x environment interactions were observed. From within this it was possible to determine differences in sensitivity between different attributes and identify seasonal periods that were better predictors of the 'true' genetic merit for some attributes. This could allow a breeder or evaluator to reduce workloads by targeting a seasonal growth period for analysis and exclude those cultivars with lower phenotypic potential. It may be possible to further improve predictability of this minimal approach by using a combination of seasonal growth periods while reducing cost and time. This merits further study.

Acknowledgements

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Strategies for mechanical weed control of False Hellebore (*Veratrum album* L.)

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Abstract

In the last decades, mountain farms in the Alps have experienced a reduction of available manpower. For this reason, maintenance measures of such as removing ungrazed plants and weeds from the pasture at the end of the season have often been omitted. Plants avoided by grazing livestock are then able to spread, leading to a deterioration of forage quality and yield. Increasing problems with *Veratrum album*, a poisonous forb, have been reported in the Alps. In order to develop a control strategy for this species, a field experiment was conducted in two contiguous subalpine pastures (1900 m a.s.l., Taufers im Münstertal, South Tyrol, Italy). Four treatments (control, mowing, plant break above the first leaf, and pulling out of epigeal parts) were applied for three years at two treatment dates; a fifth treatment (digging out the roots) was applied in a single growing season in a further experiment. Shoot fresh weight was found to be strongly reduced by most control methods, whereas shoot density was only partly reduced. Only digging out the root, a very time-consuming method, showed great effectiveness after one application. Mechanical weed control should therefore start at the first appearance of weeds.

Keywords: *Veratrum album*, mechanical weed control, shoot density, shoot fresh weight

Introduction

Because of ongoing socioeconomic changes, mountain farms in the Alps have experienced a considerable reduction of available manpower in the last decades. For this reason, time-consuming maintenance measures of summer pastures, such as cleaning the pasture of ungrazed plants and weeds at the end of the grazing season, have often been neglected. As a consequence, weeds can spread over time on the pastures, leading to a deterioration of forage quality and yield. Increasing infestation with False hellebore (*Veratrum album* L.) in alpine pastures has been repeatedly reported in South Tyrol. False hellebore is a poisonous forb, containing toxic alkaloids in the whole plant (Roth *et al*., 2008). According to Schaffner *et al*. (2001) grazing animals usually reject *Veratrum album*, but especially in the later season, when the surrounding vegetation has been heavily grazed, they feed upon it. The intake of the plant material may cause diarrhoea, slow respiration, colic, lameness and muscular cramps. Also, deadly intoxications are known to occur (Roth *et al*., 2008). In order to ascertain the effectiveness of several methods suggested for the mechanical weed control of this species and to develop a control strategy, two field experiments were conducted in South Tyrol between 2001 and 2005.

Materials and methods

Two field trials were conducted in two contiguous, nutrient-rich summer pastures: Mitteralm and Mangitzalm (10°25‘4,2“E, 46°40‘1,35“N; 1900 m a.s.l., Taufers im Münstertal, South Tyrol, I). At the beginning of the trial both pastures exhibited a weed infestation of False hellebore. At the Mitteralm an early cut had been performed in the previous three years as a weed control measure, while at the Mangitzalm no countermeasure had been undertaken before the trial start. In trial 1, four different treatments were applied for three years: mowing

(M); plant break above the first leaves (B); pulling out of the epigeal parts down to the plant collar (P); and an undisturbed control (C). All mechanical treatments were applied once a year. The effect of different growth stages of False hellebore were also investigated; the weed control treatments were performed either at the beginning of June before the start of the grazing season or towards the end of the month. The trial design was a randomised complete block design with four replicates. The plot size was 2.5 m×4 m. In each treatment the number of False hellebore-shoots per plot was counted prior to applying the weed control treatments. From 2002 to 2004 the fresh weight of shoots of M, B and P treatments was measured as well. In trial 2, which was established in 2005 near to trial 1 with the same design, weed control treatments were applied for one year only and B was replaced by digging out the roots by means of a dock-weeding fork (D). As a difference to experiment 1, only the shoot density was measured. Treatment efficacy on shoot density was calculated according to Henderson and Tilton (1955). The effect of the repeated early cut on plant density before trial start at the Mitteralm was investigated through analysis of variance of shoot density at the start of the trial, assuming pasture to be a fixed factor. Data on treatment efficacy were subjected to analysis of variance taking into account pasture, weed control method and date of treatment as fixed factors. Statistical analysis of shoot fresh weight data was performed by means of a mixed model including pasture, weed control method, date of treatment, year and their interactions as fixed effects, with the year as a repeated factor. Multiple comparisons were performed by Least Significant Difference. Prior to analysis, all data were logarithm-transformed in order to meet the requirements for ANOVA. Back-transformed means are displayed.

Results and discussion

At the start of trial 1 in 2001, shoot density was found to be lower at the Mitteralm than at the Mangitzalm (6.8 *vs.* 11.2 plants m^{-2} respectively, $P < 0.05$). The same was observed in trial 2 in 2005 (9.9 *vs.* 13.9 plants m^{-2} respectively, $P = 0.05$). These findings suggest that repeated mowing leads to a reduction in the density of False hellebore. In both trials there were clear differences concerning efficacy of the weed control methods ($P < 0.001$ in trial 1 and 2). Over three years of repeated treatment, none of the methods tested in trial 1 exhibited far more than 50% efficacy in reducing the density of False hellebore, with M and B being less effective than P (Table 1).

Table 1. Effect of the weed control methods on efficacy and shoot fresh weight in trial 1 and 2. Means without common letters significantly differ from each other.

Weed control method	Efficacy (%) Trial 1	Trial 1	Shoot fresh weight (g shoot^{-1}) Trial 2
M	31.8^{b}	6.2^{c}	2.80^{b}
B	33.4^{b}		2.34^{b}
P	51.8^{a}	16.4^{b}	3.15^{a}
D		88.4^{a}	

The same figure was observed for M and P in trial 2 in one single application year with 16% efficacy of P and 6% of M. In other experiments, M was found not to significantly reduce shoot density over time (Schaffner *et al.*, 2001). In trial 2, D proved to be a very effective method to drastically decrease shoot density. However, at an initial shoot density of 10 shoots m^{-2} this very time-consuming method seems not to be a viable solution to be employed in the praxis. The date of treatment affected the efficacy only in trial 2 (41.4% at the beginning of June *vs.* 32.6% at the end of June), partly supporting the hypothesis of Schaffner *et al.* (2001) that optimal timing may be important to deplete resources in the rhizome and in turn to improve the efficacy of M.

The shoot fresh weight in trial 1 was affected by the weed control method ($P < 0.05$), the date of treatment ($P < 0.05$) and the pasture ($P < 0.001$). As expected, P and M resulted in a higher shoot fresh weight (3.15 and 2.80 g shoot^{-1}) than B (2.34 g shoot^{-1}), as plants were broken at a higher distance from the ground. Also, the shoot fresh weight was expectedly higher at the later treatment date (2.84 *vs.* 2.42 g shoot^{-1}) because of the later growth stage of the plants. An interaction was found between year and pasture ($P < 0.001$). At the start of the trial, the shoot fresh weight at the Mitteralm had already been reduced by mowing in the previous years and it was about one-fourth of that at the Mangitzalm (Figure 1). Differences between the pastures became smaller and smaller over time, as the shoot fresh weight at the Mangitzalm strongly decreased within two years.

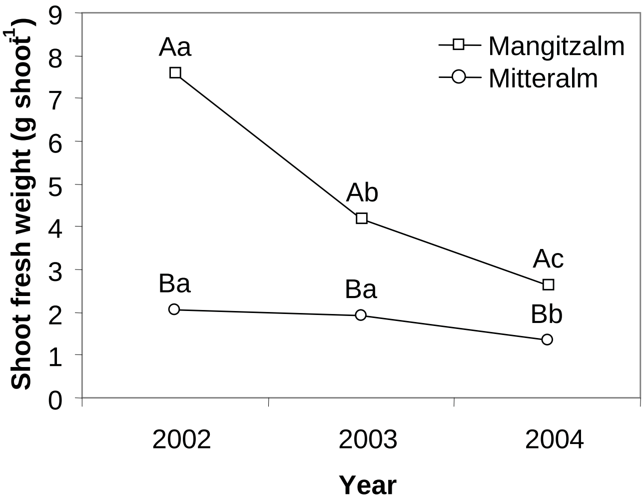

Figure 1. Changes of shoot fresh weight of *Veratrum album* over time at the two investigated pastures. Means without upper case letters in common within each year and means without lower case letters in common within each pasture significantly differ from each other.

Conclusions

Only by digging out the root is high effectiveness of mechanical control of *Veratrum album* ensured in a short time. Mechanical weed control should therefore start at first appearance of weeds. All other methods have to be carried out consistently over a long time to reduce plant density, while reduction in plant height can be rapidly induced by all of the tested weed-control methods.

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Grassland evaluation based on GIS model and Remote Sensing data for beef cattle grazing

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Abstract

The aims of this study were to evaluate grasslands in terms of suitability for beef cattle grazing and produce grassland-suitability and availability maps. The study area is located in eastern Turkey. In order to monitor vegetation cover and chemical composition of grass, 3 sub-plots were fenced to collect grass samples and herbage was measured by hand clipping at ground level within quadrats and then biomass was calculated on a fresh and dry matter basis. Sward height was measured as the height of the top surface of the leaf canopy. LANDSAT satellite data were used to realize geographical correction of the data. The image of the area was produced selecting red (0.45-0.52 μm), near infrared (0.52-0.60 μm) and infrared (0.63-0.69 μm) bands, and reflection histograms and curves were created and interpreted. GIS was used to produce classification maps. Grassland suitability for beef cattle grazing was considered and, as a result, three classes of suitability were determined as highly suitable, moderately suitable and marginally suitable.

Keywords: grassland, beef cattle, GIS, Remote Sensing

Introduction

Remote Sensing (RS) is the science of obtaining and interpreting information from a distance, using sensors that are not in physical contact with the object being observed. A Geographic Information System (GIS) is a system for capturing, storing, analysing and managing data and associated attributes which are spatially referenced to the earth. Satellite remote sensing has contributed to various aspects of grassland management, such as plant cover mapping and monitoring changes (Roberts *et al*., 2002), evaluation of ecosystems, estimation of biomass, carbon flux and productivity and the feasibility of developing an integrated information system (Janglong *et al*., 1995; Alves *et al*., 1999). The objective of this study was to evaluate grasslands in eastern Turkey in terms of their suitability for beef cattle grazing and produce grassland suitability and availability maps.

Materials and methods

The study area is located in Kars Province of eastern Turkey, 40°33‘N, 43°21‘E, with 2090 m area. In general, in eastern Turkey beef cattle production is carried out under extensive conditions and based on grasslands (Avcioglu, 2000). In order to monitor the chemical composition of grass in terms of Crude Protein, Dry Matter and Crude Fibre, 3 sub-plots (16 m²) were fenced to provide sampling areas to collect grass samples every two weeks, and in order to monitor vegetation cover quadrats were used on 3 different sites for 3 years from 2005-2007. Herbage biomass was measured by hand clipping herbage at ground level within quadrats then biomass production was calculated on a fresh weight and dry matter basis. Sward height was measured as the height of the top surface of the leaf canopy using a wooden sward stick. These parameters were collected to produce a grassland availability map. LANDSAT 5 TM satellite data taken on 25 July 2005 were used. Reflection ranges known for green cover were used for the distribution of grasslands on the satellite image of the study area. Geographical correction of satellite data was realized using ERDAS Imaging 9.0 software. The image of the area was produced selecting red (0.45-0.52 μm), near infrared (0.52-0.60 μm) and infrared (0.63-0.69 μm) bands according to the literature (Rao *et al*., 1991) and reflection histograms of the whole bands were created, and the reflection curves were interpreted and GIS software ARCview was used to produce classification and suitability maps.

Results and discussion

A GIS model was created by using parameters based on field data (Figure 1). The input parameters of the model are shown on the left hand side of Figure 1. Grassland availability and suitability for beef cattle grazing were considered and three classes of suitability were determined as being highly suitable (Type 3), moderately suitable (Type 2) and marginally suitable Type 1) as shown in Figure 2.

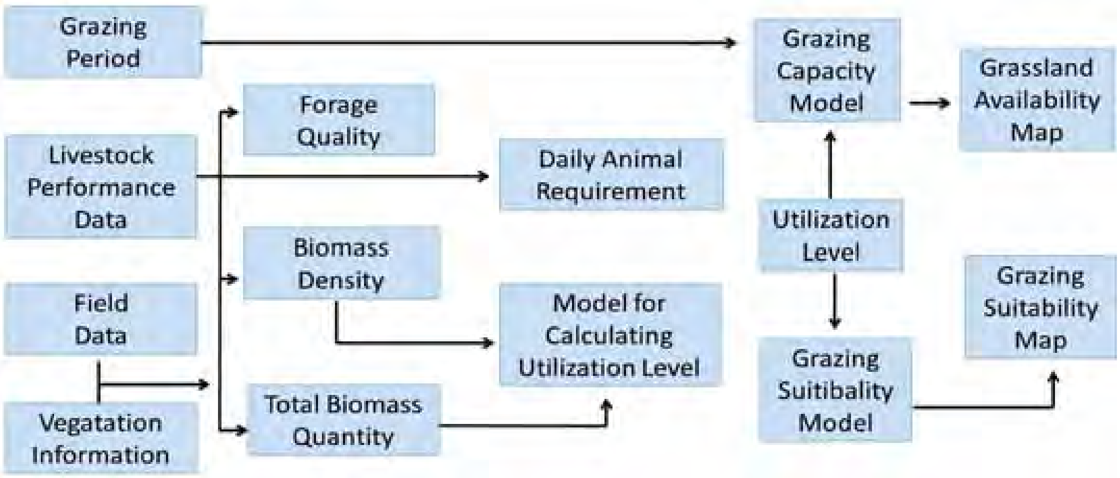

Figure 1. GIS Model Flow chart for Grassland Classification Map

Two-thirds of the total area of Kars province is grassland. However, in terms of plant-cover-density this accounts for only one-third of the total area (Figure 2). On this basis, only 181 276 ha of the 638 394 ha total grassland area is in a good status and highly suitable in terms of plant cover for beef cattle grazing. It was also found that the best quality grasslands (highly suitable) for cattle grazing are in the North-west of the province starting from the West of Sarikamis Forests to the North-western range of Allahuekber Mountains and to the foothills of Erdagi Mountains.

Conclusions

The results of this study can be beneficial for improvement of beef cattle production in the Region. GIS Modelling and RS data can provide better information and easier integration of various information layers to support a model of grassland assessment for beef cattle grazing. Therefore, GIS and RS can be useful techniques to provide greater flexibility and accuracy for grassland assessment.

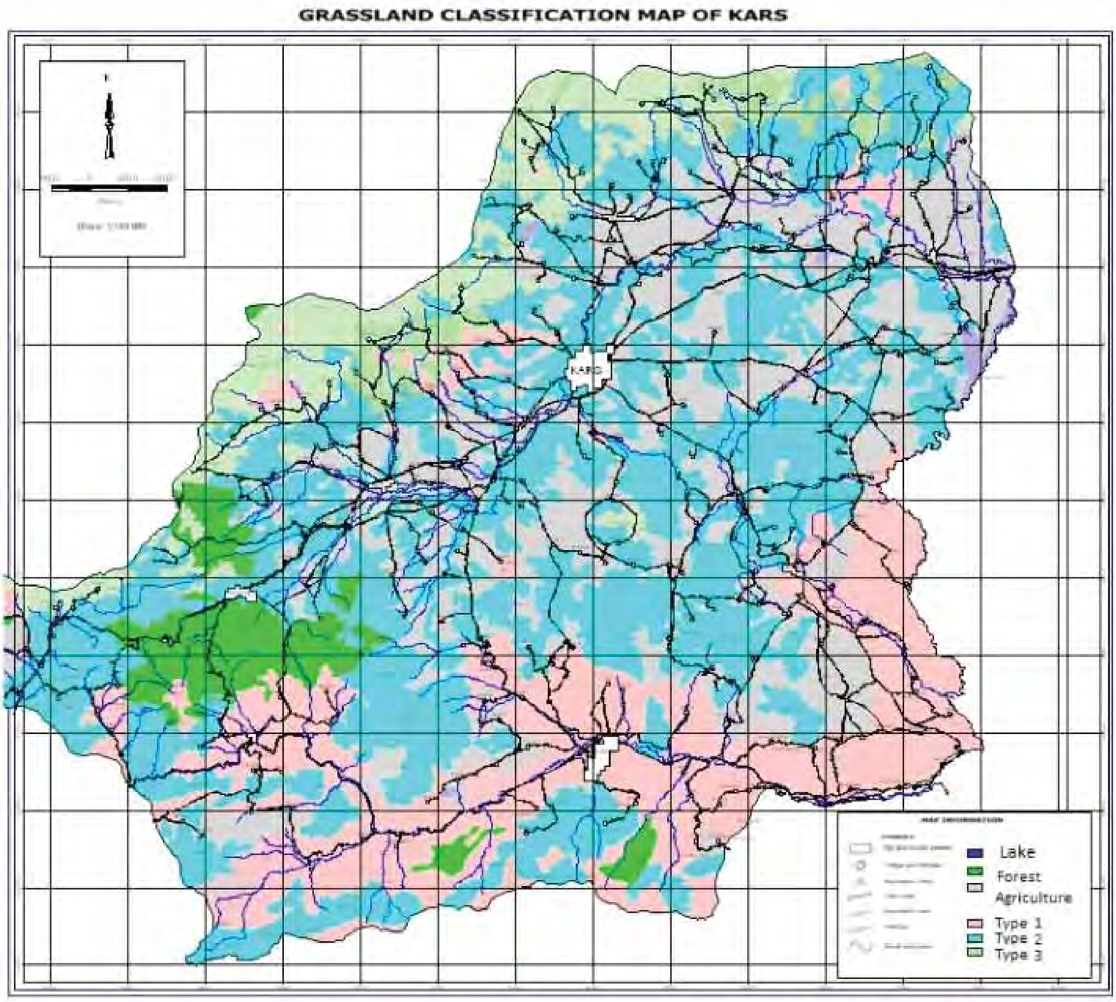

Figure 2. Grassland Classification Map

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Effect of heading date, ploidy level and cutting regime on yield and feed quality of perennial ryegrass (*Lolium perenne* L.)

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Abstract

Due to economic constraints in dairy farming at least four cuts per year are generally considered necessary in order to fulfill demands in forage quality of grass silage for high genetic merit cows. However, we hypothesize that late-heading cultivars of perennial ryegrass might also perform well in a 3-cut system and thus reduce production costs of grass silage. In a 2-year (2009 and 2010) field trial, yield performance and forage quality of twelve perennial ryegrass cultivars from three maturity groups (early, intermediate and late) and two ploidy levels (diploid and tetraploid) were tested under different cutting frequencies (3, 4 and 5 cuts per year) at two sites in northern Germany. There were no significant differences detected in yield or digestibility of organic matter (DOM) for an early first-cut as conducted in the 5-cut system, whereas a late first-cut revealed the expected differences between maturity groups in DOM for at least one site, but not for yield performance. Results for the annual yield showed a significant interaction between years, sites and cutting regime. We conclude that although using late cultivars of perennial ryegrass, forage quality is not sufficient in a 3-cut system.

Keywords: perennial ryegrass, digestibility, yield, maturity group, ploidy level, cutting regime

Introduction

Forage production based on grassland is costly, as 4-5 cuts per year are needed to achieve adequate digestibility to feed high yielding dairy cows. From an economic point of view late-season cuts are inefficient as they result in low yields and poor digestibility of forage. The objective of the current study therefore was to investigate the potential of reducing cutting frequency from 5 to 4, or 4 to 3, cuts per year by using late-maturing cultivars. In this paper results of two growing seasons are presented for digestibility and dry matter yield of perennial ryegrass.

Materials and methods

A 2-year (2009-2010) field experiment was conduced at two sites, Hohenschulen (sandy loam, 8.8°C, 760 mm) and Schuby (humouse sand, 8.0°C, 850 mm), in northern Germany. In a split-plot design with four replicates twelve cultivars of perennial ryegrass (Table 1) with different heading dates (early (MG1), intermediate (MG2) and late (MG3)) and ploidy levels (diploid (2n) and tetraploid (4n)) were tested in 3 cutting regimes (3, 4 or 5 cuts a year) as main plots. Plots were sown in September 2007. Data from the growing seasons in 2009 and 2010 are included here. Nitrogen fertilization was applied as calcium ammonium nitrate at an amount of 360 kg N per year split into 3-5 dressings, depending on cutting regime. First cuts of the 5-, 4- and 3-cut system were taken at heading of the early, intermediate and late cultivars, respectively. Following cuts were taken after 32 ± 3 days, 40 ± 4 days or 55 ± 5 days for the 5-, 4- and 3-cut system, respectively. The plots were harvested with a Haldrup plot-harvester, herbage samples dried at 59°C and ground through a 1 mm sieve. Forage quality parameters were estimated by NIRS. Digestibility of the organic matter (DOM) was calculated according to Weißbach *et al*. (1999), based on a cellulase-method. Data were statistically analysed using the Mixed procedure of SAS, with the least significant difference procedure for mean comparisons. Probabilities were adjusted by Bonferroni-Holm test.

Table 1. Cultivars included in the study. Heading dates are provided in brackets as days after 1st of April (Bundessortenamt 2009).

Heading	MG 1 early	MG 2 intermediate	MG 3 late
diploid	Lipresso (41)	Fennema (52)	Gladio (62)
	Marika (44)	Respect (51)	Sponsor (64)
tetraploid	Lacerta (44)	Trend (52)	Gemma (63)
	Pionero (44)	Maritim (58)	Delphin (62)

Results and discussion

The digestibility of organic matter (DOM), observed for the first cut declined from about 87% at an early harvest (5-cut system) to 75%-80% at a late harvest (3-cut system), as also reported by Rinne *et al*. (1997). At Schuby, the herbage had higher digestibility and lower yield, possibly as a result of drought stress (Wilson, 1982). At Hohenschulen, reducing cutting frequency from 5 to 4 or 4 to 3 cuts showed less decline in DOM for the late compared to the early maturity group (Figure 1). This effect of maturity could not be confirmed at Schuby. It may be assumed that low water availability at Schuby, caused by a light sandy soil, had a more pronounced effect on growing processes than genetically caused differences among cultivars. Overall the difference in digestibility of the first cut among the twelve used cultivars was smaller than anticipated but increased during later cuts.

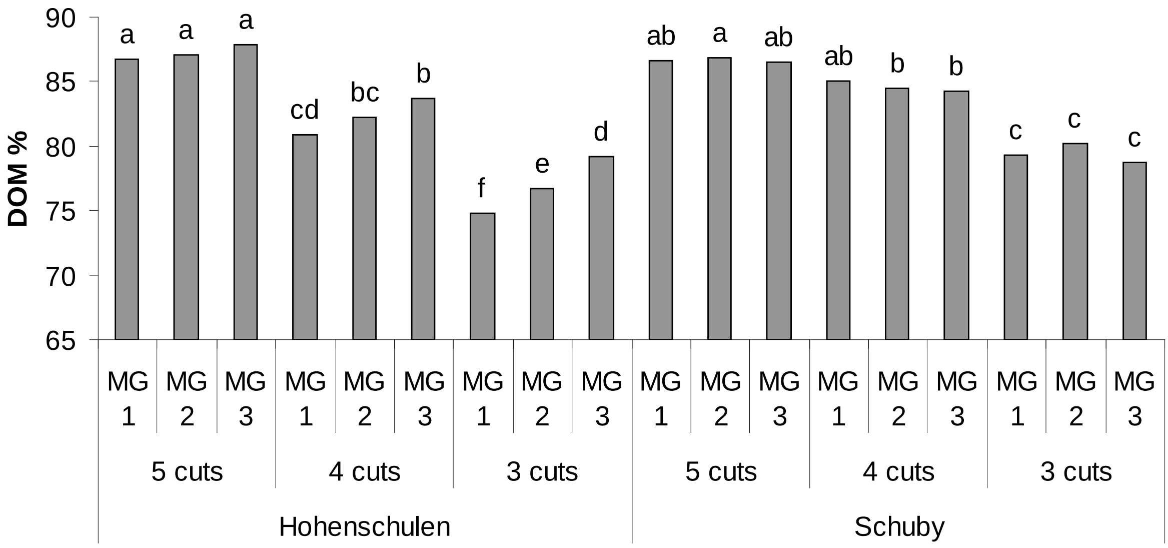

Figure 1. First cut digestibility of organic matter (DOM, %) of perennial ryegrass as influenced by maturity group (MG1 early, MG2 intermediate, MG3 late) and cutting regime. Means within one site marked with different letters were significantly different (Bonferroni-Holm, $P < 0.05$).

Dry matter (DM) yield of the first cut increased when the first cut was delayed (Figure 2). Surprisingly, we did not find any significant differences among maturity groups for the 5-cut system. The annual DM yield consistently decreased from 2009 to 2010 at both sites (Table 2), which might be due to sward age and a hot and dry summer in 2010. The ranking of the cutting regimes in Hohenschulen changed over the years. In 2009 the 3-cut system had a higher yielding performance (17.1 t ha^{-1}) compared to the 5-cut system (12.6 t ha^{-1}), maybe caused by a very late first cut in the 3-cut system. The situation was opposite in 2010 with a higher annual yield in the 5-cut system than the 3- and 4-cut systems. Maturity group and ploidy level had no significant impact on annual DM yield.

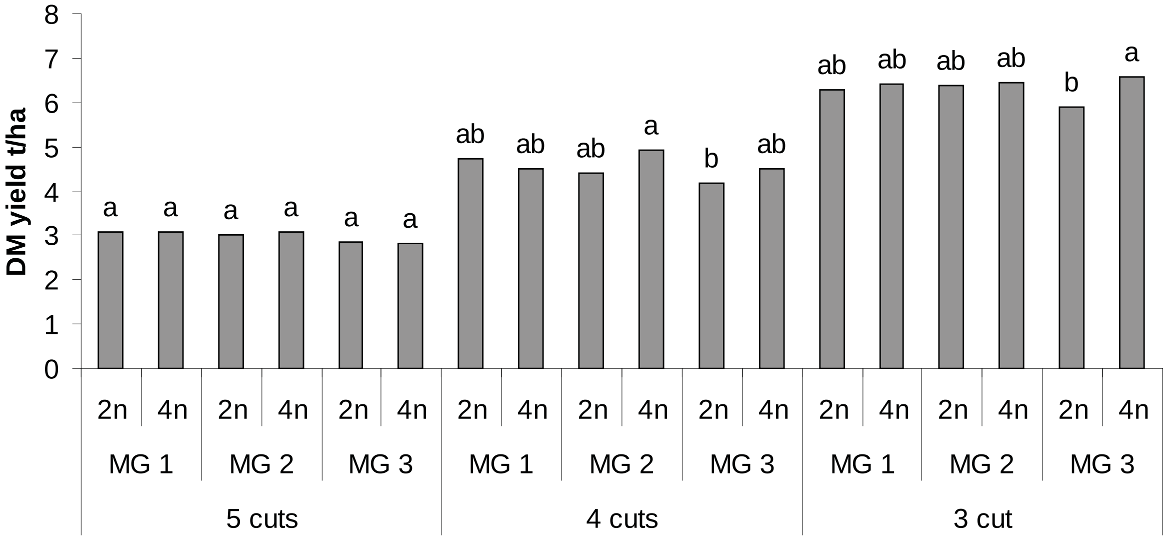

Figure 2. First cut DM yield of perennial ryegrass as influenced by maturity group (MG), ploidy level (diploid (2n) and tetraploid (4n)) and cutting regimes. Means within one cutting regime marked with different letters were significantly different (Bonferroni-Holm, $P < 0.05$).

Table 2. Annual dry matter yield of perennial ryegrass cultivars within different cutting regimes. Means within one site and year marked with different letters were significantly different (Bonferroni-Holm, $P < 0.05$).

Site	Year	Dry matter yield t ha^{-1} a^{-1} 3 cuts	4 cuts	5 cuts
Hohenschulen	2009	17.1 a	13.9 b	1.6 c
	2010	9.9 b	1.2 ab	10.7 a
Schuby	2009	10.5 ab	10.9 a	10.3 b
	2010	9.6 a	9.3 a	9.2 a

Conclusions

Assuming that digestibility of organic matter of about 75-80% is adequate for feeding high yielding dairy cows, a reduction of cutting frequency from 5 to 4 cuts seems feasible for an economic optimisation of forage production. A further reduction, i.e. from 4 to 3 cuts, cannot be recommended for any of the tested maturity groups.

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Estimation of grassland productivity by using climate parameters in the French Piedmonts Pyrenean Mountains

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Abstract

Meadows were studied in 2008 and 2009 in 'Pyrénées-Atlantiques' and 'Hautes-Pyrénées', French Piedmonts Pyrenean Mountains, to elaborate models to predict grassland yield. These statistical models use linear regression linked yield with different prediction parameters. The model of first production cycle, without fertilization, links yield to sums of temperature accumulated from February 1st. The studied grasslands have very different production potentials without fertilization, so other parameters are tested to improve predictions. The index of nitrogen nutrition (INN) is the most pertinent variable. Two models are constructed according to grasslands INN: low or high. Nitrogen fertilization increases the growth rate if the nutrition status of grassland is not optimum (low INN) but has no effect otherwise. These models are included in a computer tool to improve predictions of grass yields and optimize the grassland management in the French 'Piedmonts' Pyrenean Mountain.

Keywords: meadows, production, modelling, Pyrenean, mountain

Introduction

A large percentage of agricultural land in mountain areas is under grass. Constraints like altitude, slope and climate reduce the possibilities of other uses for these lands. The essential challenges facing these areas are technical, economic and environmental issues. Grassland farming systems have to meet production targets of farmers in terms of quantity and quality within the constraints of the environment. Obviously, they have to be economically viable, while contributing to the preservation of natural areas. The aim of this study is to understand the dynamics of growth of the grass on the meadows of the French 'Piedmonts' Pyrenean Mountains in order to improve the grassland use practices. Different models have been developed on the first cycle of grassland production based on climatic conditions of two successive years.

Materials and methods

The experimental sites are located in farm fields. They are distributed throughout two French areas, the 'Pyrenees-Atlantiques' and 'Hautes-Pyrenees'. Trials were performed in 10 meadows over two springs, 2008 and 2009. Plots are located at altitudes ranging from 135 m to 850 m. Three types of grassland are represented: arable meadow, permanent grassland, and native grassland. Detailed information on experimental sites is given Table 1.
The main use of these grasslands before the establishment of the trials was mowing, followed mostly by autumn or winter grazing by sheep or cattle. In this study, grassland yield was measured three times during the first grassland production cycle so as to provide one sample per month. Samples of grass are made with a frame of 0.5×0.5 m or 1×1 m. The grass

is cut with mini-lawnmower to 5 cm above the ground. The last cut is synchronous with the farmers' mowing date for hay. According Gaillard and Le Bris (1988), sums of temperature are the common climatic parameter used in the empirical models to predict grassland yield at the first production cycle. The accumulation of daily mean temperature from Météo France station starts at February 1st (Duru *et al*., 1998) with base temperature of 0°C and an upper threshold of 30°C. Differential altitude between the station and the plot is taken into account by a withdrawal of 0.6°C on average per day for elevation of 100 m (Theau and Zerourou, 2008). The simple linear models elaborated link the grass DM yield to sums of temperature accumulated from February 1st, in different conditions: with or without fertilization, different levels of index of nitrogen nutrition (INN) defined by nitrogen content measured compared to the theoretical nitrogen content, various percentage of legumes or organic matter soil content. These models are included in a computer tool. Using this tool, agricultural advisers of the French 'Piedmonts' Pyrenean Mountain are now able to estimate grassland productivity as weather conditions, altitude and grassland agronomic characteristics (% legumes, INN, …). The date of achieving the desired yield is also indicated.

Table 1. Experimental sites and types of grassland

Sites	Altitudes (m)	Types of grassland	Age (year)	Dominant species
Armendarits	145	Arable meadow	3	*Festuca arundinacea*, *Poa pratensis*
Banca	575	Native grassland	> 20	*Agrostis stolonifera*, *Lolium perenne*, *Holcus lanatus*
Bugnein	175	Permanent grassland	8	*Dactylis*, *Festuca arundinacea*
Cazes	575	Arable meadow	3	*Dactylis*, *Anthoxanthum odoratum*
Habatjou	850	Native grassland	> 20	*Holcus lanatus*
Laran	410	Native grassland	> 20	*Anthoxanthum odoratum*, *Holcus lanatus*, *Agrostis tenuis*
Manse	500	Native grassland	> 20	*Poa trivialis*, *Holcus lanatus*
Paucis	790	Native grassland	> 20	*Festuca*, *Holcus lanatus*
Uzan	135	Arable meadow	2	*Holcus lanatus*, *Festuca arundiniacea*, *Dactylis*
Vignau	435	Permanent grassland	>10	*Lolium multiflorum*, *Holcus lanatus*, *Poa trivialis*

Results and discussion

The model of first production cycle (Figure 1), without fertilization (T0 N), explained DM yield variability by 76% (R^2 = 0.76). The growth rate is 6.4 kg DM ha^{-1}°C day^{-1} and the vegetation starts at 238°C day. However, the residual standard deviation and RMSE (Root Mean Square Error) of the model are quite high, respectively, at 1000 kg DM ha^{-1} and 983.5 kg DM ha^{-1}. Different exposures of the studied meadows on slopes of the mountain or different soil organic matter content could explain this prediction level. The second model, with fertilization, indicates that nitrogen application (60 kg N ha^{-1}) increases growth rate by 1.6 kg DM ha^{-1}°C day^{-1} but residual standard deviation and RMSE are

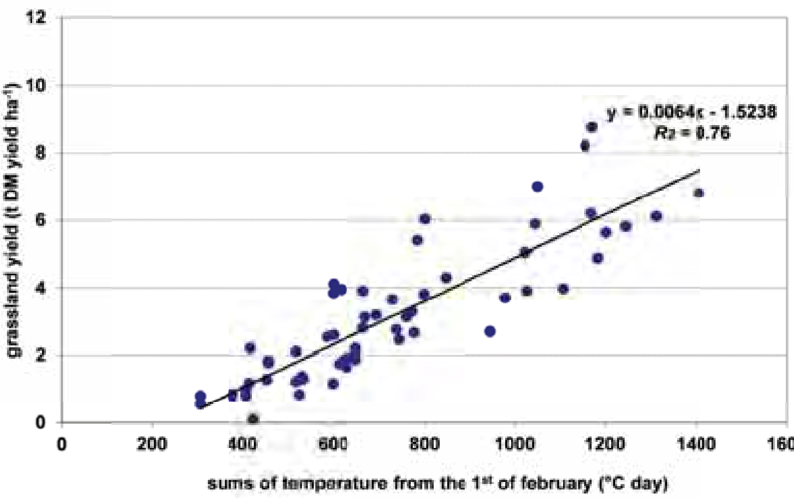

Figure 1. model of first production cycle, without fertilization (T0 N). 10 meadows, in 2008 and 2009.

still high. Other parameters are tested to improve predictions. The index of nitrogen nutrition (INN) is the most pertinent variable. The grass DM yield is explained by 80% ($R^2 = 0.8$), the residual standard deviation and RMSE are respectively of 920 kg DM ha^{-1} and 896 kg DM ha^{-1}. When taking account of the organic matter or percentage of legume, it explained similarly by 77% ($R^2 = 0.7$). Thus, two models are elaborated according to grass INN: low or high (Figure 2). The growth rates are respectively 5.8 and 8.9 kg of DMha^{-1} °C day. INN is considered low when below 0.7. Nitrogen fertilization with a dose at 60 kg N ha^{-1} increases the growth rate of 1.8 kg of DM ha^{-1} °C day if the nutrition status of grassland is not optimum (low INN) but has no effect otherwise (Figure 2). These results seem consistent. Indeed, meadow in high INN level is well supplied with nitrogen.

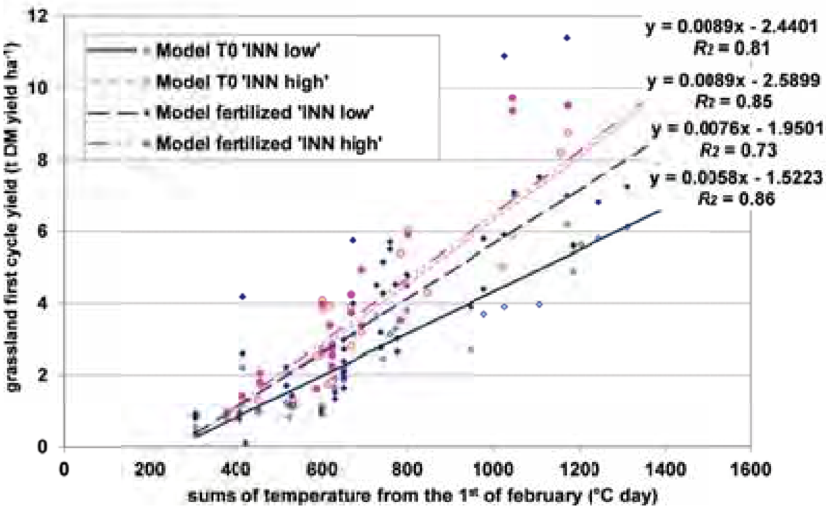

Figure 2. models of first production cycle without or with fertilization, low or high INN. 10 meadows, in 2008 and 2009.

Conclusion

Nitrogen application increases growth rate in the first production cycle compared to unfertilized grassland. Models using index of nitrogen nutrition (INN) improve predictions.

With nitrogen application, the growth rate of grass, in low INN level, is improved compared with unfertilized grass in similar conditions. Otherwise, nitrogen fertilization on grass in high INN level has naturally no effect on growth rate of grass compared to unfertilized grass in similar conditions.

The four models presented here are included in a computer tool to improve predictions of grass yields and optimize grassland management in the French 'Piedmonts' Pyrenean Mountain.

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Milk volatile compounds derived from a hay-based diet or different grazing systems on upland pastures

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Abstract

This research aimed at comparing volatile organic compounds (VOCs) in milk from cows fed a hay-based diet (I) or grazing two different upland grasslands: a highly diversified pasture (74 botanical species; area: 12.5 ha) managed under a continuous mode (CG), and a less-diversified pasture (31 botanical species; area: 7.7 ha), an old temporary grassland, managed under a rotational mode (RG). Three equivalent groups of 8 Montbéliarde cows were used. Individual milk was sampled after 2 weeks of experimental treatments. Headspace (HS) volatile compounds were extracted by solid-phase microextraction (SPME), and determined with GC-MS. Seventy-four VOCs were identified. Terpenes - which are directly transferred from feed to milk - dimethyl sulfone, skatole, toluene, undecanoic acid, 1-octadecene, benzeneacetaldehyde, octanoic acid, 2-pentanone-4-hydroxy-4-methyl - which are derived from animal metabolism - concentrations differed according to feeding systems. Pasture-derived milk was richer ($P < 0.05$) in camphene, sabinene, β-caryophyllene and skatole than I milk. The CG milk was richer in β-pinene, cymene-(p), β-caryophyllene, alloaromadendrene, germacrene-D, γ-cadinene and 1-octadecene than RG milk, while RG milk was richer in benzeneacetaldehyde compared to CG milk. This study thus suggests that milk VOCs of metabolic origin could be potential tracers of animal feeding systems.

Keywords: milk; volatile organic compounds; cow diet; grazing management, hay

Introduction

Several studies have investigated milk volatile organic compounds (VOCs), especially focusing on terpenes which are directly transferred from animal feed to milk (Viallon *et al*., 2000). Pasture-derived milk generally has more terpenes than milk from cows given preserved forages (Martin *et al*., 2005), and terpene quality and quantity varies according to pasture botanical diversity (Bugaud *et al*., 2001; Tornambé *et al*., 2006). The effect of animal feeding on the VOCs of metabolic origin has been extensively investigated in meat (Prache *et al*., 2005), whereas little is known about the effect on milk. The aim of this study was to investigate the effect on cow milk VOCs, particularly non-terpenoids, of a control diet (hay and concentrate) and two grazing systems typically adopted in upland areas: continuous grazing on extensively managed pasture with high biodiversity, or rotational grazing on intensively managed and less-biodiverse grassland.

Material and methods

The experiment was carried out at the INRA experimental farm of Marcenat (mountain area of central France) where three equivalent groups of 8 Montbéliarde dairy cows were used: the first group (I) was kept indoors and fed a concentrate and hay-based diet; the second one

(CG) grazed continuously at a low stocking density (0.96 LU ha^{-1}) ona species-rich heterogeneous pasture (74 species; 12.5 ha; 3.27 t/ha of dry matter (DM) of biomass availability); the third one (RG) grazed, by rotational grazing, at higher stocking density (1.56 LU ha^{-1}) an old temporary grassland (7.7ha) that was less botanically diverse (31 species), with 2.67 t/ha of DM of biomass availability. Group I cows were fed with 12.5 kg of DM of hay produced on RG plot the year before, 5.8 kg of DM of maize/barley flakes (50:50), and 1.1 kg of DM of soybean cake. Individual milk from two consecutive milkings was collected at the end of May, after two weeks of experimental treatments. At milk sampling, CG herbage had 37.1% DM, 114.5 g/kg DM of crude protein (CP), and 55.4 % of organic matter digestibility (OMD), while RG herbage had 19.7 % DM, 197.3 g/kg DM of CP, and 66.4% of OMD. Milk volatile compounds were extracted by solid-phase microextraction (SPME), and determined with GC-MS. The log10 transformed peak areas were analysed using a GLM ANOVA procedure of SPSS (16.0) using animal feeding system as fixed factor. The REGWQ test was used as post-hoc test.

Results and discussion

Seventy-five VOCs were identified: 4 alcohols, 9 aldehydes, 2 heterocyclic compounds, 18 hydrocarbons, 9 ketones, 9 organic acids, 6 esters, 4 phenolic compounds, 2 indoles, 7 monoterpenes, 4 sesquiterpenes and 1 sulphur compound. Milk VOCs affected by animal feeding are reported in Table 1. Feeding system affected the concentration of 4 monoterpenes and 4 sesquiterpenes, as expected, based on previous studies (Martin *et al.*, 2005; Prache *et al.*, 2005). The concentrations of β-pinene and cymene-(p) and of all sesquiterpenes, were higher in CG milk ($P < 0.01$) compared to RG and I ones, which is consistent with numerous studies on the concentrations of major terpenes in pasture with high botanical diversity and rich in dicotyledons (Martin *et al.*, 2005; Prache *et al.*, 2005). Benzeneactealdehyde and 2-pentanone-4-hydroxy-4-methyl were present respectively at higher and lower concentrations ($P < 0.05$) in RG milk than in I and CG milk. 1-Octadecene tended ($P < 0.1$) to be lower in I than in C milk. Octanoic acid methyl ester, dodecanoic acid methyl ester, undecanoic acid, toluene and skatole were found at higher concentrations ($P < 0.05$) in milk from pasture-fed cows than in I milk, while an opposite trend was observed for dimethyl-sulfone.

Benzeneactealdehyde, 2-pentanone-4-hydroxy-4-methyl, 1-octadecene, octanoic acid methyl ester, dodecanoic acid methyl ester and undecanoic acid are known to be products of the degradation of milk poly-unsaturated fatty acids (PUFA) (Moio *et al.*, 1993; Bendall *et al.*, 2001). It is known that feeding animals at pasture significantly increases milk PUFA content (Prache *et al.*, 2005). Toluene is a product of β-carotene degradation (Moio *et al.*, 1993) and therefore its greater concentration in CG and RG milk than I milk could be due to the greater concentration of β-carotene in green grass than in hay and concentrates. The higher concentration of skatole in RG and CG milk is consistent with literature data indicating skatole as a tracer of a pasture-based diet (Bendall, 2001). Skatole is produced by the desamination and decarboxylation of the free amino acid tryptophan by bacteria in the rumen (Priolo *et al.*, 2001). The high protein content and the high protein-to-readily digestible carbohydrate ratio in herbages increase the amount of rumen tryptophan available to bacteria, consequently increasing skatole production (Vasta and Priolo, 2006). The higher skatole concentration in RG than CG milk could be related to the presence in RG pasture of Fabaceae species, which are richer in protein than Poaceae.

Conclusions

Our results show that the milk VOCs of metabolic origin are strongly affected by cow feeding system, suggesting their possible use as potential tracers of animal feeding. Skatole, toluene and fatty acid methyl esters seem to be good candidates for distinguishing between milk from pasture-fed and hay + concentrate-fed cows. Feed chemical composition (e.g. PUFA and protein content) has a major impact on the appearance in milk of some VOCs of metabolic origin, with possible involvement in the development of milk odour and flavour. Conducting further research, using a larger number of animals and also other types of pasture swards, would be useful to identify other robust markers for tracing animal feeding system.

Table 1. Milk volatile compounds (expressed as $\log_{10}$ peak area unit) affected by animal feeding. I = indoor diet (hay and concentrate), RG = rotational grazing system on low-biodiversity pasture, CG = continuous grazing system on high-biodiversity pasture, SEM = Standard error of the mean, Ald = aldehyde, Hyd = hydrocarbon, Ket = ketone, Acd = organic acid, Est = ester, Ind = indole, Mter = monoterpene, Ster = sesquiterpene, Sul = sulphur compound, ns = not significant, † = $P < 0.1$, * = $P < 0.05$, ** = $P < 0.01$, *** = $P < 0.001$.

Compound	Family	I	RG	CG	SEM	Treatment effect
Benzeneacetaldehyde	Ald	3.47^b	3.78^a	3.41^b	0.087	*
Toluene	Hyd	4.45^b	5.41^a	5.34^a	0.150	**
1-octadecene	Hyd	5.35	5.55	5.78	0.066	†
2-pentanone-4-hydroxy-4-methyl	Ket	4.40^a	4.16^b	4.45^a	0.048	*
Undecanoic acid	Acd	3.35	3.85	4.20	0.140	†
Octanoic acid methyl ester	Est	3.70^b	4.53^a	4.24^a	0.100	***
Dodecanoic acid methyl ester	Est	3.28^b	4.67^a	4.33^a	0.216	*
Skatole	Ind	4.03^c	4.77^a	4.59^b	0.098	**
Camphene	Mter	1.22^b	3.63^a	3.92^a	0.324	***
Sabinene	Mter	0.97^b	2.29^a	3.06^a	0.261	**
β-pinene	Mter	0.00^b	0.00^b	3.70^a	0.404	***
Cymene-(p)	Mter	0.49^b	1.51^b	4.07^a	0.424	***
β-caryophyllene	Ster	3.48^c	3.98^b	5.06^a	0.161	***
Alloaromadendrene	Ster	0.00^b	0.00^b	3.77^a	0.372	***
Germacrene-D	Ster	0.00^b	0.78^b	2.59^a	0.333	**
γ-cadinene	Ster	0.97^b	1.56^b	4.77^a	0.450	***
Dimethyl-sulfone	Sul	4.14^b	4.51^a	4.66^a	0.069	**

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Influence of plant competition on biomass production and nutritive quality of three grassland species - results of a pot experiment

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Abstract

The objective of this study was assessing the influence of grassland species in mixtures on biomass yield and on nutritive quality of selected species in terms of digestibility of organic matter and net energy content. Three grassland forage crop species (perennial ryegrass, chicory and red clover) were grown in binary mixtures with each of nine different companion species in an outdoor pot experiment. All plants were harvested at the same time and the produced biomass was measured for each species separately. Crop biomass was in some cases reduced due to competition with companion species when compared to pure-stand crop yield, disregarding the crop species. Digestibility of organic matter of crop species was not significantly changed. Quality yield was similar to biomass yield and did not show changes due to interspecific competition except for treatments with high-producing companion species where crop biomass was significantly decreased.

Keywords: grassland, competition, chicory, nutritive quality, quality yield

Introduction

Grassland forms the basis for the nutrition of ruminant livestock in many parts of the world. Generally, grassland consists of several plant species which form diverse grassland stands that are known to be better in productivity and resource efficiency than pure stands with only one plant species (see e.g. Helgadóttir *et al*., 2008; Lüscher *et al*., 2008; Picasso *et al*., 2008). Little information is available on how competition with other plants influences the nutritive quality of grassland crop species but it has been shown that some changes in quality can occur in grass-legume mixtures (Lehmann and Meister, 1982; Opitz von Boberfeld and Biskupek, 1995). The current study aims at testing if grassland crop species result in different plant biomass yields when they are grown with companion species in binary mixtures compared to pure stands. Furthermore, it was examined if the competition with companion species has effects on the nutritive value of crop species in terms of digestibility of organic matter, net energy content and on quality yield (net energy content×biomass yield).

Material and methods

Grassland species belonging to three distinct functional groups (grass, deep-rooted herb, legume) were sown in binary mixtures with companion species from the same functional groups. Grassland species perennial ryegrass (*Lolium perenne* cultivar ‘Helmer’), chicory (*Cichorium intybus* cultivar ‘Grasslands Puna’), red clover (*Trifolium pratense* cultivar ‘Ares’) and companion species annual meadow-grass (*Poa annua*), common bent (*Agrostis capillaris*), red fescue (*Festuca rubra*), dandelion (*Taraxacum officinale*), chicory (*Cichorium intybus*), caraway (*Carum carvi*), common vetch (*Vicia sativa*), tufted vetch (*Vicia cracca*) and black medic (*Medicago lupulina*) were selected for the experiment. Due to unsuccessful germination rates of the preferred companion species cow parsley (*Anthriscus sylvestris*) and curled dock (*Rumex crispus*), chicory was chosen both as a crop and a companion species. The species were sown in rectangular pots (27×17×14 cm, L×W×H) in an enclosed outdoor area located in Uppsala, Sweden. Each companion species was sown with each of the grassland species in binary mixtures, replicated three times. 21 plants of crop species and 8 plants of companion species were finally established per pot. Pots with mixtures were surrounded by cover pots containing perennial ryegrass. In addition to natural rainfall, water was added when needed. Plants were harvested at an age of eight weeks and plant material was separated into species. Digestibility of organic matter of crop samples was analysed according to the method of Tilley and Terry (1963). Net energy lactation (J NEL) content was calculated on the basis of digestible organic matter. Data were analysed by analysis of variance using the GLM procedure of SAS.

Results and discussion

Table 1. Biomass yield, digestibility of the organic matter, and quality yield of crop species in pure stands and in mixtures with companion species. Mean values of three replicates. Means with the same letter in each column are not significantly different ($P < 0.05$)

	Biomass yield (g DM pot^{-1})			Digestibility of the organic matter (g kg^{-1} DM)			Quality yield (J NEL pot^{-1})		
	Perennial ryegrass	Chicory	Red clover	Perennial ryegrass	Chicory	Red clover	Perennial ryegrass	Chicory	Red clover
Pure stand	9.1^{ab}	20.2^{a}	20.0^{a}	76.3^{a}	87.0^{a}	71.8^{ab}	55.7^{a}	148.6^{ab}	113.0^{a}
Annual meadow-grass	7.5^{ab}	19.6^{a}	19.5^{a}	76.7^{a}	84.5^{a}	71.4^{abc}	45.1^{a}	138.1^{abc}	107.3^{ab}
Common bent	10.2^{a}	19.9^{a}	19.2^{a}	79.4^{a}	85.5^{a}	73.1^{a}	66.5^{a}	143.4^{ab}	110.3^{a}
Red fescue	10.0^{ab}	19.1^{a}	17.2^{ab}	78.3^{a}	84.9^{a}	66.8b^{c}	63.4^{a}	136.8^{abc}	85.4^{abcd}
Dandelion	6.8^{ab}	18.5^{ab}	16.4^{ab}	74.4^{a}	86.6^{a}	70.0^{abc}	38.9^{a}	135.2^{abc}	89.8^{abcd}
Chicory	6.2^{b}	14.6^{ab}	11.9^{b}	78.9^{a}	88.2^{a}	71.0^{abc}	39.4^{a}	109.7^{bc}	67.3^{cd}
Caraway	9.3^{ab}	20.7^{a}	19.2^{a}	77.9^{a}	88.6^{a}	68.8^{abc}	58.0^{a}	157.7^{a}	102.2^{abc}
Common vetch	7.2^{ab}	12.5^{b}	12.8^{b}	76.5^{a}	86.1^{a}	66.4^{c}	43.6^{a}	91.3^{c}	64.7^{d}
Tufted vetch	7.5^{ab}	18.1^{ab}	13.4^{b}	76.3^{a}	86.6^{a}	71.0^{abc}	45.2^{a}	132.6^{abc}	74.4^{bcd}
Black medic	7.8^{ab}	18.3^{ab}	20.2^{a}	75.3^{a}	85.5^{a}	69.3^{abc}	46.0^{a}	131.5^{abc}	107.8^{ab}

For all three crop species, competition with companion grasses had no significant influence on the biomass yield of the crops (Table 1). High yielding companion herbs chicory and dandelion as well as the two vetch species common vetch and tufted vetch tended to reduce the productivity of all three crop species. Especially chicory and red clover showed lower amounts of biomass in mixtures with high yielding companion species compared to pure stands.

The digestibility of the three crop species seemed to be only little or not at all influenced by the presence of companions in binary mixtures (Table 1). For perennial ryegrass and chicory which performed best in this experiment, no significant change in digestibility was observed when comparing pure stands with mixtures. Red clover showed significantly lower values of digestibility in mixtures with common vetch when compared to pure stand clover.

Quality yields of the three crop species are presented in Table 1. For perennial ryegrass, no significant influence of competition by companion species on the quality yield was observed. In combination with companion species common vetch, crop species chicory produced a significantly lower quality yield (38% less) than in pure stand. Again, companion species chicory, common vetch, and tufted vetch had significant negative effects on red clover quality yield. Common vetch reduced clover quality yield by 43% compared to pure stand red clover. The negative effects on quality yield were mainly caused by reduced biomass production of forage crops in these mixtures and less induced by changes in digestibility. Other studies (e.g. Pötsch and Resch 2010) have demonstrated the importance of investigating plant interactions and their influence on nutritive quality over a longer period of time, which has led to results that could not have been obtained in a short-term experiment.

Conclusion

It can be concluded that under the conditions of the present experiment, growing crop and companion species in binary mixtures did not lead to considerable changes in nutritive quality of the crop species in the majority of the mixtures. High yielding companion species such as chicory, common vetch and tufted vetch which were the most productive ones in companion species pure stands as well as in binary mixtures with crops had the greatest effects on both biomass yields and quality yields of crop species chicory and red clover. Under commercial farming conditions, forage from mixtures is not separated into their plant species components as it has been done in this study. The companion plants in mixtures will therefore also contribute to the nutritive quality of the forage. For agricultural practice the proper composition of seed mixtures using new and promising species needs to consider their possible impact on total yield with respect to quality parameters. Further work has to be conducted to clarify the influence of competition on nutritive quality of grassland plants under commercial farming conditions.

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Influence of different cutting dates on regrowth and achene germination capacity of *Senecio jacobaea*

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Abstract

The ragwort species *Senecio jacobaea* is a poisonous plant currently spreading in Germany. It is found on roadsides, waste land, pastures and occasionally on extensively managed hay meadows. Cutting at the onset of flowering is recommended to control spreading by seeds, but may lead to increased regrowth of the plant. This experiment tests the influence of different cutting dates on *S. jacobaea* to find the cutting date that minimises regrowth, number of newly formed capitula and germination capacity of achenes. *S. jacobaea* plants were observed from June to September 2010 under four treatments: cutting at pre-flowering (I), start of flowering (II) and first withered capitula (III) as well as an uncut control. A number of phenological and morphological traits were assessed at bi-weekly intervals. Samples of capitula from different stages of maturity were collected at cutting dates II and III. A laboratory germination test was carried out for four weeks to identify the germination capacity of achenes. Cutting date III resulted in the slowest regrowth and no newly formed capitula, but germinable achenes were already present at cutting. Cutting date II, combining slow regrowth and absence of germinable achenes at cutting, is therefore to be recommended.

Keywords: *Senecio jacobaea*; weed control; cutting dates; germination; regrowth

Introduction

Ragwort (*Sencio jacobaea* L.) is a poisonous plant that has become more abundant in many parts of Germany in recent years. Cutting at the beginning of flowering has been recommended as a strategy to control generative spreading of *S. jacobaea* (Siegrist-Maag *et al*., 2008). However, vegetative regrowth and reflowering after defoliation of *S. jacobaea* have been reported (Cameron, 1935; Cox and McEvoy, 1983). The plant, often described as a biennial, may also act as a triennial or perennial, particularly if prevented from flowering by disturbance (Harper and Wood, 1957), but plant mortality as a result of defoliation has also been reported (Islam and Crawley, 1983; Siegrist-Maag *et al*., 2008). An experiment was set up at a site with high *S. jacobaea* density to assess which cutting date best suppresses regeneration while assuring that no germinable achenes are present at the cutting date.

Material and methods

The field experiment was established on a road verge in Southwest Germany (48.668 °N, 9.559°E; altitude: 395 m.a.s.l.) on 14 June 2010. The site has previously been managed by yearly cutting in August with removal of the biomass and corresponds to an *Arrhenatherion* grassland vegetation. Three cutting treatments and an uncut control were compared in a randomised block experiment with four replications (Table 1). The dates of the cutting treatments were set by phenological stages oriented at four pre-defined phenological stages adapted from Wardle and Rahman (1987; Table 2). On each 1-m² experimental plot five *S. jacobaea* plants were permanently marked. At each cutting date, the relevant plots were cut with hedge clippers at 5 cm height. A number of phenological and morphological traits were assessed at bi-weekly intervals for all plants.

At each cutting date, one capitulum per plant and age category, as far as present, was collected on the cut plots. One capitulum per plant was also collected from the control when pappi were fully extended. Capitula were stored at room temperature before using the achenes for a germination experiment using 100 achenes per sample. The experiment was run in a climate chamber at 20°C and 24 h of light for two weeks, and at 8 h 10°C/dark and 16 hours 20°C light for another two weeks, with weekly controls for germinated achenes.

Numbers of plants per treatment with new rosettes, stems or capitula or without living plant parts were compared using an exact log-likelihood ratio chi-square test.

Table 1. Cutting treatments; for age categories of capitula see Table 2.

Treatment	Phenological stage at cutting	Cutting date	Rainfall during the week after cutting
I	all capitula in stage 0	14/06/2010	89.0 mm
II	10% of capitula in stage 1 in 50% of plants	03/07/2010	2.4 mm
III	10% of capitula in stage 2 in 50% of plants	10/07/2010	15.6 mm
control	no cut	---	---

Table 2. Age categories of capitula.

Stage	Description
0	capitula closed or slightly opened; all florets closed, green-yellow
1	capitula open; florets opening, yellow
2	beginning senescence of capitula; disc florets brownish; corollae of ray florets yellow
3	disc florets brownish; corollae of ray florets abscised or brownish; pappus extended or fully developed

Results and discussion

Significantly more plants had died after treatment III (35%) and in the control (45%) than after treatment I (5%); treatment II (20%) ranging in between (Table 3). In all cutting treatments, surviving plants formed multiple rosettes, reaching a maximum with an average of 8.8, 7.6 and 6.0 rosettes per plant at 14, 35 and 28 days after cutting in treatments I-III respectively. In treatment I, the first plants had formed new capitula 26 days after cutting. In treatment II, only one plant had formed new capitula by the end of the experiment, and in treatment III, no plant had formed stems or capitula at all. For cutting dates similar to those of treatments II and III, Siegrist-Maag *et al*. (2008) observed lower plant mortality and a higher percentage of plants flowering in the regrowth. The different results of this study may have been caused by the dry weather following cutting in treatment II, as moisture stress has a negative effect on the regeneration of *S. jacobaea* (Cox and McEvoy, 1983).

Table 3. Morphological plant traits on 6/09/2010; n = 20. Upper part of table: different letters represent significant differences at $P = 0.05$; lower part of table: mean ± standard deviation.

Trait	Treatment I	Treatment II	Treatment III	Control
number of plants without living above-ground parts	1 a	4 ab	7 b	9 b
number of plants with new leaf rosettes after cutting	17 a	16 a	13 a	−
number of plants with new stems after cutting	12 a	2 b	0 b	−
number of plants with new capitula after cutting	12 a	1 b	0 b	−
average plant height of living plants (cm)	23.2 ± 13.4	6.4 ± 3.1	6.0 − 1.5	119.2 ± 16.3
average number of leaf rosettes per plant [(1)]	2.8 ± 1.4	5.6 ± 3.1	4.3 ± 1.7	−
average number of stems per plant [(1)]	3.1 ± 2.2	1 ± 0.0	−	1.9 ± 2.4
average number of capitula per plant [(1)]	65.3 ± 60.2	1 ± 0.0	−	123.4 ± 79.0

[(1)] for the averages, only those plants were considered that had formed rosettes / stems / capitula on 6/09/2010.

Only capitula in stages 1 and 2 were present at cutting in treatments I and II (Table 4, Figure 1). Achenes from these capitula did not show any germination, so these cutting dates were successful in preventing generative spread in the first growth. In contrast, on average six capitula per plant were in stage 3 at cutting in treatment III. Their achenes had a germination capacity of 37.3%. From these figures, an average number of 165 germinable achenes per plant at cutting can be calculated for treatment III. While not fulfilling the objective of preventing generative spread, this is a considerable reduction of the reproductive success compared to the control (Figure 1).

Table 4. Reproductive plant traits at cutting date (treatments I-III) or 31/7/2010 (control).

Trait	Treatment I	Treatment II	Treatment III	Control
germination rate of capitula in stage 1 / 2 / 3 (%)	– / – / –	0 / 0 / –	0 / 0 / 37.3	– / – / 69.8
average number of capitula per plant in stage 1 / 2 / 3	0 / 0 / 0	10 / 1 / 0	19 / 13 / 6	–
average number of achenes/capitulum (stage 1 / 2 / 3)	– / – / –	70 / 76 / –	66 / 74 / 73	– / – / 75
calculated number of germinable achenes per plant	0	0	165	–

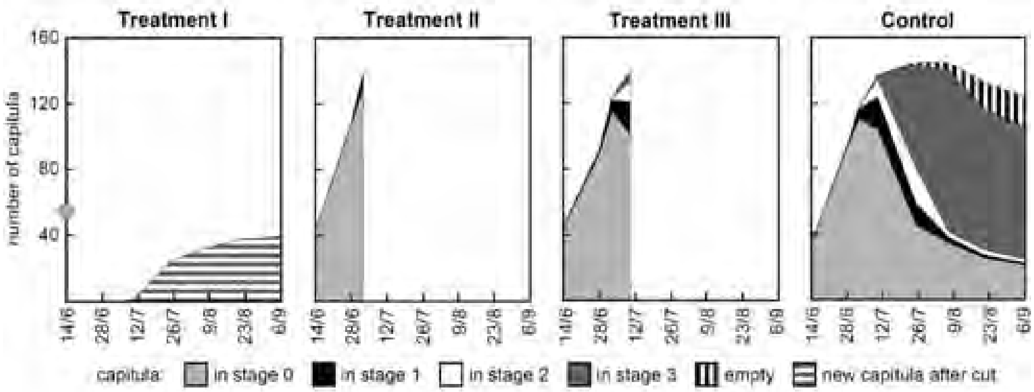

Figure 1. Development of capituala during the field experiment.

Conclusion

Treatment II, cutting when 10% of capitula were open in50 % of the plants, best achieved the combined objectives of minimising regrowth and preventing formation of germinable seeds. In this treatment, drought presumably further delayed development, so that cutting before a dry period would be favourable. Depending on weather conditions, a second cut may be necessary to prevent seed formation in the regrowth. With a plant mortality of only 20%, combined with the production of daughter rosettes, cutting helped to prevent seed formation, but was not immediately effective as a weed control measure. The effect of the cutting treatments on over-winter survival will be assessed in spring. As Figure 1 shows, development of capitula can be very fast, and the number of germinable achenes can increase quickly in a short time. If the optimum cutting date is to be chosen, close monitoring of the development of *S. jacobaea* is necessary.

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Risk of climate change for productivity of permanent grasslands in Czech Republic in the light of past drought events

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Abstract

Over the past years, the changing climate has affected parts of Central Europe by drought spells of an intensity and extent that have been unprecedented in recent decades. These events have had a significant impact on agricultural areas, especially grasslands, and there is possible risk of even larger drought events in the future. This contribution focuses on the analysis of drought impact on grassland production between 1920 and 2006 in the Czech Republic, and it studies the climatic suitability of the Czech Republic and northern Austria for sustainable grassland production. Results demonstrate that drought events can explain over 40% of inter-annual grassland yield variability and that the changing climate might decrease substantially the area suitable for grasslands.

Keywords: drought stress, modelling, grassland

Introduction

Permanent grassland used for forage production, either as meadows or pastures, comprise a significant portion of the Central European landscape and provide a range of ecosystem services. Grasslands in the region are located in alpine and near-alpine regions and also in highlands and riverside zones and thus occur over a large altitudinal range (200-2000m). Expected changes of climate conditions are likely to lead to marked shifts in grassland productivity as drought events might become more frequent (Dubrovský *et al*., 2009). The analysis of past drought events is essential for understanding potential impact of climate change in those parts of the region where grasslands are rain-fed, and in many cases they could not be changed to arable land (as climate conditions change) due to the configuration of the terrain, as e.g. in the Czech Republic.

Methods

The first analysis of period drought impacts on grassland productivity was carried out for period between 1920 and 2006 using seasonal (April-July) relative Palmer drought Z-index (rZ-index). This index uses monthly mean temperature and sum of precipitation to estimate deviation of available soil moisture.

Results

There is an obvious tendency for low grassland yields during dry years (Figure 1) in the Czech Republic. As Figure 1 also shows, rZ-index can explain over 42% of variability of the national mean yields of hay. The relationship between and yields grassland productivity is well represented by the second order polynomial. It closely approximates to the nature of the crop-yield water relationship (Ash *et al*., 1992) as crop yields might be inhibited not only through water stress but also by low global radiation, below-normal temperatures, root anoxia and higher infestation pressure of fungal diseases that tend to be associated with unusually wet seasons. The highest influence of droughts on the national grassland yields can be found in the years 1934, 1947, 1976, 1993, 2000 and 2003. Two years with the wettest vegetation season (1926 and 1965) also showed yield stagnation for hay production.

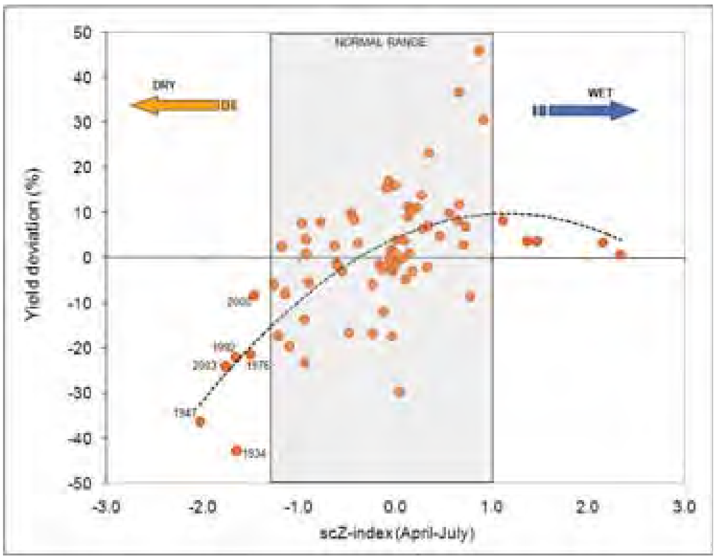

Figure 1. Relationships between rZ-index (Dubrovský *et al*., 2009) and yield deviations from a 5-year running average of hay from meadows in different months for the Czech Republic during 1918-2006 (except 1939-1944). The yield departures are significantly correlated with drought intensity, with a Pearson correlation coefficient of 0.65 respectively (significance level α = 0.01). The dotted line indicates the course of a second-order polynomial function. Values of rZ-index were calculated using weather data described in Brázdil *et al*. (2009) while yield values represent national mean provided by the Statistical Office.

Drought events in the region are likely to become more severe and prolonged, although the magnitude of the predicted change depends on the particular climate-change scenario (Dubrovský *et al*., 2009). We reason that prolonged summer droughts might affect the suitability of particularly region for sustainable grassland production. Sustainable grassland production requires relatively high and well-distributed precipitation in most years, with sufficient precipitation during summer months. Therefore, in the second step of the study the areas with suitable climate conditions for grasslands were estimated. Areas treated as unsuitable were those that had accumulated water deficits (difference between precipitation and reference evapotranspiration) during summer higher than 50 mm (80 mm) in more than half of the years. Analysis was based on data from 129 weather stations and soil quality indicators at 500 m grid. Figure 2 shows how the areas climatically suitable for use as productive grasslands in Czech Republic and northern Austria might change under approximately 2°C global warming. It is worth noting that climate conditions anticipated by all three global circulation models would lead to severe reduction in the areas suitable for grassland production. While under the ‘present’ (1961-2000) climate conditions, 29.8% of the domain is climatically suitable for grassland production, under a 2°C increase the area would be reduced to 0.5% (HadCM), 2.4% (ECHAM) and 10.5% (NCAR).While suitable grassland areas presented in Figure 2 are likely to suffer from overestimation of negative effects from climate change, it highlights drought effects on extent of grassland area in the future.

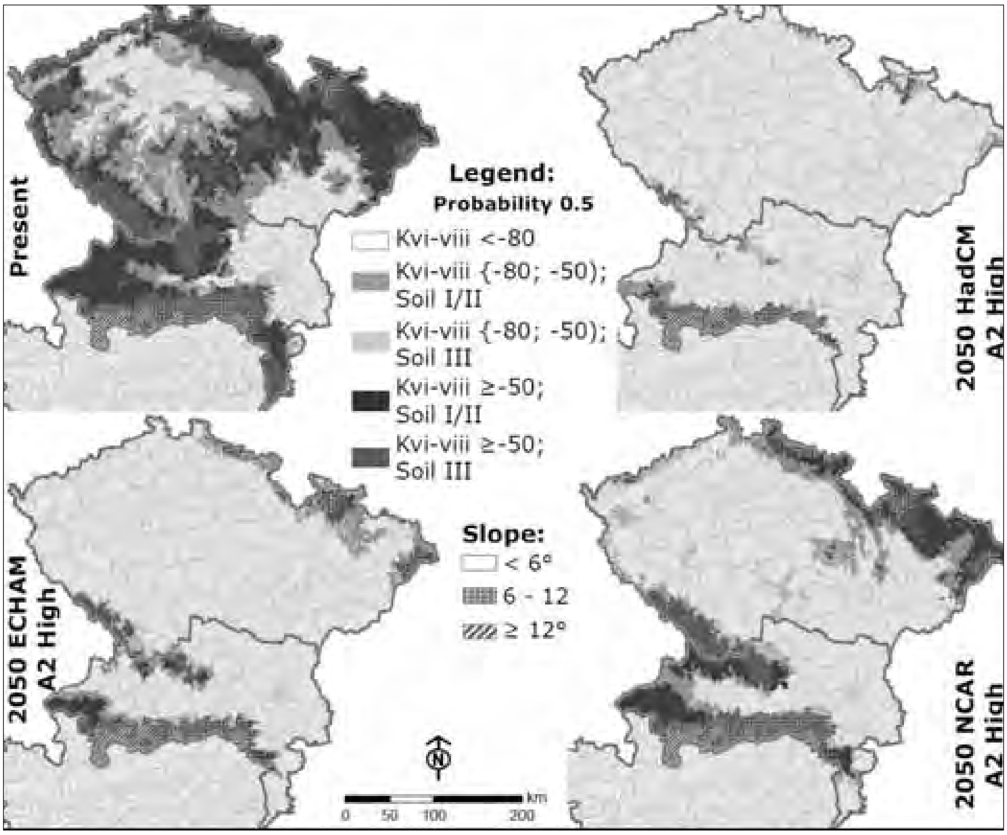

Figure 2. Estimated area suitable for grassland production during baseline (1961-2000) period and by 2050 according to 3 outputs Global Circulation Models assuming A2 emission scenario (approximately +2°C warming and 536 ppm of CO_2). Black areas are suitable in terms of climate (especially during summer) for grassland production with dark grey areas having favourable soil and slope conditions, dark have rather poor soils and steep slopes. Light grey areas are climatically less suitable (but still acceptable in some cases) due to drought stress.

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Effect of application timing on the effectiveness of chemical weed control of Alpine ragwort

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Abstract

Alpine ragwort (*Senecio cordatus* Koch) is a poisonous weed containing pyrrolizidine alkaloids (PA). It occurs in pastures (and occasionally in meadows) in mountainous areas of Europe. PA cause irreversible liver damage to animals and can also be retrieved in small amounts in the milk of dairy animals, posing a potential threat to humans. As infestation with alpine ragwort can be prevented by and controlled with different management strategies, the chemical weed control must be regarded as the last possible measure. In this case, high effectiveness is required to avoid repeated herbicide application. In a field study, the effectiveness of five herbicides containing different active ingredients (thifensulfuron-methyl, aminopyralid+fluroxypyr, metsulfuron-methyl, dicamba+mecoprop, glyphosate) was investigated in a mountain summer pasture in combination with varying application time (beginning or end of the growing season). The shoot density in control plots nearly doubled within one year. The effectiveness of the chemical weed control varied greatly depending on both the herbicide and the application timing. A spring application improved the effectiveness of most herbicides both in the short and in the mid term.

Keywords: *Senecio cordatus*, Alpine ragwort, poisonous plants, chemical weed control, application timing

Introduction

Alpine ragwort (*Senecio cordatus* Koch) is a poisonous weed containing pyrrolizidine alkaloids (PA) in all parts of the plant, which persist also after hay-making and ensiling (Dietl and Jorquera, 2003). It thrives in pastures (occasionally also in meadows), mainly in the montane and subalpine zone, on moist soils with good nutrient availability. Fresh plants are avoided by grazing animals and, if pasture maintenance is neglected, they can reproduce and expand, leading to deterioration of productivity and forage quality of the pasture. When fed to animal in conserved forage, PA cause irreversible liver damage and can be also retrieved in small amounts in the milk of dairy animals, posing a potential threat to humans (Cheeke, 1988). Infestation with alpine ragwort can be prevented by and controlled with different management strategies, such as a balanced fertilisation and practices of pasture maintenance (Dietl and Jorquera, 2003). Therefore, chemical weed control must be regarded as the last possible measure. In this case, high effectiveness by use of effective herbicides at the right time is required to avoid unnecessarily repeated herbicide application.

Materials and methods

A field experiment to investigate the efficacy of several herbicides was conducted from 2009 to 2010 in the montane summer pasture Petersberger Leger (1545 m a.s.l., Aldein/Aldino, South Tyrol, Italy), which exhibited increasing abundance of Alpine ragwort in the last five years. The trial was established in a pasture located near to the forest edge, on an acidic soil (pH 5.7), rich in organic matter (200 g kg^{-1}) and nutrients (74.1 mg kg^{-1} P, 141.1 mg kg^{-1} K, 476.7 mg kg^{-1} Mg). The effectiveness of five herbicides with different active ingredients was tested: 22.5 g ha^{-1} thifensulfuron-methyl (TM), 60 g ha^{-1} aminopyralid + 200 g ha^{-1} fluroxypyr (AF), 4 g ha^{-1} metsulfuron-methyl (MM), 116.2 g ha^{-1} dicamba + 1.5 kg ha^{-1} mecoprop (DM) and a 0.213 *M* glyphosate solution (GL). A control treatment was included in the experiment. All herbicides except GL were applied in water solution (400 l ha^{-1}) on whole plots with a 1 l-garden sprayer. GL was applied to single weed plants. The treatments were carried out at two different times: at the beginning of the growing season (12 June) and after the end of the grazing period (30 September). The experiment was laid out as a two-factorial randomised complete block design, with three replicates, and a plot size of 5 m² (2×2.5 m). Shoot density was recorded in each plot on three dates: immediately before herbicide application and at two later dates, thus allowing treatment evaluation in the short and mid term (Table 1).

Table 1. Dates of herbicide application and shoot density counts of *Senecio cordatus*.

Herbicide application	1st count	2nd count	3rd count
12.06.2009	12.06.2009	30.09.2009	18.05.2010
30.09.2009	30.09.2009	18.05.2010	07.06.2010

At the first count, up to 20 shoots per plot were counted and marked with plastic rods. At the second count, the number of undamaged, dead and damaged live shoots was assessed among the marked shoots. At the third count, all occurring shoots without distinction between marked and unmarked ones were recorded. The biomass proportion of legumes and forbs was visually estimated at each observation date. The herbicide efficacy on *Senecio cordatus* was computed as the percent of dead plants at the second count date. Efficacy in the mid term was evaluated on the basis of the shoot density of Alpine ragwort at the third count date compared to the control. Data were subjected to ANOVA, with herbicide and application timing as fixed factors, or separately analysing each application date in case requirements for ANOVA were not met by the complete data set. Multiple comparisons were performed by LSD. A *P*-value < 0.05 was considered to be significant.

Results and discussion

The shoot density of Alpine ragwort in control plots nearly doubled over the winter (from 7.1 shoots m^{-2} in 2009 to 12.8 m^{-2} in 2010), proving the colonising potential of this weed if control measures are lacking. In contrast, the increase of shoot density within the growing season was negligible. The efficacy of weed control in the short term was affected by the herbicide ($P < 0.001$), by the application time ($P < 0.001$) and by their interaction ($P < 0.05$). Three out of the five herbicides (MM, GL and DM) had higher efficacy at the earlier treatment date (Table 2). This may be due to the fact that by the end of September temperatures at the experimental site had already dropped and weed plants had no longer intense growth. MM exhibited a particularly large difference between the two dates (84.4% *vs.* 13.3% respectively). Only AF had a complete efficacy at the earlier treatment date and showed sufficient efficacy also at the later treatment date. TM turned out not to be suitable for the chemical control of Alpine ragwort, irrespective of the treatment date. GL and DM had sufficient efficacy at the earlier date, but not at the later one. The proportion of shoots that were damaged by the herbicides, but were still alive, was affected only by the herbicide ($P < 0.01$), irrespective of the application time. MM, GL and DM had proportions of damaged shoots between 7.7% and 16.8% on average (Table 2), whereas they were very low for TM and AF. The shoot density of Alpine ragwort

Table 2. Herbicide efficacy in the short term and share of live damaged shoots of Alpine ragwort depending on herbicide and time of application.

	Short-term efficacy (%)		
Herbicide	Early application	Late application	Live, damaged shoots (%)*
AF	100.0^{Aa}	83.0^{Aa}	0.0^{b}
MM	84.4^{Aab}	13.3^{Bc}	16.8^{a}
GL	81.9^{Aab}	50.9^{Bb}	8.5^{a}
DM	67.2^{Ab}	38.8^{Bb}	7.7^{a}
TM	25.0^{Ac}	4.2^{Ac}	1.3^{b}

* Analysis with logarithm-transformed data; back-transformed means are shown. Means without upper case letters in common within each herbicide treatment and means without lower case letters in common within each treatment date are significantly different from each other

in the mid term was significantly affected by the herbicide at each application time ($P < 0.01$ for early application; $P < 0.05$ for late).

Following the early application AF, MM and DM showed a lasting effect in reducing the shoot density, while all herbicides but AF allowed a recovery of Alpine ragwort following a late herbicide application (Table 3). Both the application time and the herbicide affected the proportion of legumes and forbs at the end of the experiment ($P < 0.01$ and $P < 0.001$ respectively): a late herbicide application resulted in higher percentages (15.0% *vs.* 9.3% following an early treatment), probably due to the overall low efficacy of the herbicides in the late growing season. The use of AF resulted in a nearly complete removal of these functional groups from the plant stand.

Table 3. Effect of herbicides on the shoot density of Alpine ragwort and on the biomass proportion of legumes and forbs on the last assessment date.

	Shoot density (shoots m^{-2})*		
Herbicide	Spring application	Autumn application	Legumes and forbs proportion (%)**
AF	0.0^{c}	1.4^{b}	2.6^{b}
MM	1.6^{bc}	12.7^{a}	13.6^{a}
GL	5.4^{ab}	7.1^{a}	13.5^{a}
DM	1.8^{bc}	7.7^{a}	15.0^{a}
TM	9.4^{a}	6.9^{a}	13.7^{a}
Control	14.9^{a}	15.8^{a}	17.2^{a}

Analysis with * log-transformed and ** arcsine-transformed data; back-transformed means are shown. Means within each assessment date without common letters significantly differ from each other.

Conclusions

In order to achieve a good effectiveness, a herbicide application at the beginning of the growing season seems to be advisable, although the treated pastures can not be used for grazing in the period following herbicide application. The choice of the herbicide should take efficacy as well as herbicide persistency into account, and also the effect of herbicide on legumes and forbs.

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The relationship between farming systems and grassland diversity in dairy farms in Valle d’Aosta, Italy

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Abstract

Dairy farming is the main agricultural activity in Valle d’Aosta, a mountain region in NW Italy. Traditional breeding is based on permanent grassland mown for hay or grazed by cows of local breeds. Since dairy farmers are the main users of these semi-natural grasslands, their management decisions play a key role in the preservation of these resources. In 2009 a two-year project was started, aimed at investigating the diversity of permanent meadows in the region and analysing how it was related to the management decisions made by farmers. Twenty-seven dairy farmers were interviewed and vegetation surveys carried out to gather comprehensive information. The data collected were used to determine the diversity of environment, vegetation and farming techniques adopted on grasslands and to profile the organization of farming systems. This information resulted in the classification of five different farming systems and their relationship with grassland diversity was established. Even in a small region, we found farming practices within the same production system to be quite diverse and grasslands with different functions (hay production and pasture variously combined during the year) to have a higher number of species than those whose utilization was not as complex.

Keywords: dairy farming, grasslands, pastures, farming system, biodiversity

Introduction

The relationship between agriculture, biodiversity and landscape represents a key issue in the management of territories, especially in tourist regions and in high nature value areas. Dairy farming is the main agricultural activity in Valle d’Aosta (NW Italy), a mountain region with an average elevation of more than 2000 m a.s.l. Foraging is based on permanent grasslands, in the lowland (300-1300 m a.s.l.), in middle elevation areas (the May pastures, also called ‚mayen‘, at 1300-1800 m a.s.l.) and in alpine summer pastures (1800-2500 m a.s.l.). These are mown for hay or grazed by cows of local breeds (mainly Aosta Red Pied and Aosta Chestnut); their milk is used to produce Fontina PDO (Protected Designation of Origin) cheese. Long winters and a relatively short vegetation period have a strong impact on grassland utilization and farming system. Since dairy farmers are the main managers of these semi-natural meadows and pastures, it is necessary to understand how their farming techniques (type and intensity of utilization, fertilization, irrigation etc.) can influence species diversity and landscape characteristics. Past surveys assessed species composition and functional diversity of permanent meadows, resulting in a classification of the main meadow types (Roumet *et al*., 1999; Tarello *et al*., 2000). In 2009, an Interreg-Alcotra project (NAPEA) began to analyse the relationship between farming systems and grassland diversity.

Materials and methods

Twenty-seven dairy farmers, cultivating at least 3 ha of grassland, were selected to represent farms in the different areas in the region. They were interviewed to collect comprehensive information about their farming systems: farm structure (livestock, grassland area, work force,

equipment and buildings, manure handling), grassland and animal management (mowing and grazing schedule, allotment, feeding, calving and summering periods).
To overcome any problems caused by the fragmentation of land property, on each farm the lowland meadows were subdivided into homogeneous lots, gathering all the parcels subjected to the same agricultural management together. The main meadow type of each lot was determined using the typology defined by Roumet *et al*. (1999). Floristic surveys were carried out on representative plots using the De Vries and De Boer method (1959). The 27 farms were classified, using the SPSS® software, through a cluster analysis based on variables describing the main features of grasslands and animal management, presented in Table 1. Data were standardised using the Z-scores and we used Ward's method for the clustering and the squared Euclidean distance as a measure of similarity. The variables were then submitted to analysis of variance and Spearman's correlation was calculated on the data set.

Results and discussion

The cluster analysis divided farms into five groups (Table1). Cluster A groups the 4 biggest farms, with an average of about 70 LSU and 35 ha of lowland grassland. The entire herd is kept on lowland grasslands all year long and the calving period is distributed over 10 months. Cluster B, grouping only 2 farms, is characterized by relatively big herds (> 65 LSU) and nearly 40 ha of ‚mayen'. These are predominantly grazed in spring and autumn, while lowland grasslands are mown for hay. In summer, dairy cows are entrusted to other farmers to graze alpine pastures for about 2 months. The calving period takes some 3 months, as in cluster C which includes 6 small farms (LSU = 25.2) without ‚mayen'. Only a quarter of their grassland is both mown and grazed during the year, while the rest, depending on seasonal weather conditions and herd needs, is either cut or grazed. Cluster D consists of 6 medium size farms (14 ha of lowland grassland and 38 LSU) that keep their dairy cows in lowland areas even during summer; calves are delivered over a period of more than 6 months, hence, as in cluster A, and unlike the other types, milk production is more constant throughout the year. Cluster E includes 9 farms with an average of 30.6 LSU and only 10.7 ha of lowland grasslands. Therefore, dairy cows are handed over to other farmers in summer, to graze upper mountain pastures for about four months, and most lowland meadows are mown in spring and summer and grazed in autumn.

Table 1. Main features of the five groups of 27 farms classified through cluster analysis.

	Cluster					
	A	B	C	D	E	*P*-values
No. of farms	4	2	6	6	9	of effects
Lowland grasslands (ha)	35.0	16.0	15.7	14.3	10.7	< 0.001
Double use (cut and grazed) grasslands (%)	58.7	71.2	23.8	65.6	89.5	< 0.001
‚Mayen' grasslands (ha)	1.5	39.5	0.0	3.2	2.3	< 0.001
Livestock Units (LSU)	69.9	65.3	25.2	38.0	30.6	0.001
Calving period (d)	293.8	105.0	92.5	205.8	90.0	< 0.001
Dairy cows summering period (d)	0.0	54.0	60.2	0.0	116.3	< 0.001

The floristic survey confirmed the consistency of the typology put forward by Roumet *et al*. (1999). All farming systems had at least 5 meadow types, except small farms with little dual-use grassland from cluster C, which showed only 3 types (Table 2). According to Tarello *et al*. (2000), vegetation types were divided into species-poor (fewer than 25 species per 200 m²), medium (25 to 30 species) and species-rich (more than 30 species). Meadows from farming types A and D, gathering farms whose lowland grasslands are grazed during summer, presented a medium-to-high number of species, whereas those from farms sending their animals to the alpine summer pastures were relatively poorer.

Table 2. Number of meadow types, number of lots and percentage distribution of lots in relation to their species richness in the five farm types classified through cluster analysis.

Farm types	Total No. of meadow types	Average No. of lots per farm	Distribution of lots in relation to species richness (%) Low	Medium	High
Cluster A	6	3.5	7.1	42.9	50.0
Cluster B	5	4.5	22.2	55.6	22.2
Cluster C	3	2.7	-	50.0	50.0
Cluster D	5	4.2	12.0	40.0	48.0
Cluster E	6	2.9	11.5	61.5	26.9

No correlation was found between the total area of lots and the number of vegetation types determined in the surveys. We observed more species-rich meadows at lower altitude, near the central axis of Valle d'Aosta, and less in the lateral upper valleys (*P*-value = 0.047). Species-poorer grasslands were found in farms with a higher concentration of animals (*P*-value = 0.049) or which spread liquid instead of farmyard manure (*P*-value = 0.020). Grasslands both cut and grazed showed a higher number of species than those that were only grazed or, even more, than those that were only mown (*P*-value = 0.029). We noticed, however, that management decisions made by farmers rarely take the floristic richness of their meadows into account. It was confirmed, as Roumet *et al*. (1999) and Andrieu *et al*. (2007) have already demonstrated, that floristic diversity is more a result of farming techniques rather than one of the factors which influence them.

Conclusions

Even in a relatively small region, farming techniques within the same production system can be quite diverse. More data about the influence of agricultural techniques on species richness will be available from vegetation surveys that are still ongoing. The first results, however, have confirmed that farming techniques influence the species richness of permanent semi-natural grasslands and that meadows with different functions (hay production and pasture variously combined during the year) present a higher number of species than those whose utilization is not as complex.

Acknowledgments

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Mechanical weeding of *Rumex obtusifolius* in organically managed grassland

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Abstract

The effect of mechanical weeding of *Rumex obtusifolius* performed at two different depths was studied in the north of the Czech Republic (near Liberec) under organic farming conditions from 2007 to 2010. Applied treatments were: unmanaged control, grazing management without mechanical weeding (digging of taproots) and grazed management with mechanical weeding at a depth of 5 cm or 20 cm once or twice. The first weeding was made in August 2007 and the second in May 2008. Numbers of *R. obtusifolius* plants per 1m² were counted during four years of the experiment. Repeated weeding was more effective than by digging out only once during the experiment. Digging out *R. obtusifolius* taproots showed better results at a depth of 20 cm below ground than at 5 cm (below ground). After weeding two times at a depth of 20 cm, resprouting plants were no longer found. It seems that repeated mechanical weeding at 20 cm depth is effective for *R. obtusifolius* suppression in grassland under organic farming.

Keywords: broad-leaved dock, taproot, digging out, grassland, weed

Introduction

Broad-leaved dock (*Rumex obtusifolius*) is one of the most troublesome weeds in grasslands worldwide (Zaller, 2004). These plants often colonise grasslands as well as permanent agricultural crops (Novák, 1994; Brant *et al*., 2006), where they can survive for a long time (Martínková *et al*., 2009). In conventionally managed grassland systems, *R. obtusifolius* can be controlled chemically but results are not straightforward and require repeated treatment (Niggli *et al*., 1993). However, under conditions of organic farming the use of chemical substances is prohibited and only biological or mechanical methods are allowed. Biological methods include use of specific insects or pathogenous fungi controlling *R. obtusifolius* plants. Nevertheless, their application is still problematic (Strnad *et al*., 2010). Mechanical methods can be used with a variable intensity of defoliation. In the current study the effects of manual digging taproots of *R. obtusifolius* at different depth and frequency was investigated.

Material and methods

The experiment was conducted in the northern Czech Republic, 5 km north from the town of Liberec on an oganically managed farm. The experimental grassland was infested by broad-leaved dock (*R. obtusifolius*). Mechanical weeding of taproots was performed manually using a special narrow hoe on a particular plot. The first intervention was made in August 2007 and the second one was made in May 2008. Six treatments were applied:

(1) grazing with digging out of taproot of *R. obtusifolius* at a depth of 20 cm below ground twice
(2) grazing with digging out of taproot of *R. obtusifolius* at 20 cm below ground only once
(3) grazing with digging out of taproot of *R. obtusifolius* at 5 cm below ground twice

(4) grazing with digging out taproot of *R. obtusifolius* at 5 cm below ground only once
(5) grazing without digging out of taproot of *R. obtusifolius*
(6) unmanaged control.

The experiment was arranged in four complete randomised blocks with individual plot sizes of 3 m×3 m. Numbers of broad-leaved dock plants were monitored in 2 m×2 m areas allocated in the middle of each plot from 2007 to 2010. The experimental grassland was rotationally grazed with four grazing cycles. One way ANOVA and repeated measures ANOVA were used to evaluate the number of broad-leaved dock plants. The success rate referred to the initial number of *R. obtusifolius* plants as calculated in 2010.

Results and discussion

During 2008, a gradual decrease in the plant number of *R. obtusifolius* was recorded mostly in the treatments with mechanical weeding (Figure 1). The lowest abundance was found in treatments where mechanical weeding was applied twice. At the end of the experiment three groups of treatments showed a similar density of *R. obtusifolius*: i) unmanaged and without mechanical weeding; ii) mechanical weeding once (5 and 20 cm) and iii) mechanical weeding twice (5 and 20 cm). There was a similar pattern for the unmanaged treatments and the treatments without mechanical weeding in terms of the number of *R. obtusifolius* plants; however, abandonment can sometime suppress *Rumex* cover considerably (Pavlů *et al*., 2008; Martínková *et al*., 2009).

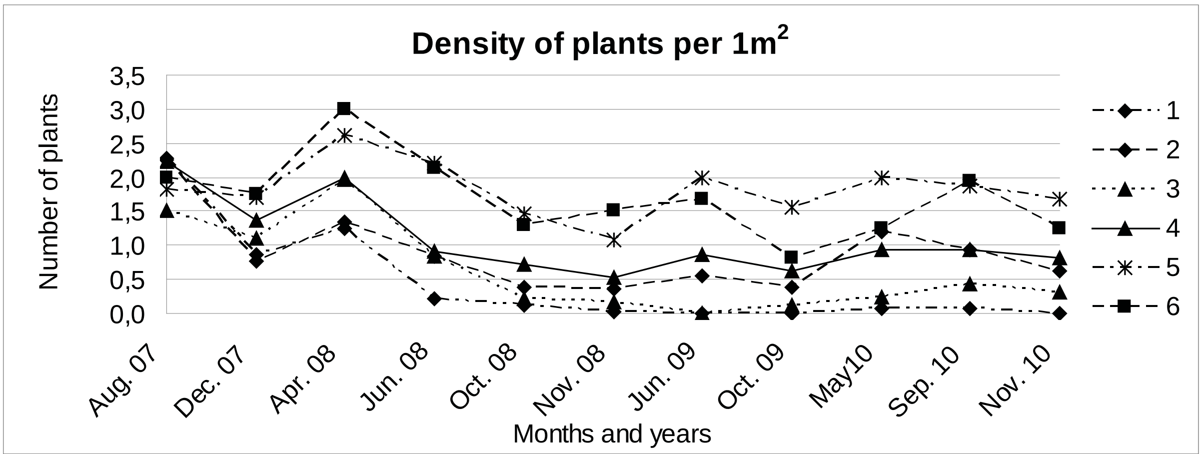

Figure 1. Development of numbers of *Rumex obtusifolius* plants per 1 m² during four years of experiment. Repeated ANOVA measures, study effects: Treatment $P < 0.001$, Year $P < 0.001$, Treatment×Year $P < 0.057$. For treatment number see Materials and methods.

Regeneration of *R. obtusifolius* plants dug out once from 5 cm below the soil surface was 37% (Figure 2), which is higher than results reported by Bond *et al*. (2007). On the other hand, Dierauer (1993) even recorded a regeneration rate of 73% for plants cut at the same depth. It seems that for successful weeding the soil nutrient content may play an important role. For example, in grassland with high phosphorus (P) and potassium (K) contents in the soil, Strnad *et al*. (2010) found no effect of mechanical weeding at a depth of 5 cm. On the other hand, Bond *et al*. (2007) suggested that plants did not regenerate after a cut at a depth of 10 cm and more and Dierauer (1993) reported that mechanical weeding at 10 cm depth resulted in a 20% rate of regeneration only. In our study, mechanical weeding at the depth of 20 cm below ground without repeating showed a regeneration of about 28%. However, no plants were found after weeding twice at a depth of 20 cm.

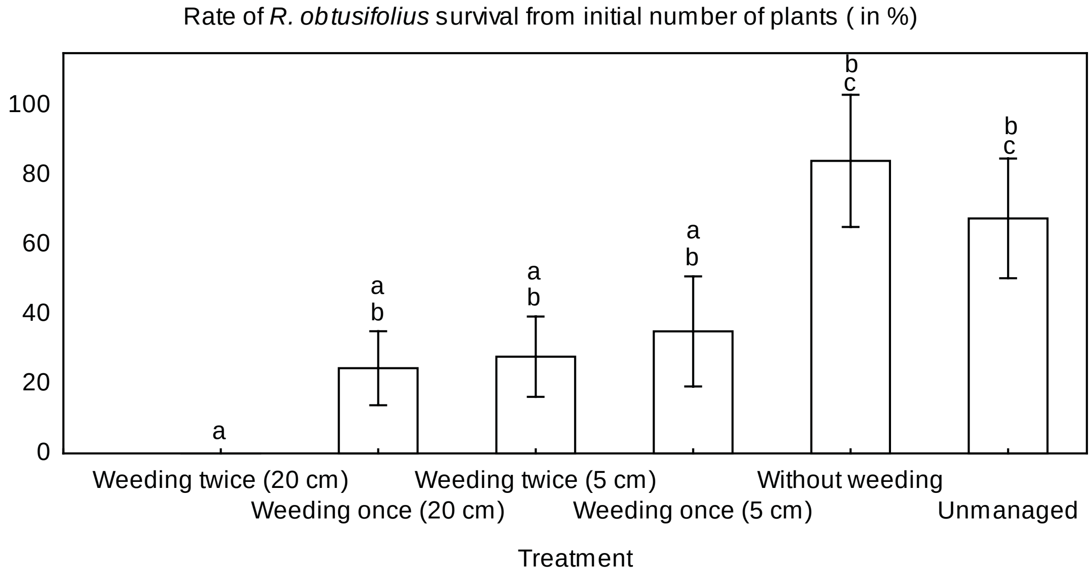

Figure 2. Survival rate of *R. obtusifolius* in November 2010 referred to the initial number of plants. Significant differences ($P < 0.001$) according to the Tukey post hoc test are indicating by different letters. Error bars represent standard error of the mean.

Conclusion

Repeated mechanical weeding of *Rumex obtusifolius* was more effective than a single treatment, especially at the depth of 20 cm. It seems that repeated mechanical weeding at the depth of 20 cm is effective for *R. obtusifolius* suppression in grassland under organic farming.

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Modelling approach for evaluating the seasonal drought impact on the productivity of permanent grasslands under conditions of the Czech Republic

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Abstract

Grassland productivity in the Czech Republic is significantly affected by variability in the weather, which in recent years has exhibited more frequent drought episodes (e.g. in 2000 or 2003) leading to lower yield-stability. The negative effects of drought could be partly prevented by a system combining a body of knowledge obtained from past long-term grassland experiments with spatially explicit information about the soil water availability in the given season, and to issue a probabilistic forecast of seasonal water stress and yield levels. Such a system was shown to well represent the between-year yield variability (R^2 between 0.6-0.9) at individual sites and provide useful forecasting ability surpassing standard statistical forecast methods.

Keywords: drought stress, modelling, GRAM, grassland

Introduction

Permanent grasslands constitute an important element of the landscape as well as part of the agricultural production system in the Czech Republic. These grasslands, however, generally enjoy less precipitation as they are situated in areas that are relatively dry (compared with, e.g., Austria) with annual precipitation being frequently less than 700 mm per year and mostly without access to irrigation. Therefore, grassland production varies considerably among sites, individual years and also during the growing season due to climatic factors. This is of major importance to dairy farmers since the whole farming system must take account of the risk of unfavourable weather conditions. To satisfy the present and expected needs in the Czech Republic for reasonably accurate grassland drought stress and yield estimates (following droughts such as those in 2000 or 2003), a relatively simple approach, relying on the established statistical linkages between a limited number of daily or seasonal variables, is being developed by the authors of this study. Operational use is expected in season of 2012.

Methods

In order to achieve the goals of the study a two-step approach is being implemented. As the first step, a dynamic daily soil water balance model is applied and its outputs are then used to estimate biomass production either for a given cut or the whole season. The grassland yield model is based on the statistical model, which takes as predictors accumulated temperature sums, global radiation and water stress, as well as cutting and fertilization to estimate grassland production. The major innovation of this approach that has been presented by Trnka *et* *al*. (2006) is the focus on spatial aspects of the production potential through incorporation of the model algorithms into a Geographic Information System (GIS).

Initially, the daily meteorological data are interpolated over the domain at 500 m resolution by a team of the Czech Hydrometeorological Institute. Then these data are 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. These factors are then combined with the sum of effective temperatures and radiation and are used as predictors for the GRAssland statistical Model (GRAM) which estimates the grassland yield in the given grid (Trnka *et al*., 2006). In order to produce a probabilistic seasonal forecast with a lead time of up to 30 days, a stochastic weather generator is being combined with monthly weather forecast as Figure 1 indicates.

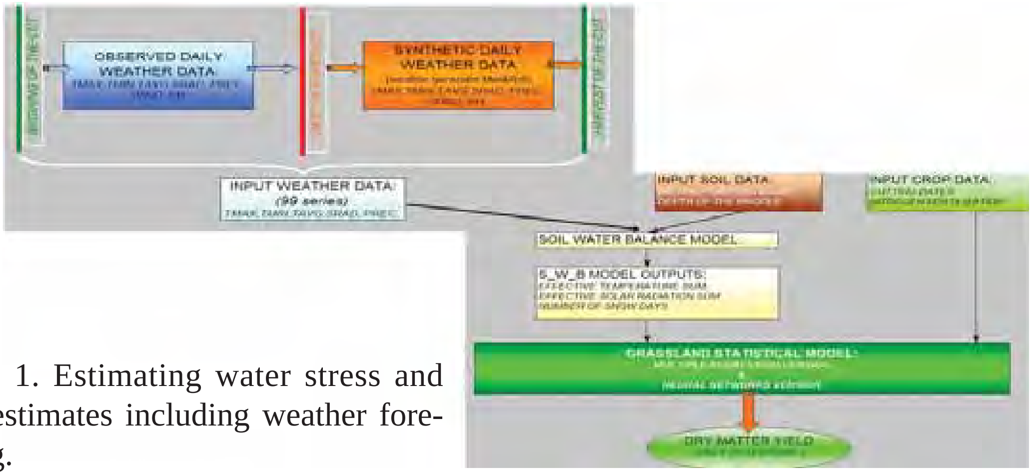

Figure 1. Estimating water stress and yield estimates including weather forecasting.

The resolution of soil and weather data is 500 m and the system considers the slope and aspect of the terrain. 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 the growth-supporting factor. For the spatial application, the growth-supporting factor also has to be available as a continuous surface like the daily temperature and radiation. Therefore, the reference evapotranspiration is calculated at 500 m grid level and then improved by using the radiation factor which represents the topographic variability. For the next step, the transformation from reference to crop evapotranspiration, it is necessary to specify management aspects of grassland production. A spatial model of cutting dates and growth duration, respectively, is a challenge 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, particularly field capacity, and the precipitation values as geodata layers at an adequate accuracy. Finally (after preparing raster datasets for the individual predictors) the GRAM model is applied.

Results and discussion

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. As an illustration for this study, long-term trial data of a multiple cut regime with multiple fertilization managements at two Austrian sites, as well as results from the Jevíčko site (Figure 2b) were used. Austrian datasets were used also to demonstrate the concept of yield forecasting before similar experiments will be available for the Czech Republic during 2011. In this case the

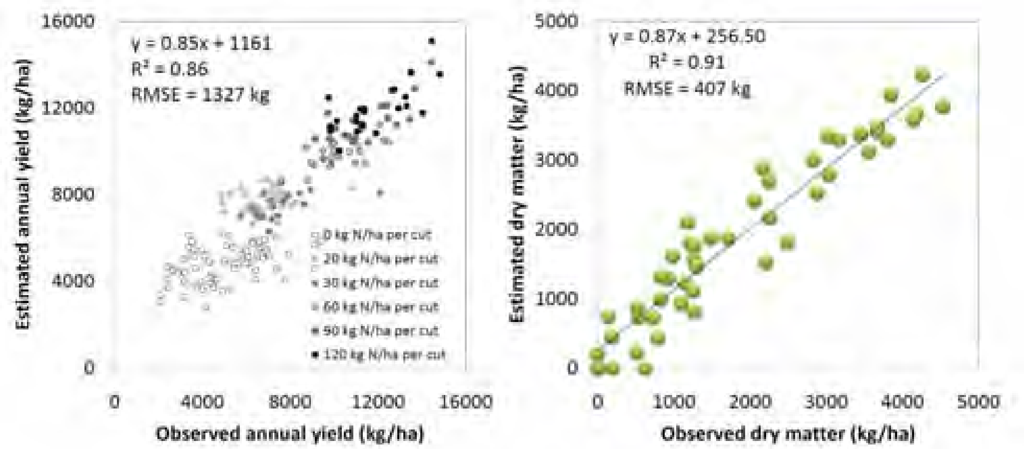

Figure 2.
a) Left: Performance of the GRAM statistical model (verification by the independent dataset) at Gumpenstein and Piber sites for the period 1971-2003 (annual yields in kg/ha) and b) Right: Performance of the first version of the GRAM-CZ model at the site in Jevíčko (2003-2009) for individual cuts.

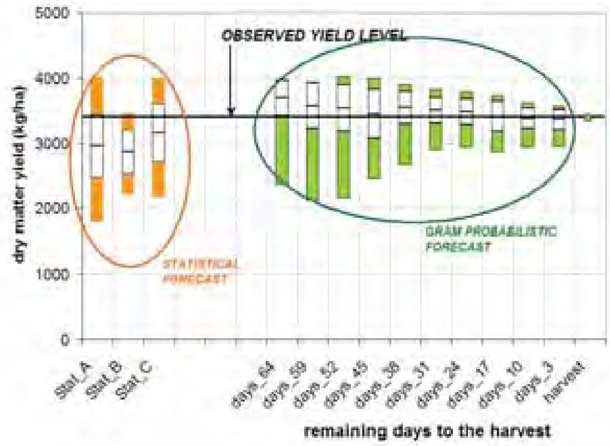

Figure 3. An illustration of a probabilistic yield forecast (bars on the right) for a single site in comparison with statistically based forecasting at Gumpenstein station (3 bars on the left side). The white bars depict ± one standard deviation range from the mean of the 99 realizations prepared for each forecasts with grey bars depicting highest/lowest predicted value.

GRAM model was coupled with the weather generator and a probabilistic forecast was issued for the Gumpenstein site several times during the seasons of 2002 (a ‘normal’ year) and 1981 (lowest yield on record). At the same time, long-term yield data were used to issue a ‘statistical’ forecast of the yield. Three types of the statistical forecasts were prepared: Stat_A: based on the long-term yield statistics for the period 1961-2002; Stat_B: based on yields of 10 seasons with similar cutting dates of the previous cut; Stat_C: based on the 10 seasons with the accumulated (April-June) standardized precipitation index (SPI) value closest to 2002 and 1981 seasons, respectively. GRAM probabilistic yield forecast was then issued 6-10 times during the growing season of the second cut using observed weather data till the date of the forecast and generated weather for the remaining period. The mean yield estimate issued with GRAM on the harvest date was within a 90 kg ha^{-1} range to the observed yield in high yielding 2002, and 760 kg ha^{-1} in the extreme 1981 season. Similar testing for the first and third cuts leads to very similar results, with even better results in the case of the 1981 season.

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Impact of experimentally induced summer drought on biomass production in alpine grassland

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Abstract

The future summer climate in the European Alps is predicted to be drier and warmer, with an increased probability of extreme events such as severe droughts. However, the way alpine grassland ecosystems will respond to changing precipitation regimes is unclear. We simulated summer drought with rainout shelters at three alpine grassland sites with contrasting macroclimate and geology in the Swiss Central Alps at about 2500 m a.s.l. to study the impact of prolonged summer drought on several key ecosystem processes. In this paper, we focus on responses in aboveground biomass production at the community and functional-group levels. After two years of simulated summer drought, community standing aboveground biomass of the alpine swards had decreased significantly, by up to 35%. The moderate drought treatment had already led to substantial reductions in biomass production, whereas the extreme drought treatment did not further reduce biomass. Some results indicate that responses to drought may differ among functional groups of plant species. We conclude that two years of summer drought considerably reduced alpine grassland biomass production. Since biomass production is one of the essential ecosystem processes in grassland, we assume that a drier climate will strongly affect alpine grassland ecosystems in the future.

Keywords: Alpine grassland, climate change, biomass production, plant functional group, standing biomass, summer drought

Introduction

In its fourth Assessment Report, the Intergovernmental Panel on Climate Change states that human-induced climate change is unequivocal and ongoing, leading to an increase in global air temperatures, changing precipitation regimes, and a higher occurrence of extreme weather events (IPCC, 2007). For Switzerland, projections for future climate predict a strong decrease in summer precipitation (OcCC, 2007), meaning that severe summer droughts will be more likely. How alpine grassland will respond to changing precipitation regimes is unclear.

In a manipulative field experiment, established in the Swiss Central Alps, we studied the impact of prolonged summer drought on several key ecosystem processes in alpine grassland. Here we present data of aboveground biomass production at the community and functional group levels after two years of treatment. We addressed the following questions: (i) Does community aboveground biomass production of alpine grassland respond to two years of simulated summer drought? (ii) Does the severity of drought matter? (iii) Does summer drought have different effects at sites with contrasting macroclimate and geology? (iv) Are there functional group-specific reactions to drought?

Methods

The experiment was conducted at three sites in the Swiss Central Alps that represented contrasting conditions in macroclimate and geology: one site at Albula Pass (continental-dry, calcareous bedrock) and two sites at Furka Pass (temperate-moist, calcareous and siliceous bedrock, respectively). The sites were located on steep slopes at about 2500 m a.s.l. The vegetation represented typical alpine grassland communities: *Sesleria caerulea* swards (*Seslerio-Caricetum sempervirentis*) on calcareous bedrock and a *Carex curvula* sward (*Caricetum curvulae*) on siliceous bedrock.

During the summers of 2008 and 2009 (from late June to mid-September) summer drought was simulated with rainout shelters. The treatments included a control (ambient rainfall in both years), moderate drought (six weeks rainfall exclusion in both years) and extreme drought (twelve weeks rainfall exclusion in 2008, six weeks in 2009). The experimental design was a completely randomized block design with four replications of each of the three treatments. At the time of peak biomass (early August) in 2009, all aboveground plant parts were cut at 0 cm above the ground, representing standing biomass, including a high proportion of biomass produced in previous years. The biomass was separated into functional groups, dried at 70°C and weighed to determine dry matter.

Statistical analyses were performed using SPSS Statistics 17.0. Square-root transformed biomass data were analysed with a two-way analysis of variance (ANOVA) to test for main effects of site and treatment and interactions between these two factors. A Tukey HSD test was used for multiple comparisons of means.

Results and discussion

Due to the varying growth conditions, community standing aboveground biomass of the alpine swards differed significantly between sites ($P < 0.001$, Figure 1), ranging from 232 g DM m^{-2} (Furka Pass, siliceous bedrock) to 533 g DM m^{-2} (Albula Pass, calcareous bedrock). Surprisingly, the effect of drought was the same at each site (P = n.s., interaction site×treatment). Overall, summer drought significantly reduced community standing aboveground biomass of the alpine swards ($P = 0.017$), with decreases of 12 to 35%. This effect was already strong under moderate drought and did not further increase under extreme drought. This clearly shows that moderate drought is sufficient to induce significant biomass responses. A drought-induced reduction in biomass production has also been found by other studies (Gilgen and Buchmann, 2009; Bloor *et al.*, 2010).

Different functional groups tended to respond differently to summer drought (Table 1). The graminoids ($P = 0.096$) and forbs, as the main functional groups of the swards, both showed a trend towards reduced standing aboveground biomass under drought conditions. But the legumes and dwarf shrubs seemed to profit from a drier climate and tended to produce more aboveground biomass when exposed to extreme drought. However, due to large variation (standard errors, Table 1), after two years of summer drought, the functional group responses are not clear; thus further analysis of the data is required to verify this.

Conclusions

Our results show that two years of summer drought considerably reduced alpine grassland biomass production. Since biomass production is one of the essential ecosystem processes in grassland, we assume that alpine grassland ecosystems could be particularly susceptible to prolonged summer drought in the future.

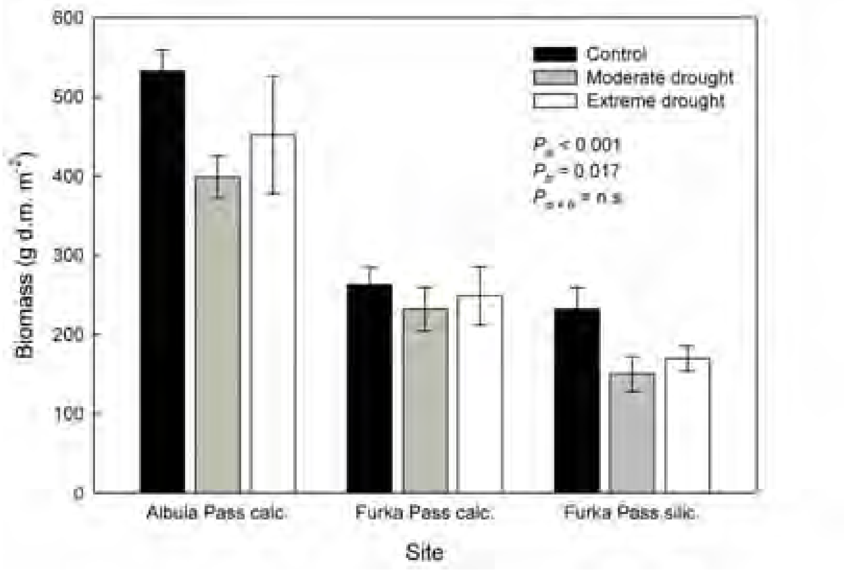

Figure 1. Effect of summer drought on community standing aboveground biomass (mean ± standard error, n = 4) of alpine swards at Albula Pass (calcareous bedrock) and Furka Pass (calcareous and siliceous bedrock) in 2009. Significance levels (ANOVA) for effects of site (si) and treatment (tr) and their interaction (si×tr) are indicated.

Table 1. Standing aboveground biomass (g DM m^{-2}, mean ± standard error, n = 4) of the functional groups graminoids, forbs, legumes and dwarf shrubs of alpine swards at Albula Pass (calcareous bedrock) and Furka Pass (calcareous and siliceous bedrock) under summer drought in 2009.

	Albula Pass calc.			Furka Pass calc.			Furka Pass silic.				
Biomass	ct	md	ed	ct	md	ed	ct	md	ed	P_{si}	P_{tr}
Graminoids	342±47	250±51	289±52	159±18	137±14	112±30	109±20	76±14	78±5	< 0.001	0.096
Forbs	143±21	111±18	106±23	83±32	65±17	69±8	97±15	61±10	63±9	0.005	n.s.
Legumes	15±10	5±1	24±17	19±17	10±2	40±24	26±9	14±3	28±9	n.s.	n.s.
Dw. shrubs	33±13	32±16	34±11	2±2	20±16	27±22	0±0	0±0	0±0	< 0.001	n.s.

Ct = control, md = moderate drought and ed = extreme drought. Significance levels (ANOVA) for effects of site (si) and treatment (tr) are indicated.

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Differential responses to climatic conditions in Ireland by five grass species

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Abstract

Five grass species were grown for four years in monoculture with white clover at three locations, differing in altitude and latitude and at three different fertility levels. Significant rank changes in efficiency of production were reconciled with the incident temperature and light energy levels during the spring, summer and autumn periods. Perennial ryegrass was higher yielding per unit of light and temperature in summer, but was less efficient in the lower light and heat of spring and autumn than Timothy and fescues, with cocksfoot the most adaptable across all conditions.

Keywords: grass species, nitrogen, PAR, temperature, yield

Introduction

The predominant use of perennial ryegrass (*Lolium perenne* L.) for reseeding in temperate climates is based on its superior yield performance over other pasture grass species. This advantage is highly dependent on favourable management and climate, but Frame (1991) has shown that this can reduce or reverse where conditions become poorer but not actually acutely stressful. Given current predictions on climate change (IPCC, 2001), the earliest and greatest negative growth responses can be expected in more marginal areas, where conditions are already sub-optimal. Keane and Collins (2004) report declining summer rainfall totals and an emerging increase in spatial contrast in the precipitation geography across Ireland. They also predict wetter cooler winters that will contract the practical grazing season. These factors support predictions that changes in climate may weaken ryegrass performance advantages, with a possible westward shift in livestock agriculture. As reviewed by Hopkins and Del Prado (2007), recent genetic improvements in species of *Festuca* make them potentially able to provide a highly productive platform for improving swards in the more marginal temperate zones in Europe. In addition *Dactylis glomerata* L. is known to prevail under temperature and drought stresses. The current study evaluated the dry matter productivity potential of five grass species in relation to prevailing temperature, light energy and nitrogen fertility, over four harvest years at three sites in Ireland.

Material and methods

During four years (2007-2010), five forage grasses, cocksfoot (*Dactylis glomerata* L., Donata) (CF), meadow fescue (*Festuca pratensis* Huds., Pradel) (MF), perennial ryegrass (*Lolium perenne* L., Portstewart) (PR), tall fescue (*Festuca arundinacea* Schreb., Barolex) (TF), and Timothy (*Phleum pratense* L., Dolina) (TM) were grown with white clover (*Trifolium repens* L., Chieftain) at three Irish locations: Backweston, Co. Kildare (52°26‘N, 06°30‘W, alt. 15 m), Crossnacreevy, Co Down (54°32‘N, 05°52‘W, alt. 120 m), and Moorepark, Co Cork (52°09‘N, 08°13‘W, alt. 30 m). Keane and Collins (2004) predict that by the mid-century, average summer temperatures will be 2 and 3°C higher at the northern and southern sites, respectively, with significantly increased evapotranspiration and soil moisture deficits. Plots (1.5 m×7 m) were grown at low (105 kg ha^{-1} N), medium (210 kg ha^{-1} N) and high (420 kg ha^{-1} N) nitrogen levels, with final applications on 1 September. Each treatment comprised a three replicate randomised block design, under simulated grazing with a regrowth of 21 days, extended to 35 days in late season. Dry matter yield was determined using a plot harvester (Haldrup, Logstor, Denmark), cutting at 5 cm, with 250 g subsamples dried at 80°C for 16 h. Mean daily temperatures (hourly max-min) and total PAR integrated on a daily basis, were recorded using a weather station (Skye Instruments Ltd, UK). Data in 2010 were only available for Crossnacreevy and PAR were not available for Moorepark. All data were divided into three seasonal periods (spring, 1 Feb-15 Apr; summer, 16 Apr-30 Sept; autumn, 1 Oct-15 Nov). Data were compared across years and sites using analysis of variance by Genstat 8 (VSN International Ltd., Hemel Hempstead, UK).

Results and discussion

Significant interactions occurred between all yield treatment factors, but the majority of site and year effects were due to year on year increases at Crossnacreevy and decreases at Backweston (previously reported by Gilliland *et al*., 2010). This was not a confounding factor for this study as the data were used without subdivision by location or date, to examine only the responses to incident conditions by each species. Within each of the seasonal periods, species differed significantly in DM yield; however, the biggest differences were within species (Table 1). These were largely due to the applied nitrogen treatments, as shown previously by Gilliland *et al*. (2010). Similar to Bailey (2000), however, there were underlying effects of the incident growing conditions on the relative performance of each species that differed between seasonal periods. The spring period was characterised by a low mean daily temperature range of 4.7-7.4°C and low PAR of 4.8-104 MJ m^{-2} d^{-1}. Under these conditions perennial ryegrass had the lowest DM yield per degree centigrade (0.95 t DM ha^{-1}), with Timothy and tall fescue the highest. Perennial ryegrass was also least productive per unit of light energy (32.5 kg DM per kJ m^{-2} d^{-1}), which was similar to meadow fescue, but significantly less than tall fescue, with Timothy significantly most productive (48.5 kg DM per kJ m^{-2} d^{-1}). This ranking in productivity per unit of temperature or light energy was largely reversed during the summer period, when the mean daily temperature range was 9.9-11.9°C and PAR of 106-181 MJ m^{-2}d^{-1}. During this time, perennial ryegrass had the highest productivity (4.4 t DM ha^{-1} °C^{-1} d^{-1} and 109.6 kg DM per kJ m^{-2} d^{-1}). Cocksfoot was largely similar, as was Timothy, while meadow and tall fescue were significantly low for both parameters. In the autumn period perennial ryegrass again had the lowest efficiencies with cocksfoot highest and the other species intermediate. It was also notable that the ranking changes in species nitrogen efficiency were broadly similar to above, with ryegrass and cocksfoot having the greatest response change between spring and summer and fescues the lowest response.

Conclusions

The productivity achieved by these five grass species under different growing conditions revealed differential responses to climatic conditions that were not acutely stressful. Similar to the findings of Bailey (2000), perennial ryegrass was shown to be most sensitive to more marginal conditions but with the expected boost in performance when conditions improved. The fescues and Timothy were clearly better able to maintain the efficiency of production at lower light and temperature conditions. Cocksfoot was the most adaptable species as it maintained a high ranking in all three seasonal periods. Despite the newer varieties in all species probably having increased production, the species characteristics previously reported, e.g. by Frame (1991) or Haggar (1976), appear largely retained despite breeding efforts to improve early/late seasonality.

Table 1. Species DM yield response during three seasonal periods, to nitrogen, temperature and photosynthetically active radiation (PAR) during four years at three sites in Ireland.

Species	DM Yield (t ha^{-1})	Dry matter yield response per unit temp, PAR, nitrogen (t DM ha^{-1} per °C d^{-1})	(kg DM per kJ m^{-2} d^{-1})	(t ha^{-1} DM per kg N)
a) Spring Growth		Temperature	PAR	Nitrogen
	Parameter Range	4.7-7.4°C d^{-1}	4.8-104 MJ m^{-2} d^{-1}	50-100 kg N ha^{-1}
PR	0.35-2.72	0.9	32.5	33.6
TM	0.05-3.86	1.3	48.5	50.5
MF	0.03-3.38	1.1	35.4	44.3
TF	0.36-4.55	1.4	43.5	53.8
CF	0.03-3.24	1.1	44.4	44.9
	SE	0.04	0.79	0.83
b) Summer Growth		Temperature	PAR	Nitrogen
	Parameter Range	9.9-11.9°C d^{-1}	106-181 MJ m^{-2} d^{-1}	55-320 kg N ha^{-1}
PR	4.96-18.09	4.4	109.6	66.6
TM	5.58-16.92	4.2	91.9	67.3
MF	5.37-15.82	3.6	84.9	54.4
TF	5.71-16.99	3.7	90.4	58.3
CF	4.76-16.17	4.2	106.4	66.1
	SE	0.06	1.83	1.13
c) Autumn Growth		Temperature	PAR	
	Parameter Range	5.9-10.9°C d^{-1}	17-79 MJ m^{-2} d^{-1}	
PR	0.19-2.01	0.31	19.1	No nitrogen was applied after the 1st of September
TM	0.11-2.38	0.41	22.8	
MF	0.21-2.30	0.37	22.7	
TF	0.30-2.61	0.36	22.2	
CF	0.10-2.76	0.46	26.9	
	SE	0.11	0.76	

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The forage quality of meadows under different management practices in the Italian Alps

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Abstract

In many alpine valleys in northern Italy there is evidence of an ongoing intensification of farming systems in favourable locations. In contrast, marginal grasslands on mountain slopes tend to be abandoned. Extensive management is necessary to preserve the cultural landscape here. The present study was carried out to investigate the forage quality of meadows in Valle d'Aosta (NW Italian Alps), Trentino and South Tyrol (NE Italian Alps), under different management intensities, in order to find suitable usage of the forage harvested. Two cutting frequencies and two NPK fertilization levels were applied to semi-natural meadows over a period of four years. The yield and all quality parameters were affected by cutting frequency, whereas only yield and crude fibre responded to fertilization. The yield from meadows cut once a year can be increased by fertilization, but their forage quality is not suitable for dairy cows. Fertilization is considered reasonable in three-cut meadows to ensure adequate yield, taking nutrient balance into account.

Keywords: forage quality, mountain meadows, management techniques

Introduction

Meadows ensure the production of forage which is essential for satisfying the nutritional needs of the different ruminant species present on the farms in mountain areas. Over the last decades political and economic strategies have encouraged these farms to become markedly specialized in the production of dairy milk. On the one hand, since more productive dairy cows are being bred, it is necessary to optimise meadow management practices in order to meet their increasing needs for high-quality forages. On the other hand, there is an ongoing abandonment of marginal areas, leading to shrub encroachment, fires and an increase of forested areas. Under such conditions, extensive management of meadows, with minimal intervention, is required to ensure the preservation of their functionality, biodiversity and landscape appeal, particularly in tourist areas. As the forage quality determines its possible use for animal nutrition (i.e. for cows or only for heifers), a study was carried out to investigate the effect of cutting frequency and fertilization on the forage quality of permanent meadows in the Italian Alps.

Materials and methods

From 1997 to 2000, four treatments were compared on semi-natural meadows in Ville sur Nus (Aosta, NW Alps, 1120 m a.s.l.), Aldino (Bolzano, NE Alps, 1250 m a.s.l.) and Borgo Valsugana (Trento, NE Alps, 520 m a.s.l.), combining two NPK fertilization levels (F0 = 0 NPK, *vs.* F1 = 40-11-42 kg ha^{-1} cut^{-1} for N, P and K respectively) and two cutting frequencies (C1 *vs.* C3: 1 *vs.* 3 cuts yr^{-1} respectively). In the C1-treatment, plots were harvested around mid July; in the C3-treatment, cuts were performed before mid June and then every 6 to 8 weeks. On each site, treatments were applied to plots measuring 7×2 m, arranged as a randomized complete block design with four replicates. The vegetation was surveyed according to Daget and Poissonet (1969) with 33 sampling points per plot. DM yield was obtained after weighing the fresh biomass in the field and determining its dry matter content on a 500 g subsample dried at 60°C. Ash (CA), crude protein (CP) and crude fibre (CF) were determined on these subsamples (Naumann *et al*., 1997). Absorbable protein (AP) content and net energy for lactation (NEL) were estimated by regression equations (RAP, 1999) taking the CA, CF, CP contents and the botanical composition of the plots in terms of functional groups into account. For statistical analysis, summary values of the quality parameters were examined by a mixed model. Cumulated yearly yields were computed for each plot and averaged across the investigation period, while quality parameters were obtained within each year as weighted means with respect to the yield and then averaged across the investigation period. The cutting frequency, the fertilization level, their interaction and the block were considered to be fixed, while the site and its interactions with the other factors were considered to be random. A P-value < 0.05 was regarded as significant.

Results and discussion

According to their floristic composition, the three grasslands were fairly representative of the main associations of mountain meadows i.e. *Arrhenatheretum* and *Trisetetum* (Table 1).

Table 1. Mean Specific Contribution (S.C.) according to Daget and Poissonet (1969) of main species at each site (%).

Aosta Functional groups/Species	S.C.	Bolzano Functional groups/Species	S.C.	Trento Functional groups/Species	S.C.
Grasses	49.2	Grasses	67.1	Grasses	67.8
Legumes	14.5	Legumes	23.4	Legumes	9.5
Herbs	36.3	Herbs	9.5	Herbs	22.7
Dactylis glomerata	21.8	*Festuca pratensis*	14.8	*Dactylis glomerata*	25.7
Poa pratensis	11.1	*Trifolium repens*	13.1	*Festuca pratensis*	19.4
Taraxacum officinale	7.3	*Poa pratensis*	10.3	*Poa trivialis*	11.3
Trisetum flavescens	7.1	*Trifolium pratense*	9.0	*Ranunculus acris*	9.5
Anthriscus sylvestris	5.8	*Lolium perenne*	7.3	*Taraxacum officinale*	6.0

In Trento and Bolzano, grasses prevailed with a fair contribution of legumes in the latter. In Aosta, herbs represented more than a third of the total grassland cover with a high proportion of *Apiaceae* such as *Anthriscus sylvestris* and *Heracleum sphondylium*.

Considering all sites, the DM yield increased significantly by about 40% both in C3 and in F1 treatments (Table 2) and the interaction between these two factors was also almost significant (P-value = 0.051), with a stronger effect of fertilization at the higher cutting frequency. Increasing the cutting frequency from 1 to 3 cuts resulted in lower CF content (from 335 to 270 g kg^{-1} DM respectively), while the fertilization increased it from 295 to 310 g kg^{-1} DM. Fertilization, promoting a more intense growth and modifying the stem/leaves ratio, resulted in a richer production of structural carbohydrates. At the same time, legumes presence were reduced in favour of grasses, in Bolzano and Trento, and also that of herbs (especially *Apiaceae* and *Asteraceae*) in Aosta, where their S.C. represented more than 50% of the vegetation in fertilized plots. In these semi-natural grasslands, it is important to control the balance between inputs and outputs carefully, in order to prevent undesirable changes in floristic composition and ensure its long term stability.

Crude protein was greatly affected by cutting frequency. It was quite low in the C1 plots, with only 91 g kg^{-1} DM, with an average increase of more than 40% in the C3 plots, from 91 to 129 g kg^{-1} DM. Fertilization did not affect this quality parameter. This result might be related to differences in the floristic composition between sites and during the investigation period.

Table 2. Mean annual dry matter yield (DMY), crude fibre (CF), crude protein (CP), absorbable protein (AP) and net energy for lactation (NEL).

Treatment	DMY (Mg ha^{-1})	CF (g kg^{-1} DM)	CP (g kg^{-1} DM)	AP (g kg^{-1} DM)	NEL (MJ kg^{-1} DM)
C1F0	5.28	331.5	89.9	75.8	4.87
C1F1	6.52	338.7	91.4	75.3	4.78
C3F0	6.68	258.6	132.1	90.2	5.48
C3F1	9.85	280.9	124.9	86.3	5.21
P-values of effects					
C (Cut)	0.007	<0.001	<0.001	0.001	<0.001
F (Fertilization)	0.011	0.032	0.486	0.179	0.217
C×F	0.051	0.071	0.098	0.286	0.123

However, total CP yield was affected positively by fertilization in Bolzano and Trento, as a result of the DMY increase, but not in Aosta because of the little effect fertilization had on DMY (Bassignana *et al*., 2003). As for CP, C1 plots showed a low AP content, while the C3 plots reached acceptable levels. Daccord (1990) showed a particularly slow ruminal degradability of proteins of grass mown in species-rich meadows, if the cut is late. He suggested a minimum NEL of 4.5 MJ kg^{-1} DM in dairy cows rations, to avoid nutritional imbalances. The grass from C1 plots had slightly higher energy levels, but in the practice they would probably fall below the recommended threshold because of the losses due to haymaking operations. In contrast, in C3 plots the forage had a higher margin of safety, exceeding 5.3 MJ kg^{-1} DM.

Conclusions

Our study on permanent grasslands, both in the western and in the eastern sector of the Italian Alps, showed that these meadows can be cut once a year, for landscape preservation, and can also be fertilized, to increase DMY, but their hay has to be reserved for less demanding animals, such as heifers or dry cows. For dairy cows, it is necessary to produce hay from more intensive meadows, with three cuts and an adequate fertilization, to assure larger yields and forage with a high nutritional value.

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Effect of forage conservation on the leaf texture of tall fescue

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Abstract

Tall fescue (*Festuca arundinacea* Schreb.) is a grass tolerant of recurring drought periods. For this reason, including this species in seed mixtures for mountain regions adversely affected by summer drought would be desirable. There is evidence that the digestibility of tall fescue is not related to leaf roughness. Furthermore, rough-leaved cultivars exhibit better competitiveness and persistency than soft-leaved ones in a mountain environment. However, there is concern about the palatability of rough-leaved cultivars. Whilst this applies to fresh leaf material, as in the case of pastures, there is a lack of information about leaf texture changes for forage conservation. Therefore, a sensory evaluation was performed on nine tall fescue cultivars with differing leaf texture. Leaf material from the first and the third cut was obtained in a field experiment and assessed as fresh material, after drying and after ensiling in laboratory microsilos. Forage conservation processes were found to decrease leaf roughness, although differences between soft-leaved and rough-leaved cultivars were still recognisable in the conserved forage. The results suggest that the palatability of conserved rough-leaved cultivars may be acceptable.

Keywords: *Festuca arundinacea*, tall fescue, leaf texture, forage conservation, palatability

Introduction

Unlike many other forage grasses, tall fescue (*Festuca arundinacea* Schreb.) is tolerant of recurring drought periods. For this reason, the inclusion of this species in seed mixtures for mountain regions adversely affected by summer drought would be desirable. There is evidence that the digestibility of tall fescue is not related to leaf roughness; furthermore, rough-leafed cultivars exhibited better competitiveness and persistency than soft-leafed ones in a mountain environment (Peratoner *et al*., 2010). However, there is concern about the palatability of rough-leafed cultivars. Whilst this applies to grazed fresh leaf material (Goodenough *et al*., 1988), there is a lack of information about leaf texture changes related to the forage conservation processes. This information is required to indirectly answer the question of whether the leaf roughness of rough-leaved cultivars and in turn their palatability may be improved through hay-making or ensiling, which is known to be a suitable conservation technique (Opitz von Boberfeld *et al*., 2004).

Materials and methods

The leaf texture of tall fescue was assessed by means of a sensory evaluation of leaf material obtained from a five-year-old cultivar trial located at the experimental farm Mair am Hof (920 m a.s.l., Dietenheim/Bruneck, South Tyrol, Italy) and conducted under intensive management (four cuts year^{-1}). Eight tall fescue cultivars (Astico, Barcel, Bariane, Barolex, Belfine, Fawn, Kora and Molva) and one Festulolium cultivar (Hykor), differing from each other in leaf texture and other plant traits, were investigated in the present experiment. The field trial was a Latin rectangle with three replications. Experimental design and management details are described in Peratoner *et al*. (2010). The sensory evaluation was performed on leaf blades from the first and the third cut. Two reference samples were obtained from a plot sown with a rather soft-leaved cultivar and from another plot sown with a rather rough-leaved cultivar. These two plots were consistently used as a source of reference material throughout the experiment. At the first assessment date the two reference samples received a value of three (soft) and seven (rough). All other samples were rated with respect to these reference samples, with decimal values and values both within and beyond the three-to-seven-interval being allowed. The assessment was carried out by a panel of four trained persons, who had conducted a preliminary test in the previous year. Leaf texture evaluation was performed by repeatedly rubbing a handful of leaves over the fingers. The leaf roughness of each sample was computed as the arithmetic mean of the values expressed by each member of the assessment panel. Prior to harvest, leaf texture was assessed in the field on fresh material, then leaf blades were harvested and divided into two samples for forage conservation. One sample was dried at 60°C for four days, whilst the other one was ensiled in laboratory microsilos (125 ml glass jars, Miko GmbH, Eppan, I). The sensory evaluation of the conserved samples took place three months after harvesting the third cut, using fresh material samples from the field and conserved material from the reference plots as reference samples. Data analysis was performed by means of a mixed model taking into account the cultivar, the leaf condition, the cut and the design factors (lines and columns) as fixed factors. The interaction cut × leaf condition was considered as a repeated factor with the plot being the subject of a repeated measurement. All possible interactions between main factors as well as the second order-interactions of the cut with the design factors were included in the model. Prior to analysis, data were logarithm-transformed to achieve normal distribution of residuals and variance homogeneity. Multiple comparisons were performed by protected LSD-test. $P < 0.05$ was considered to be significant.

Results and discussion

Leaf roughness proved to be significantly affected by all investigated factors (cultivar, cut and leaf condition; all $P < 0.001$). Also, the interactions cultivar×leaf condition and cut×leaf condition were found to be significant.

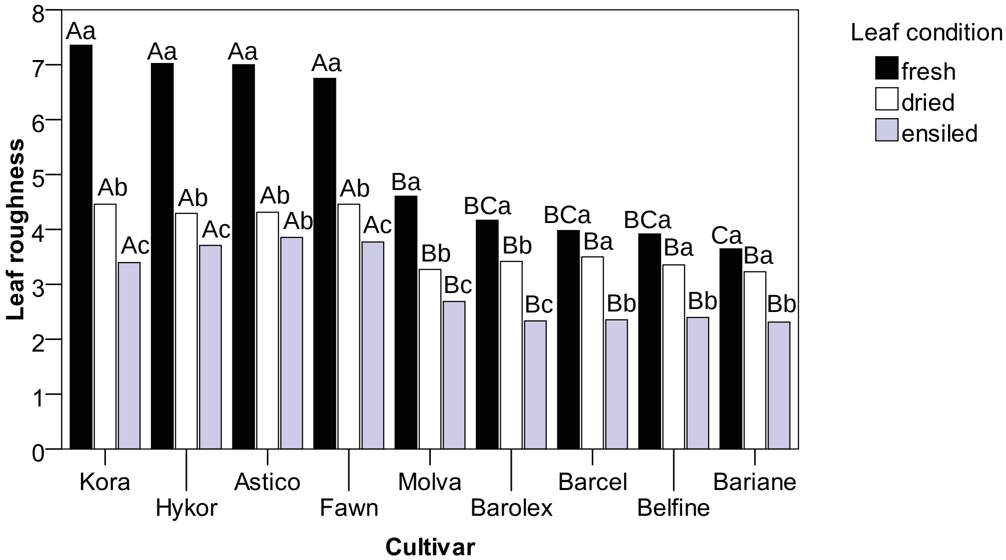

Figure 1. Effect of cultivar and leaf condition on the leaf roughness of tall fescue. Means without upper case letters in common within each leaf condition treatment and means without lower case letters in common within each cultivar significantly differ from each other.

The assessment of fresh leaf material highlighted a clear distinction between rough and soft-leaved cultivars, with Kora, Hykor, Astico and Fawn belonging to the first group (Figure 1). Drying strongly reduced differences in roughness between rough and soft-leaved cultivars and ensiling generally brought about a further small reduction in roughness. However, it is remarkable that the differences between soft and rough-leaved cultivars remained perceivable through all changes in leaf conditions.
Drying and ensiling the leaf material decreased leaf roughness within each cut (Table 1). Dried and ensiled leaves were found to be consistently slightly rougher at the third cut, but no difference between cuts was found in fresh leaf condition. This interaction might reflect the fact that a comparison of the fresh material over different cuts is not very reliable, as fresh material has to be evaluated in the field and a direct comparison of fresh material from different cuts was not feasible. Nevertheless, roughness differences between cuts are relatively small and the comparison under fresh leaf conditions does not represent the main focus of the experiment.

Table 1. Effect of cut and leaf condition on leaf roughness of tall fescue. Values without upper case letters in common within each cut and values without lower case letters in common within each leaf condition treatment significantly differ from each other.

	Leaf condition		
Cut	fresh	dried	ensiled
1st	5.2^{Aa}	3.5^{Bb}	2.8^{Cb}
3rd	5.1^{Aa}	4.0^{Ba}	3.0^{Ca}

Conclusions

Forage conservation processes were found to decrease leaf roughness, although differences between soft-leaved and rough-leaved cultivars were still recognisable in the conserved forage. The results indirectly suggest that the palatability of conserved rough-leaved cultivars may be improved by forage conservation, reducing differences in palatability between soft and rough-leaved cultivars. However, certainty can only be obtained by conducting feeding experiments.

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GrazeVision: A versatile grazing decision support model

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Abstract

Grazing management, i.e. matching the grass supply with feed demands, is complex. It involves many interventions such as varying the length of grazing rotation, nitrogen fertilization, supplementation, access time, stocking rate, paddock size, removal of surplus grass and topping. It is difficult to foresee the effects on animal and grassland production when two or more interventions are executed simultaneously. The GrazeVision decision support model is developed for farmers to simulate the effects of one or more management interventions at the same time. The inputs for GrazeVision are: nitrogen application rate, soil, season, target residual herbage mass, herd demography, paddock size, access time and supplementary feeding. The outputs are: predicted initial herbage mass, herbage intake, substitution rate of supplemental feeding, paddock residence time, herbage available for cutting, rejected herbage mass (tall patches), herbage loss due to fouling with dung, trampling and poaching, herbage utilization, total milk production and changes in milk production during paddock residence time. Farm profitability is calculated after allocation of input prices and product returns. The GrazeVision grazing decision model is incorporated in the DairyWise whole-farm decision model and available as a stand-alone internet application www.koeenwij.nl.

Keywords: grazing, modelling, management, decision support

Introduction

In the Netherlands, flexible rotational grazing with varying levels of supplemental feeding with concentrate and forage is the most common grazing practice. In short, cows are given access to a paddock which is grazed down to an acceptable level of RHM to maintain an acceptable level of milk yield. The length of paddock residence time depends on the level of IHM, level of supplementation, stocking rate, grass growth rate and deterioration of the grazed sward. A number of management interventions can be applied to match the supply grass with the feed demands of the dairy herd. These interventions include the length of grazing rotation, nitrogen (N) fertilization, removal of surplus grass as silage, feed supplementation, access time to pasture, stocking rate, flexible fencing, and topping depending on season, weather conditions and grass growth. Decision support models are useful tools to help the farmer to predict the effects of grazing management on animal and grassland production, especially when two or more management interventions are simultaneously employed. GrazeVision is such a decision support model. GrazeVision is constructed from different existing modules, each representing a sub-system of the grazing system (Figure 1). This objective of this paper is to present the conceptual outlines of the GrazeVision decision support model and to demonstrate its applications in practice.

Table 1. Abbreviations

IHM, kg DM ha^{-1}	= Initial Herbage Mass
RHM, kg DM ha^{-1}	= Residual Herbage Mass
$HL_{(\ldots), kg\ DM\ ha-1}$	= Herbage Loss
EHM, kg DM ha^{-1}	= Edible Herbage Mass
FIC, SV unit d^{-1}	= Feed Intake Capacity
$SV_{(feed)}$, kg DM^{-1}	= Satiety Value
HDMI, kg DM	= Herbage Dry Matter Intake
fEHM, %	= adjustment factor for EHM

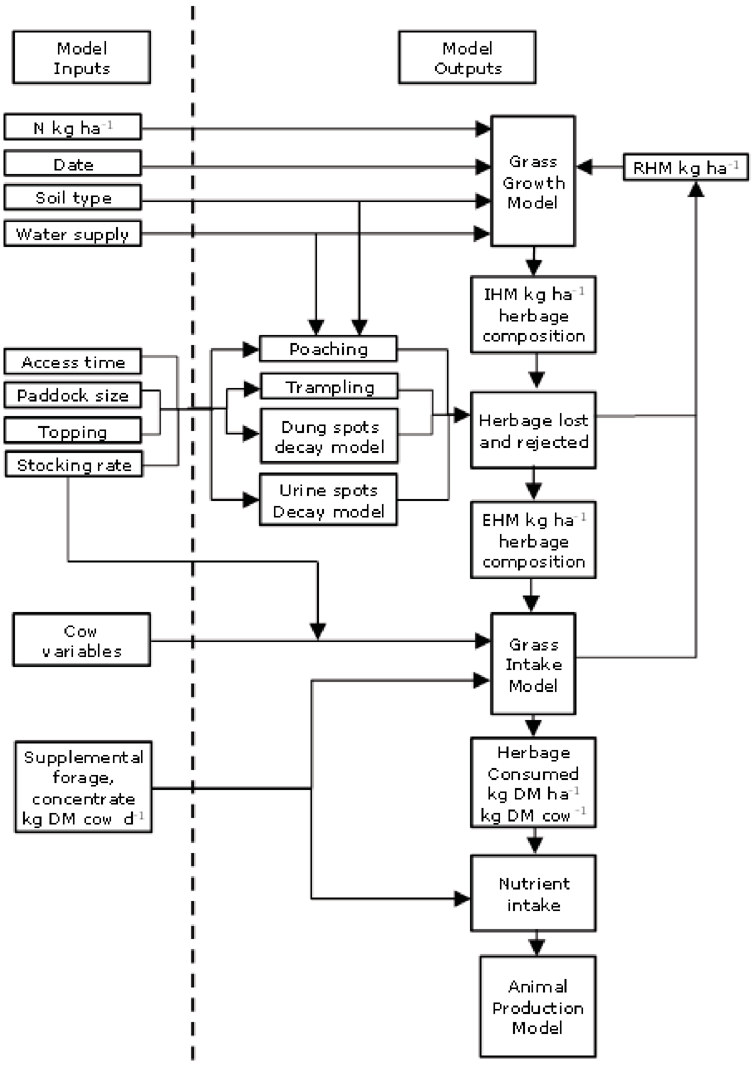

Figure 1. Scheme of GrazeVision decision support model IHM is initial herbage mass, EHM is edible herbage mass, RHM is residual herbage mass

Model inputs

There are four groups of model input variables (Figure 1). The first group regards the level of nitrogen fertilization (N kg ha^{-1}), soil type (sand, clay or peat), water supply (i.e. ground water level), date of year, growth cycle. The second group regards grazing management paddock size, access time to pasture, topping and stocking rate. The third group includes cow characteristics and milk production. The fourth group includes the level of supplemental forage and concentrate feeding and feed characteristics.

Grazing system

The Grass Growth Model (GGM; Schils *et al*. 2007) estimates the daily herbage DM accumulation, including predictions of crude fibre, CP, and crude ash and OM digestibility and subsequently initial herbage mass (IHM kg DM ha^{-1}) at the start of grazing. The user has ability to overrule the predicted IHM by using own measurements of IHM. The IHM at the start of grazing is the total herbage mass. It is recognized that not all IHM is edible (or acceptable) and that there is hierarchy in grazing preference. In descending order of preference, cows graze: 1) new regrowth of previously cut or grazed grass; 2) clean residual herbage from previous grazing; 3) grass on old urine spots rejected during previous grazing and 4) tall patches around old dung spots. Herbage that is not edible is considered as HL. The HL is a result of fouling with urine (HL_{urine}), dung (HL_{dung}), trampling ($HL_{trampled}$) and poaching ($HL_{poached}$) and dead herbage (HL_{dead}) in the lower regions of the sward. The EHM is calculated as: EHM = IHM - (HL_{dung}+HL_{urine}+$HL_{trampled}$+$HL_{poached}$+HL_{dead}). The model to predict HL_{dung} was derived from data of Hijink and Boxem (1973), Duinkerken *et al*. (2000) and Holshof (unpublished data). The HL_{urine} was calculated from a model predicting the number of urinations and $_{urine}$ covered area (Vellinga *et al*., 2001). The $HL_{trampled}$ was derived from data of Meijs (1981). The $HL_{poached}$ was predicted from penetration force as function of the ground water level, stocking density and residence time at paddock using (Holshof *et al*., 1994). The HL_{dead} was empirically estimated from the DM accumulation and aging of rejected herbage.

The HDMI is predicted as the ratio between feed intake capacity (FIC) and satiety value (SV) of the feeds included in the diet (Zom *et al*., submitted). The FIC is a function of the cow characteristics. The SV is a function of feed DM, crude fibre, CP, and digestible OM concentration. The effect of EHM on HDMI is curvilinear. When EHM is high, HDMI is restricted by the SV of the herbage and supplemental feeding SV_{supp} and FIC. EHM declines when a paddock is grazed down, thereby reducing HDMI. To incorporate the limiting effect of EHM on HDMI we followed the approach of Zemmelink (1980) by adjusting HDMI with fEHM: $HDMI = [FIC - (DM_{supp} \times SV_{supp})]/SV_{herbage} \times fEHM$.

Example of model simulation

Table 2 presents a selection of the results of some model simulations. This example was limited to estimate the effects of topping, paddock size, residence time and supplemental maize silage. (N.B. the internet application provides much more detailed information in 12-hour steps). The model gives a quick insight in effects of two or more managerial changes employed at the same time with inputs that are easy to obtain at a farm scale. The model simulations were in line with observations in farm practice. GrazeVision provides a framework for further development of a grazing management support system.

Table 2. Simulation of the effects of topping after previous grazing, paddock size, residence time at the paddock and supplementation with maize silage. The herd size 50 cows (13 primiparous, 10 second parity, 27 mature cows on average 150 days in milk), supplemented with 4.5 kg concentrate day^{-1}, initial herbage mass 1300 kg DM > 5 cm, starting date September 15

Inputs: Management interventions inputs				Outputs: Predicted effects on grazing performance				
Topping	paddock size ha	residence time days	maize silage kg DM day^{-1}	RHM > 5 cm kg DM ha^{-1}	Herbage utilization %	HDMI kg DM day^{-1}	TDMI kg DM day^{-1}	Milk yield kg day^{-1}
Yes	2.3	4.0	0	298	80	13.3	17.5	26.2
Yes	2.3	3.0	0	533	63	13.6	17.8	26.4
Yes	2.3	4.0	6	750	49	8.1	18.3	27.1
Yes	2.3	7.5	6	297	82	7.8	18.0	26.8
Yes	1.2	4.0	6	374	75	6.5	16.7	25.7
No	2.3	4.0	0	355	76	12.6	16.8	25.6
No	2.3	3.0	0	560	61	11.4	17.3	26.1
No	2.3	4.0	6	763	48	7.9	18.1	26.8
No	2.3	5.5	6	575	62	7.7	17.9	26.7
No	1.7	4.0	6	601	59	7.2	17.4	26.3

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Lucerne and white clover for long term grassland: impact on sward and yield stability

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Abstract

Different swards consisting of *Medicago sativa* L., *Trifolium repens* L., *Lolium perenne* L. and *Poa pratensis* L. were investigated from 1999 to 2010 under grazing management on a gleyic loamy Cambisol. The persistence of legumes in the legume-grass mixtures fluctuated both from year to year and within individual growth periods, and was very strongly influenced by environmental stress. Thus, yields of legumes affected the composition and total yield of swards. The reduction of sown grass-species yield and enhancement of forbs was obtained in grassland over long-term cultivation. Despite long-term use of grazing swards, the yield of legumes in the swards consisting of lucerne accounted for nearly half and even more of the total sward yield. The white clover-lucerne-grass sward out-yielded white clover-grass sward. A positive effect of lucerne on yield stability between years and its more even distribution over the grazing season was obtained.

Keywords: botanical composition, grass, grazing, legumes, yield

Introduction

In grasslands, mixed swards have mainly used grasses with white clover; however, fluctuating and unpredictable yields have frequently been reported (Frame *et al*., 1998; Rochon *et al*., 2004). Higher diversity in a sward may be an additional advantage in seeking to improve sward resistance to biotic and abiotic stresses and to increase complementarity among species (Huyghe *et al*., 2008; Frankow-Lindberg *et al*., 2009). Multi-species swards can secure better persistence and more stable productivity. Plant species diversity, their relative abundance and at the same time stability of yields, are highly dependent on soil nutrient status, management intensity and natural environmental stresses (Sulte *et al*., 2003; Hopkins and Holz, 2006). However, herbage production varies within species and is influenced more by species composition than by mixture complexity. Species selection and new varieties in mixtures for sown grasslands are very important (Deak *et al*., 2007; Huyghe *et al*., 2008; Sanderson, 2010). The objective of our experiment was to assess the balance between legumes and grasses, sustainability forage production over several years in different swards.

Materials and methods

During 1998-2010, a randomized block design field trial of pasture utilization was carried out on a loamy *Endocalcari-Epihypogleyic Cambisol* near Dotnuva, Lithuania (55°24‘N, 23°50‘E). The pasture was re-established in the spring of 1998 with an oat/vetch cover crop for green forage. Soil pH varied from 6.5 to 7.0, humus content was 2.5-3.2%, available P 50-80 mg kg^{-1} and K 100-150 mg kg^{-1}. The treatments in four replicates involved swards consisting of white clover (*Trifolium repens* L.) cv. Sūduviai, lucerne (*Medicago sativa* L.) cv. Birutė, perennial ryegrass (*Lolium perenne* L.) cv. Sodrė, meadow grass (*Poa pratensis* L.) cv. Lanka and *Festulolium* hybrid cv. Punia. Different mixtures were sown: white clover and perennial ryegrass (*T.r./L.p.*); white clover, perennial ryegrass and meadow grass (*T.r./L.p./P.p.*); lucerne, perennial ryegrass and meadow grass (*M.s./L.p./P.p.*); white clover, lucerne and perennial ryegrass (*T.r./M.s./L.p.*); perennial ryegrass without nitrogen (N) fertilization (*L.p.*/N0); perennial ryegrass fertilized with 240 kg N ha^{-1} yr^{-1} (*L.p.*/N240); white clover and *Festulolium* hybrid (*T.r./F.* hybrid). Legume/grass proportion in the seeding mixtures was 40:60 (swards without lucerne) or 60:40 (swards containing lucerne). Each spring, 26 kg P ha^{-1} and 50 kg K ha^{-1} were applied to all swards. In spring and after the first, second and third grazing, fertilizer N was applied at a rate of 60 kg N ha^{-1} for grass swards. The grazing season lasted from the beginning of May until middle of October. The interval between two consecutive grazings lasted 25-40 days, with four grazings per season. Weather conditions differed to a great extent: grazing periods 2000, 2001, 2004 and 2005 were normal; 1999, 2007 and 2010 were wet; 2003 and 2009 dry, and 2002, 2006 and 2008 were very dry and warm. Before grazing, half of each plot was cut for the dry matter (DM) yield determination. The DM yield data were statistically processed using analysis of variance.

Results and discussion

The pasture maintains sufficiently high content of legumes and rather stable yield on average for a few years; however, DM yield of all swards decreased markedly between first and last years of use, with significant differences between swards from the first year (Figure1).

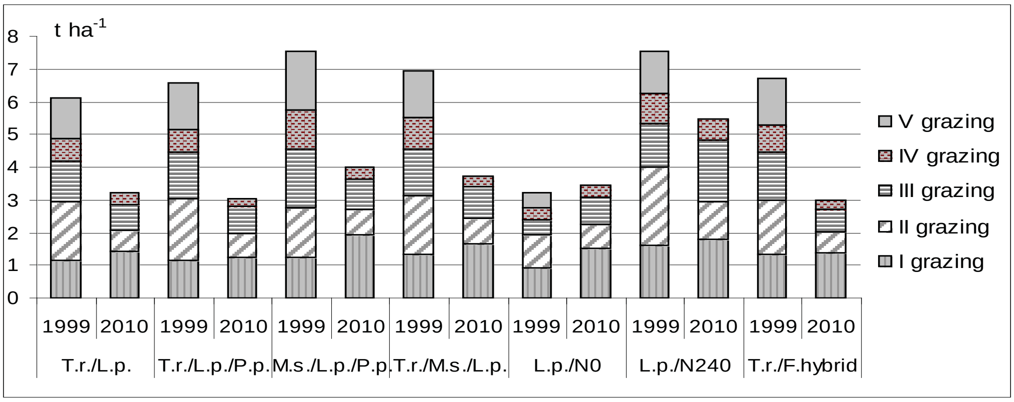

Figure 1. Total dry mater yield of different swards in the 1st and 12th years of use, LSD = 0.779 for 1999 and LSD = 0.295 for 2010 (LSD - least significant difference at P < 0.05)

The findings from the pasture mixtures experiment showed that sward yield stability and quality of lucerne can be maintained for about eight years (Kadziuliene and Kadziulis, 2007). However, lucerne remained the main herb in the mixture until twelve years of sward use. The DM yield of the lucerne, perennial ryegrass and smooth stalked meadow grass mixture was the highest, except swards fertilized with nitrogen (Figure 1). In years most conducive to the growth of perennial grasses the yield of this mixture was as high as 8-9 t, and average long-term yield was about 6.5 t DM ha^{-1}. The mixture of white clover, lucerne and perennial

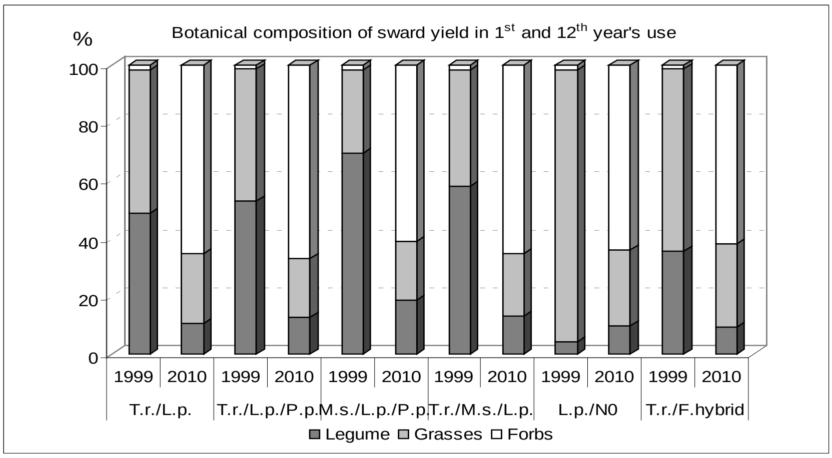

Figure 2. Botanical composition of different swards in the 1st and 12th years of use

ryegrass was only slightly less productive. Marked changes occurred in sward species and botanical groups' composition during a decade of sward use. In the first year, sown grasses prevailed in the mentioned swards and only traces of forbs were found. In the 10th year, sown grasses were still prevalent and accounted for 55-65%, and in the 12th year forbs accounted for 60-70% (Figure 2). Even in the swards in which lucerne still accounted for nearly 20%, the proportion of sown grasses was insufficient for the sward to be productive.
Sward yield was positively influenced by legumes proportion during experiment, although not to an important extent (Figure 3). Proportion of legume differed between years; in particular the proportion of white clover was very low in dry years. Swards inter-annual coefficients of variation were comparatively low in all swards.

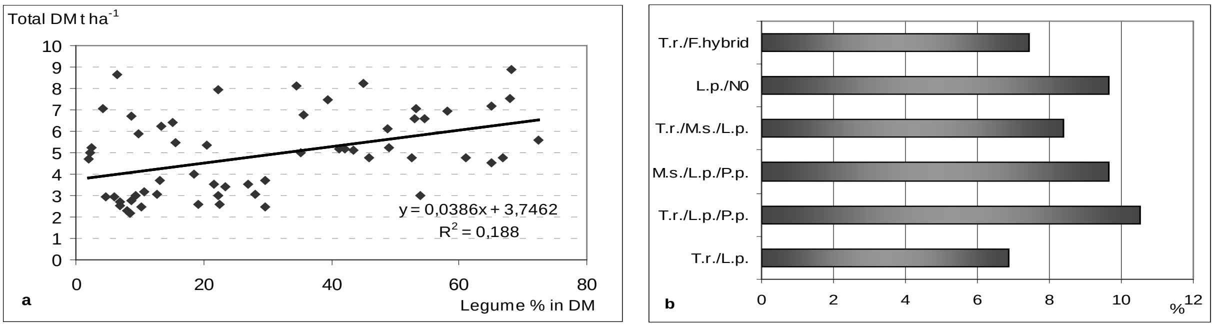

Figure 3. Relationship of annual dry matter yield and proportion of legumes in swards (a), and swards inter-annual coefficient of variation (b).

Conclusions

Yield differences were marked and were highly dependent on sward species and seasonal weather conditions. The legume proportions of different swards fluctuated between years and within individual growth periods; however, legumes enabled a substantial expansion of annual yield. Lucerne-based swards had a higher total and legume yield and showed a positive effect on yield stability over each grazing season. Dominance of forbs after more than ten years of use of swards use shows the necessity of re-establishing grassland.

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Influence of harvesting techniques on forage production in alpine regions

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Abstract

During the whole working process of forage harvesting, different options contribute to keep forage quality at a high level. Different ground adaptation techniques by front mowers were measured. The bearing pressure of front mowers ranges between 50 and 180 kg m^{-1} of working width and was influencing the ash content (with active frame compared to classical frame 71.3 to 81.0 g ash kg DM). The variability of mowing height differs between 25% (mower with active frame) and 41% (mower with classical frame) on an uneven ground. Conditioning of forage shortens the field drying process by 1-4 hours and reduces the fermentation losses. Therefore, harvesting of artificial drying hay needs only one day. Tedding intensity and tedding frequency may also impact on forage quality (crop losses increase from 7.5 to 17% when the tedding frequency is enhanced from 3 to 6 times by field hay drying).

Keywords: harvesting techniques, mower, tedder, permanent grassland, forage losses

Introduction

Agriculture in alpine regions requires high forage quality. Beside a well-balanced plant stand and the right moment of harvest, forage quality is also influenced by harvesting and conservation techniques. In this paper, forage harvesting is analysed from a technical point of view and relevant parameters are quantified on the basis of several individual experiments.

Materials and methods

In a first trial (1999), two fixed mowers on the rear of a tractor, with and without tine conditioner, were deployed on a temporary meadow (Pöllinger *et al.*, 2001). The following adjustments were made: working width 2.45 m, number of revs 540 U min^{-1}, rotation speed at the conditioner 720 U min^{-1}, and driving speed 12 km h^{-1}. After the mowing the forage was variably turned by means of a rotary tedder (0-6 times). The silage was brought in on the same morning as the forage was cut; the artificial dried hay was brought in after midday and the field hay on the evening of the following day.
The field losses were measured after swathing. For this purpose, 10 plots of 1 m² each spread on the field were treated by means of a special vacuum cleaner. Ash content and dry matter weight of the collected material were determined. The drying process on the field was characterised by the measurement of the dry matter content of the forage at different points of time. The data were statistically evaluated as a regression analysis by the program LSMLMW PC-1 Version after Model 1.
In a second trial (in 2005), two front mowers with 3.0 m working width each were deployed with different ground adaptation techniques (Paar *et al.*, 2006). The ground pressure was set at 160 kg m^{-1} (mower with 'active' frame - Alpha Motion) and 340 kg m^{-1} (mower with 'classic' frame). The experiment took place on a permanent meadow with uneven ground surface. On 10 plots of 1 m² each, the cutting height was measured five times in the direction of driving and five times transverse to this direction. Forage samples were taken in order to determine the ash content.

In the third trial (in 2010), a rake with single rotor and large working width (diameter 3.60 m) was compared with a twin rotor rake with side swath (diameter 3.30 m). The field losses after swathing were measured at different driving speeds (8 to 12 km h^{-1}) on flat and uneven areas.

Results and discussion

First experiment. Ensiled forage, which was cut by the conditioner and tedded twice, could be harvested with a DM-content of 32% one hour earlier than the forage which was cut without conditioner. Artificial dried hay was brought in with a DM-content of 60%. This target value was obtained three hours earlier with the conditioner than without it. In terms of leaf shatter losses, clear differences were shown between the harvesting procedures (Table 1). The influence of the rotary tedder can best be reproduced with the harvesting system No. 3 'field hay'. Especially the variant No. 43 'without mowing conditioner and tedding 6 times' produced 394 kg DM ha^{-1} (13.7%) leaf shatter loss and differed significantly from the variant No. 13 'with mowing conditioner and tedding 3 times' with only 216 kg DM ha^{-1} (7.5%).

Table 1. Leaf shatter losses by using different mowing systems (with or without mower conditioning) and conservation systems (silage, artificial dried hay, field dried hay) on a temporary grassland (DM-yield 2870 kg ha^{-1}, 1999)

	working-intensity (WI)				harvesting-system (HS)			WI×HS[1)]							*P*-value		
field losses	1	2	3	4	1	2	3	11	12	13	41	42	43	S_e	WI	HS	WI×HS
%	5.9[a]	7.1[a]	6.7[a]	7.7[a]	2.5[c]	7.3[b]	10.8[a]	2.3[c]	7.9[b]	7.5[b]	2.9[c]	6.4[b]	13.7[a]	2.1	0.084	0.000	0.004
kg DM ha^{-1}	169	204	193	221	71[c]	210[b]	309[a]	67	225	216	84	185	394	60	0.085	0.000	0.004

Working-Intensity (WI): 1 = with mowing conditioner, less tedding, 2 = with mowing conditioner, normal tedding, 3 = without mowing conditioner, normal tedding, 4 = without mowing conditioner, high tedding intensity
Harvesting-System: 1 = silage, 2 = artificial hay drying, 3 = field-dried hay
[1)] The Interactions 21 to 33 are not included, because of less place and the focus to the tedding intensity

The results from Experiment 2, comparing two models of front mowers, are presented in Table 2. The coefficient of variation is the criterion of evaluation for the consistency of the cutting height. The front-mounted mower with classic headstock obtained a coefficient of variation of 41%. The front-mounted mower with 'active' supported frame achieved a coefficient of variation of 25%. The ash values of 81.0 and 71.3 g kg DM^{-1} indicate very good harvesting conditions, but they also show a small advantage for the mower with active frame.

Table 2. Mean mowing height, coefficient of variation and ash content in the forage with classically fixed front mower in comparison to a front mower with special soil adaption of the mower bar, permanent meadow, 1[st] cut at the AREC Raumberg-Gumpenstein, 2006.

Parameter	Unit	Mower with Classical frame	Mower with Active frame	Number of replications
Cutting height (mean)	cm	6.8	6.9	90
Coefficient of variation	%	41	25	90
Ash content	g/kg DM	81.0	71.3	4

In Experiment 3, the comparison of both rotor rakes was done with measurement of losses (Table 3). The rake with a single rotor caused higher losses (46.8 g DM m^{-2}) compared to the twin-rotor rake with side swath (32.5 g DM m^{-2}). The topography conditions showed a clear influence of the raking losses, as expected: 14.3 (flat land) to 64.9 g (uneven land) DM m^{-2}.

Table 3. Raking loss in g DM m^{-2} from rakes with single rotor and twin rotor rake with side swath, permanent meadow, at the 1st and 4th cut 2010, with different driving speed and site

Parameters		mean value	number = n	*P*-value
System	Rake with single rotor	46.8	36	0.0039
	Twin rotor rake with side swath	32.5	35	
Surface	flat land	14.3	48	0.0000
	uneven land	64.9	23	
Speed	8 km h^{-1}	42.5	39	0.2106
	12 km h^{-1}	36.8	32	
Cut	1st cut	45.0	23	0.0277
	4th cut	34.3	48	

R^2 = 69.2; Standarderror = 18.6 (regression analysis, Harvey, 1987)

Conclusion

Harvesting techniques have influence on forage quality. A conditioner can, depending on the harvesting procedure (silage, hay), shorten the drying process by 1-4 hours and hence can reduce the fermentation losses. Under difficult topographic conditions (uneven ground surface), a meliorated management of the mower bar can reduce the danger of contamination. With a good management of the tedding, it is possible to decrease the leaf shatter losses by 5 to 10%. A low PTO shaft speed is clearly important in reducing the leaf shatter losses when the DM-content of the forage is higher than 60%.
By swathing an impact of surface could be found, but no impact of driving speed. The limits of working width, which can be achieved by means of a rotor, are already being obtained on areas with permanent meadows. Swathers with a rotor diameter of more than 3.30 m cannot adequately adjust themselves to the ground surface in conditions with difficult topography.

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Effects of folding on nitrogen mineralization and the instantaneous concentration of mineral forms of nitrogen in grassland soil

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Abstract

Research was conducted in central Slovakia at Priechod (altitude 577 m) and Šajbianska Bukovina (altitude 1,162 m) during the 2006-2009 growing seasons. Effects of folding with sheep and heifers on the total N-mineralization (TMN), nitrification rate (NIT) and instantaneous concentration of NH_4^+ -N and NO_3^- -N were studied in semi-natural grassland soil. During the year of folding and in the following two years, the stimulation of TMN and NIT was evident at both research sites. Consequently, due to very high input of excreta and notable damage to original sward induced by animals, excessive concentration of mineral N forms were recorded at both the sites, mostly as nitrates at Priechod and as ammonia at Šajbianska Bukovina. A residual stimulatory influence of folding on TMN and NIT also continued in the year 2009. High concentration of mineral N forms, as well as intensive TMN and NIT, were also found at the older folding areas of the Priechod site.

Keywords: nitrate N content, ammonia N content, nitrification rate

Introduction

Provided that appropriate management practices are respected, folding with livestock on grassland may improve biological and chemical properties of soil as well as increase herbage production and quality. Conversely, excessive folding may result in intensive pollution of small areas, mainly by mineral forms of nitrogen (N) (Ondrášek *et al.*, 2000). Moreover, the original phytocoenoses on eutrophic soils are transformed into ruderal grassland, producing poor forage and having very low landscape value (Opitz von Boberfeld, 1994). The objective of this research was to assess, under farm conditions, the impact of folding with sheep and heifers on the intensity and course of N mineralization and also on the concentration of mineral N forms in grassland soil.

Materials and methods

The research was carried out on semi-natural grassland in 2006-2009 on sites chosen from the old and fresh areas on which sheep and heifers were folded in practice, under farm conditions. The research sites were at Priechod and Šajbianska Bukovina (central Slovakia). At Priechod (48°47‘N; 19°13‘E; altitude 577 m asl) the soil was a cambisol (initial soil $pH_{(nKCl)}$ of 4.4; C_{ox} of 44.0 g kg^{-1} and total N 4.1g kg^{-1}), and at Šajbianska Bukovina (48°41‘N; 19°26‘E; altitude 1162 m asl) the soil was a cambisol (initial soil $pH_{(nKCl)}$ 4.0; C_{ox} of 74.5 g kg^{-1} and N_t of 8.3 g kg^{-1}). The following treatments were investigated at Priechod: PR 1 - non-folded sward (control; southern orientation); PR 2 - folded in August 2005 (southern orientation); PR 3 - folded in autumn 2004 (southern orientation); PR 4 - folded in May 2006 (northern orientation); PR 5 - folded in autumn 2006 (northern orientation) and PR 6 - non-folded sward (control; northern orientation). At the Šajbianska Bukovina site the following treatments were studied: BK 1 - non-folded sward (control); BK 2 - folded in July 2006; BK 3 - folded in October

2006 (BK 2+BK 3: with 200 sheep, the fold area 8×12 m); BK 4 - folded in July 2006; BK 5 - folded in October 2006 (BK 4+BK 5: with 62 heifers, the fold area 12×12 m). Soil samples were taken (0-10 cm, 10-20 cm, 20-30 cm depth) from both sites 5 times in 2006 (May, June, July, August, October), 4 times in 2007-2008 (April, June, August, October) and three times in 2009 (April, June, August). The fresh soil samples were passed through 2 mm sieve, then analysed to determine these parameters:
a) instantaneous concentration of NH_4^+-N and NO_3^--N (colorimetry by SKALAR); b) the intensity of total mineralization of nitrogen (TMN) and the rate of nitrification (NIT) after 14-day aerobic incubation at 25°C (0-10 cm layer). Data were analysed by multiple analysis of diffusion using the Statgraphics program. The significance of differences between the mean values of the research parameters was determined by LSD test ($P = 0.05$).

Results and discussion

Throughout the research period, TMN and NIT were notably stimulated in the soil under folded sward, and the values of TMN and NIT were nearly identical at the Priechod site. This indicates that nearly all the N coming from ammonification was oxidised to nitrate N (NO_3-N), despite the low pH. Therefore, only the TMN data are assessed for this site. TMN was between 1.7 to 2.9 times higher at the old folding areas PR2 and PR3 than at PR1 (control) during 2006-2009 (Table 1). At the fresh-folded sites (PR4 and PR5), TMN was 1.6 to 3.8 higher than at the control (PR6) during the research period. The increased TMN and NIT resulted in high NO_3-N concentration in soil (Table 2). In 2006, it was 272.3 mg N ha^{-1} at PR5 site in the 5th soil sampling (0-10 mm; 25 Oct. 2006) immediately after the folding. At PR4 site, it was 66.8 mg N ha^{-1} in the 2nd sampling (0-10 mm; 9 June 2006); and in the 5th sampling (25 Oct. 2006) it was 42.3 (0-100 mm) and 39.2 (200-300 mm) mg N ha^{-1}, respectively. High NO_3-N concentration was recorded at the folded areas also during the following two research years (Table 2). At Šajbianska Bukovina, the fresh folding also resulted in notably increased TMN (Table 2). In comparison with the control (BK1), the intensity was 2.9 (BK5) to 3.5 times (BK2) higher in 2007, and as much as 3.9 (BK4) to 6.5 times (BK2) higher in 2008. In the year of folding (2006) and in 2007 especially, the stimulated TMN and a mass of excreta caused accumulation of mineral N forms in soil (Table 2). In the 1st sampling of 2007 (24 April), there was 237.6 (0-100 mm) and 123.8 (100-200 mm) mg N ha^{-1} at BK3, and 103.1 (0-100 mm) and 134.2 (100-200 mm) mg N ha^{-1} at BK5, nearly all as NH_4-N. The dominance of NH_4-N resulted from the higher acidity of soil than at the Priechod site, which is even less suitable for development of nitrification bacteria, as shown by the diverse data in Table 1.
On average, the highest TMN was found at BK2 and the highest concentration of mineral N forms was recorded at BK3, which indicates a higher stimulating effect of sheep faeces on N mineralisation. The research results showed a notable influence of folding on TMN and on the presence of mineral N forms in soil. This confirmed the conclusions of our earlier research performed under practical farm conditions (Ondrášek *et al.*, 2000) and also in research experiments (Čunderlíková *et al.*, 2002).

Conclusions

As a general rule, in the year of folding application and in the following year, mineral N forms accumulated in soil, mainly as NO_3-N, except for the very acid soil at Šajbianska Bukovina, where NH_4-N prevailed. This resulted from high input of animal excreta and massive damage of the original sward as well as from marked stimulation of N mineralization and nitrification. Such a situation can last a long time, in relation to the livestock stocking rate at the folded site. The sites at which excessive heavy folding is followed by inappropriate sward utilisation can retain increased ability to mineralize nitrogen. Consequently, and as related to hydro-thermic conditions, such areas might be potential sources of contamination by NO_3^--N and of environmental pollution.

Table 1. Mean intensity of total mineralization of nitrogen (TMN; mg NH_4^+-N kg^{-1} 14 days $^{-1}$) and mean rate of nitrification (NIT; mg NO_3^--N kg^{-1} 14 days^{-1}).

		Years							
		2006		2007		2008		2009	
Sites	Treatments	TMN	NIT	TMN	NIT	TMN	NIT	TMN	NIT
Priechod	PR1	13.6^{a}	14.5^{a}	9.1^{a}	7.5^{a}	8.2^{a}	9.1^{a}	11.9^{a}	11.2^{a}
	PR2	25.4^{ab}	25.8^{ab}	16.4^{abc}	13.4^{abc}	18.7^{a}	19.5^{a}	20.7^{bc}	20.7^{ab}
	PR3	37.3^{ab}	35.5^{ab}	21.7^{c}	21.7^{c}	19.2^{a}	19.4^{a}	35.0^{d}	35.6^{c}
	PR4	46^{b}	47.0^{b}	19.8^{c}	19.9^{bc}	20.7^{a}	21.2^{a}	19.1^{ab}	19.7^{a}
	PR5	29.3^{ab}	128.0^{c}	17.9^{bc}	15.2^{abc}	36.9^{b}	37.3^{b}	29.6^{cd}	30.4^{bc}
	PR6	-	-	11.4^{ab}	11.3^{ab}	9.7^{a}	11.9^{a}	13.5^{ab}	13.7^{a}
Šajbianska	BK1	9.7^{a}	4.6^{a}	11.0^{a}	0.1^{a}	4.9^{a}	0.0^{a}	9.4^{a}	0.9^{a}
Bukovina	BK2	25.3^{b}	37.4^{b}	38.1^{b}	23.4^{c}	31.8^{c}	32.3^{b}	22.4^{b}	10.5^{a}
	BK3	9.0^{a}	9.8^{a}	27.2^{ab}	19.6^{bc}	18.0^{ab}	15.1^{a}	20.3^{ab}	9.4^{a}
	BK4	12.7^{a}	10.0^{a}	14.8^{a}	5.8^{ab}	19.3^{ab}	14.5^{a}	9.8^{a}	1.6^{a}
	BK5	16.2^{ab}	13.0^{a}	31.9^{b}	31.4^{c}	14.6^{a}	8.3^{a}	14.4^{ab}	5.0^{a}

Mean values not sharing a common letter are significantly different between treatments for each year and site (LSD test; P = 0.05).

Table 2. Means of instantaneous concentration of NH_4^+-N and NO_3^--N and their sum (∑) in grassland soil as mg kg^{-1} ($\sum \bar{x}$ of sampled soil layers: 0-10 cm, 10-20 cm, 20-30 cm).

		Years											
		2006			2007			2008			2009		
Sites	Treatments	NH_4^+-N	NO_3^--N	∑	NH_4^+-N	NO_3^--N	∑	NH_4^+-N	NO_3^--N	∑	NH_4^+-N	NO_3^--N	∑
Priechod		1.6	2.9	4.6^{a}	1.1	4.0	5.2^{a}	2.7	3.6	6.3^{a}	2.5	1.8	4.3a
	PR2	2.1	15.9	18.0^{b}	1.3	8.6	10.0^{b}	2.8	9.6	12.5^{b}	3.2	4.9	8.1^{bc}
	PR3	1.3	18.5	19.7^{b}	0.7	17.2	17.8^{c}	1.0	20.1	21.2^{c}	1.8	12.4	14.2^{de}
	PR4	2.7	26.4	29.2^{c}	0.9	17.7	18.6^{c}	1.5	16.4	17.9^{bc}	2.5	8.7	11.2^{cd}
	PR5	16.4	112.1	128.4^{d}	1.6	18.6	20.2^{c}	1.8	19.6	21.4^{c}	2.0	12.8	14.9^{e}
	PR6	-	-	-	1.9	6.3	8.2^{ab}	2.9	4.6	7.5^{a}	4.3	1.9	6.2^{ab}
Šajbianska	BK1	5.4	0.6	6.0^{a}	3.9	0.6	4.5^{a}	4.1	0.7	4.8^{a}	5.1	0.2	5.3^{a}
Bukovina	BK2	22.7	6.9	29.7^{b}	11.0	7.0	18.0^{ab}	6.1	6.3	12.4^{b}	6.3	4.1	10.5^{c}
	BK3	36.9	0.5	37.4^{b}	48.5	9.6	58.1^{c}	6.6	5.3	12.0^{b}	6.4	2.9	9.3^{bc}
	BK4	15.1	1.0	16.2^{ab}	5.0	8.2	13.2^{ab}	4.4	6.5	10.9^{b}	4.1	0.5	4.5^{a}
	BK5	7.6	0.5	8.1^{ab}	28.6	4.5	33.1^{b}	8.5	2.2	10.7^{b}	5.4	1.1	6.5^{abc}

Mean values not sharing a common letter are significantly different (LSD test; P = 0.05).

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Soil properties, yield and quality of permanent grasslands in the Vojvodina Province

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Abstract

During the period of 2006-2009, thirteen permanent grassland sites were selected in the Banat region of the Vojvodina province. In these selected sites, soil analysis, dry matter yield and quality were recorded. Regarding the soil properties, pH values varied from slightly acidic to slightly alkaline. All the locations showed predominantly high contents of nitrogen and potassium, while the phosphorus content varied from high to low. All the studied permanent grassland locations varied in yield and quality and therefore in their usability with regard to animal nutrition. The selected permanent grassland sites can be improved by the implementation of appropriate agronomy practices. The only natural grasslands in the Vojvodina Province that can be successfully improved are those that grow on soils in the early stages of degradation. Among the most effective agricultural practices for grassland restoration and maintenance timely cutting, harrowing and fertilization have to be considered.

Keywords: permanent grassland, quality, soil properties, yield

Introduction

In the Vojvodina province, permanent grasslands cover approximately 200,000 ha, of which two thirds are pastures. Different soil types affect forage yield and quality of the permanent grasslands. Allomorphic soil types are common throughout the grasslands (at about 120,000 ha). They are concentrated in the region of Banat (80%), where limeless solonetz is the predominant soil type which is not cultivated due to low content of organic matter. These areas, which are overgrown with natural vegetation, are used by local farmers mostly for cattle grazing and less frequently for mowing (Erić *et al*., 2000). Generally, the climate in the Vojvodina province, in terms of yearly rainfall and its distribution, is not suitable for high forage production. The beginning of the vegetation period (April) is characterised by a substantial increase in precipitation and a high but gradual increase in temperature. After reaching maximum levels in May and June, rainfall drops considerably. In contrast to precipitation, the temperature, that gradually increases at the beginning of the vegetation period, remains steady and high in the middle of the vegetation period, and, only after a considerable dry spell, starts to reduce significantly in October. Because of the above precipitation and temperature patterns, the studied area passes through a semi-arid period from mid-July to late September, which negatively affects the present vegetation cover. Therefore, forage yields obtained from grasslands are quite low, ranging from 0.5 (pastures) to 2 Mg ha^{-1} of dry matter (meadows) (Ćupina *et al*., 2005). On average, meadows produce one to two cuts per year. Regardless of grassland location, i.e., botanical composition and forage yield and quality, no cultivation practices are conducted. Even under rain-fed conditions, appropriate technological practices ensure significant increases in herbage yield and quality. The objective of this study was to research soil properties, dry matter yield and quality on thirteen sites of permanent grassland which were selected in the Banat region of the Vojvodina province, and to assess possibility for their utilisation in animal nutrition.

Materials and methods

During the period of 2006-2009, thirteen permanent grassland sites were selected in the Banat region of the Vojvodina province (Aradac, Titel, Melenci 1, Melenci 2, Deliblato, Bela Crkva, Kumane, Novo Miloševo, Novi Bečej, Čoka, Jaša Tomić, Boka and Sajan). In these selected sites, basic soil properties, dry matter yield (Mg ha^{-1}) and chemical composition were recorded. The plot size for measuring dry matter yield was 2 m^2. The dry matter yield was obtained by drying samples (1 kg each) to a constant mass at 70°C. The following quality parameters were assessed: crude protein (CP), crude fibre (CF), crude fat (CF), crude ash (CA), nitrogen, phosphorus and potassium. Nitrogen-free extract matter (NFEM) content was calculated. Samples for dry matter yield and chemical analyses were taken from the first cut at the end of May. Dry matter yield and quality were determinated on the basis on three replications, while the soil properties present average value of several samples.

Results and discussion

Selected sites differ regarding soil properties and grassland yield and quality.

Table 1. Soil properties of permanent grasslands on selected sites

	pH-value		$CaCO_3$	Humus	Total N	AL-P_2O_5	AL-K_2O
Locality	KCl	H_2O	(%)	(%)	(%)	mg/100 g	mg/100 g
Aradac	4.5	6.1	0.28	4.70	0.32	7.50	26.70
Titel	7.3	8.2	5.14	4.22	0.27	61.00	25.50
Melenci 1	6.4	7.2	0.51	4.90	0.30	6.90	37.40
Melenci 2	8.1	9.1	10.01	2.06	0.16	5.20	30.50
Deliblato	7.2	8.1	5.11	4.66	0.28	83.00	61.20
Bela Crkva	7.2	8.0	8.94	5.00	0.31	85.00	20.20
Kumane	5.9	4.6	0.09	6.05	0.41	7.30	87.60
N. Miloševo	4.5	6.2	0.15	4.26	0.29	7.80	30.00
Novi Bečej	5.0	5.7	0.57	5.18	0.34	2.24	25.12
Čoka	5.6	6.6	0.85	5.01	0.33	1.43	22.92
Jaša Tomić	5.4	5.9	0.71	5.53	0.36	2.73	34.66
Boka	5.8	6.7	0.71	5.46	0.36	6.37	64.71
Sajan	4.7	6.0	0.20	4.10	0.30	6.70	24.80
Average	6.0	6.8	2.56	4.70	0.31	21.78	37.79

Soil properties

In most sites such as Aradac, Kumane, J. Tomić, Čoka, Boka and Sajan, the presence of species such as Statice gmelini Willd., an endeme of the Pannonian Plain, indicated that the soil was saline, differing in wetness during growing season, with high salt concentration, belonging to the solonetz type. Characteristics of this soil type are the leaching of salts and a weakly expressed accumulating B horizon. This soil type is flooded for a short period of time during the spring and it quickly dries afterwards, forming a rock-solid pavement, thus, very often not favourable for animal grazing. Studied natural pastures are, in the ecological sense, part of the halobiome of the Pannonian (Knežević *et al.*, 2008).

With regard to the soil chemical composition, pH values varied from acidic, slightly acidic to slightly alkaline. Average humus content was quite high (4.70%), which could be explained by long-term average organic matter accumulation. All the sites displayed predominantly high contents of nitrogen and potassium, while the phosphorus content varied from high to low (Table 1).

Table 2. Yield and quality of permanent grasslands on selected sites

Locality	Yield DM ($Mg\ ha^{-1}$)	Forage quality ($g\ kg^{-1}$ of DM) CP	CC	CF	CA	NFEM	N	P_2O_5	K_2O
Aradac	1.55	82.8	270.0	15.6	127.0	458.9	14.4	2.6	15.5
Titel	1.91	93.9	200.5	14.9	110.6	432.0	17.9	2.9	12.3
Melenci 1	1.85	97.2	263.0	13.9	118.9	480.9	17.0	3.0	18.0
Melenci 2	1.63	93.3	258.1	18.9	116.7	473.5	18.9	3.5	16.5
Deliblato	2.35	102.3	248.0	16.8	129.0	455.6	16.7	5.6	16.7
Bela Crkva	2.05	85.0	240.7	16.0	125.3	468.7	16.7	3.8	17.8
Kumane	0.95	72.1	250.0	16.5	130.0	470.1	15.9	3.5	18.1
N. Miloševo	0.90	72.0	243.0	15.9	120.0	462.3	16.5	3.9	17.6
Novi Bečej	1.56	82.3	269.0	16.4	126.5	456.2	14.5	2.9	15.6
Čoka	1.93	87.6	281.0	16.4	110.8	460.0	17.1	3.5	14.6
Jaša Tomić	2.03	92.6	263.6	14.5	115.6	471.1	16.5	3.4	17.0
Boka	1.56	86.5	279.1	15.6	120.3	465.1	15.9	3.8	18.5
Sajan	1.45	86.5	280.3	16.4	130.8	470.6	17.0	3.6	19.2
Average	1.67	87.2	257.4	16.0	121.7	463.5	16.5	3.5	16.7
$LSD_{0,05}$	0.14	8.5	20.4	2.1	18.1	55.6	3.2	0.6	1.2
CV (%)	5.2	5.8	4.7	8.1	8.9	7.1	11.8	10.5	4.5

Yield and quality

According to the proportion and quality of the species, selected permanent grassland was assessed from low to medium for forage production, i.e. animal grazing. Average DM yield was 1.67 Mg ha^{-1}, and ranged from 0.90 Mg ha^{-1} (N. Miloševo) to 2.35 Mg ha^{-1} (Deliblato), (Table 2) which is in line with long-term average yield. Concerning forage quality, all average values of tested parameters are in accordance with average data for permanent grasslands in the Vojvodina province. Even under poor conditions, applying appropriate agronomy practices ensured significant increases in herbage yield and quality. It is well known that grasslands are responsive to fertilizers, especially nitrogen. Spring harrowing is also an important measure for improving permanent grassland production (Ćupina *et al*., 2005).

Conclusions

With regard to the soil properties, pH values varied from slightly acidic to slightly alkaline. All the locations showed mainly high contents of nitrogen and potassium, while the phosphorus content varied from high to low. All the studied permanent grassland sites varied in yield and quality and therefore their utility in animal nutrition.

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Measuring the loss of dry matter yield effected by Rough-stalked meadow-grass (*Poa trivialis*)

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Abstract

During the last years the proportion of *Poa trivialis* (rough-stalked meadow grass) has increased in grasslands of southern Germany. Besides the impact on forage intake by cattle through its poor acceptance, there is also a strong effect of this weed on the dry matter yield of grassland. To determine the common damage thresholds of *Poa trivialis* used for agricultural advice in Bavaria, Thuringia, Saxony and Baden-Württemberg, autochthonous *Poa trivialis* seed was included in a variety trial of perennial ryegrass (*Lolium perenne* L.) sown in these federal states of Germany in 2008. Depending on the site and the variety of perennial ryegrass, the plots with *Poa trivialis* only reached 50% to 70% of dry matter yield of the ryegrass.

Keywords: dry matter yield, weed, *Poa trivialis*, reseeding

Introduction

Besides the direct damage to grassland swards caused by snow mould and mice infestation, an indirect result of this damage has been increased proportions of *Poa trivialis* (rough-stalked meadow grass) in grasslands in southern Germany. In evaluating intensive grassland it is common to consider *Poa trivialis* as a weed species. This is due to reduced acceptance by cattle and decreased forage intake, which is difficult and expensive to test. It is generally known that *Poa trivialis* also has a strong effect on dry matter yield (Haggar, 1971; Hoving, 2004). Although this aspect is easier to measure, no regional information for Germany could be found in the literature on this topic. The trials presented in this paper should help to reduce this knowledge gap.

Material and methods

In Bavaria, Thuringia, Saxony and Baden-Württemberg, autochthonous seed of rough-stalked meadow grass (*Poa trivialis* L.) was included in a variety trial of perennial ryegrass (*Lolium perenne* L.) sown in 2008. At most sites the *Poa trivialis* was treated like the other objects in the trial. However at some sites (e and f in Figure 1) *Poa trivialis* was established by broadcast-sowing and the perennial ryegrass varieties were sown in rows as is customary. In this way the plots of *Poa trivialis* represent the situation before controlling the weed and the plots with perennial ryegrass represent the situation after controlling the weed and reseeding the area with perennial ryegrass. *Poa trivialis* covered the whole plot (gaps in the plots were quickly re-sown after their occurrence); in contrast, the ryegrass plots were commonly treated like variety trials. Because of its characteristics, *Poa trivialis* was assigned to the early maturity group of perennial ryegrass.

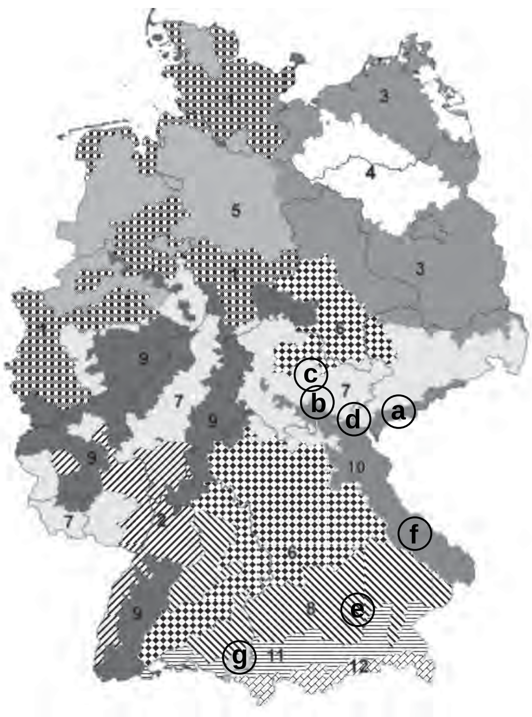

Figure 1. Sites with the implementation of rough-stalked meadow grass in the variety trials of perennial ryegrass in Germany

Results and discussion

Table 1. Comparison of dry mater yield of rough-stalked meadowgrass with varieties of perennial ryegrass (pr) - data from seven sites and two years

		Poa trivialis				*Lolium perenne* (pr) absolut	
Site	Federal state*	Absolute [t ha^{-1}]	percentage of pr max	percentage of pr min	varieties	min. [t ha^{-1}]	max. [t ha^{-1}]
			Dry matter yield (2009) [t ha^{-1}]				
Osterseeon	BY	5.32	42%	52%	39	10.34	12.66
Steinach	BY	7.43	47%	58%	35	12.82	15.81
Oberweißbach	TH	7.69	59%	68%	37	11.32	13.09
Kranichfeld	TH	8.92	57%	70%	40	12.72	15.54
Burkersdorf	TH	5.06	37%	47%	38	10.84	13.83
Forchheim	SN	8.75	65%	84%	37	10.46	13.50
Kißlegg	BW	6.18	55%	85%	37	7.26	11.19
			Dry matter yield (2010) [t ha^{-1}]				
Osterseeon	BY	3.18	24%	27%	39	11.81	13.30
Steinach	BY	8.27	55%	69%	35	11.98	14.90
Oberweißbach	TH	2.80	32%	41%	37	6.90	8.78
Kranichfeld	TH	7.49	54%	69%	40	10.87	13.88
Burkersdorf	TH	5.11	45%	64%	38	8.04	11.42
Forchheim	SN	3.28	37%	46%	37	7.16	8.76
Kißlegg	BW	9.09	73%	91%	37	10.01	12.43

* BW: Baden Württemberg, BY: Bavaria, SN: Sachsony, TH: Thuringia

Poa trivialis reached about half of the yield of perennial ryegrass varieties. Even the poorest-yielding variety of perennial ryegrass (even in the in the most unfavourable combination of site and year) exceeded the dry matter yield *Poa trivialis* by about 10%.

In terms of dry matter yield, the best combination of variety, year and site for *Lolium perenne* outperformed *Poa trivialis* by nearly three times.

Looking at the variation of the dry matter yield of *Poa trivialis*, an effect of rainfall distribution over the year and yield differences between perennial ryegrass and the *Poa trivialis* can be assumed. *Poa trivialis* suffers more from drought than *Lolium perenne* because of its relatively shallow and unstable root system. Because no appropriate statistical method was found to quantify this issue with the climatic data of the sites in the trial, details related to this topic are not shown in this paper.

Conclusions

Following the agricultural advisory service, the threshold value for reseeding grassland is a proportion of approximately 20 to 25% of *Poa trivialis* in the sward. In intensively used grassland with high proportions of *Lolium perenne* a yield loss of about 10-12% dry matter could be assumed at this proportion of *Poa trivialis*.

The costs of reseeding measures on grassland can currently be calculated with 150 to 210 € ha^{-1}. Assuming that reseeding of intensive grassland is required at every 3 years and neglecting the unfavourable feed properties of *Poa trivialis*, the value of the necessary additional yield has to reach 50 to 70 € year^{-1} only.

Related to a market price of about 80 to 100 € per t DM (silage) a higher yield of 0.4 to 0.9 t DM ha^{-1} caused by reseeding would be necessary.

Based on the above-presented estimate of the yield losses the existing threshold value of 20 to 25% of *Poa trivialis* for reseeding grassland is in most cases too high.

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Continuous and long term measurement of ruminal pH in grazing dairy cows by an indwelling and wireless data transmitting unit

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Abstract

Subacute rumen acidosis (SARA) is a significant production disease of dairy cattle. The objective of this study was the continuous and long term measurement of ruminal pH in grazing dairy cows to test the diet effect on rumen pH. Therefore, an indwelling system for monitoring ruminal pH and temperature, already described and evaluated by Gasteiner *et al.* (2009), was applied. Data were sampled in an internal memory chip and could be read out via radio transmission to an external receiver. The indwelling system was orally given to 6 multiparous cows; two of these cows were fitted with a rumen cannula. Ruminal pH was measured every 600 sec over a 40 d period. Daily mean, nadir (deepest pH drop) and time the ruminal pH was below 6.3; 6.0; 5.8 and 5.5 were determined. Statistical analysis was conducted using Statgraphic Plus 5.1. After an adaptation period (barn feeding) and pasture (10 hours per day), the 3 treatments (2 cows/treatment) included: continuous grazing only (G), continuous grazing plus 6 kg/d of hay fed twice daily (GH) and continuous grazing plus 6 kg/d of concentrate offered in two equal rations during milking time (GC). Radio transmission of data (twice daily) was trouble-free. Mean ruminal pH for G, GH and GC was 6.36, 6.56 and 6.01. Mean nadir was 5.95, 6.20and 5.58. pH time under 6.3; 6.,0; 5.8 and 5.5 for G was 583, 91, 26 and 3 min/d, for GH it was 97, 12, 0, 0 min/d and for GC pH time was 1126, 621, 347 and 101 min/d, respectively. Results were significantly influenced by the treatment, and they show that the presented method is a very useful and proper tool for long-term measurement of ruminal pH in non rumen cannulated cows.

Keywords: Rumen acidosis, indwelling pH measuring, wireless data transmission, dairy cattle, pasture

Introduction

Rumen acidosis, mainly occurring as sub-acute rumen acidosis (SARA), is characterized by abnormally low rumen pH. SARA is a widely spread problem in high yielding dairy cows and also in grazing cattle (Kleen *et al*., 2003 Bramley *et al*., 2008).
The negative effects of SARA on animal health in dairy cows are reduced dry-matter intake, decreasing body condition, diarrhoea, ruminitis and inflammation, caudal vena cava syndrome, displacement/ulceration of the abomasum, laminitis and immunosuppressive disorders.
In Irish grazing dairy cows a frequency of 11% for rumen acidosis (pH ≤ 5.5) is indicated and 42% of examined cows were affected marginally (pH ≤ 5.6-5.8) (O'Grady *et al*., 2008)
In Australian dairy cows - predominantly fed on pasture and concentrates - a frequency of 10.2% for SARA (pH 5.74 ± 0.47) was found (Bramley *et al*., 2008).
SARA is difficult to diagnose in the field. Reticuloruminal pH in grazing cattle can be measured in the rumen fluid, which is either collected by a stomach tube or by rumenocentesis. The technique used to collect ruminal fluid affects measured pH values Duffield *et al.* (2004). Rumenocentesis may have negative effects on animals. Continuous monitoring of reticulo-

ruminal pH by using indwelling probes is advantageous due to the possibility of recording diurnal variations (Gasteiner *et al*., 2009).
The aim of the present study was to measure reticuloruminal pH and temperature over a 40-d period in 2 ruminally fistulated and 4 non-fistulated grazing dairy cows to test the diet effect on rumen pH.

Material and methods

For continuous indwelling measurement of reticuloruminal pH, a system was used described by Gasteiner *et al*. (2009). The measured data were read out from the rumen by radio transmission and automatically conveyed to an external receiver. The trial was carried out using 2 ruminally cannulated and 4 non-rumen cannulated dairy cows. The following feeding trials were carried out in April and May 2009. After a 7-d adaptation period, whilst all 6 cows were fed forage (Barn Feeding), animals were given pasture 10 hours/d for 10 days. Then the cows spent 20 hours/d on pasture, only interrupted semi-daily for 2 hours for milking and for additional feeding. Beginning on day 27, three treatments (2 cows per treatment) were conducted: continuous grazing only (G), continuous grazing plus 6 kg/d of concentrate offered in two equal rations during milking time (GC), and continuous grazing plus 6 kg/d of hay fed semi-daily (GH). Statistical analysis was performed by GLM (Statgraphic Plus 5.1).

Results and discussion

During the period of examination of 40 days, all indwelling probes worked and more than 5.800 datasets/cow measured ruminal pH and temperature could be recorded. Radio transmission of data (twice daily during milking) was trouble-free.
Due to the progressive changing of pasture nutrient components, mainly fibre, protein and sugar, no Latin square design was carried out.
No significant differences in ruminal pH could be seen between the two groups while only grazing 20 hours per day (up to day 26). All cows were "off feed" for 6 hours on day 27 (Figure 1), which led to an elevation of the ruminal pH in all cows due to increased salivation. Immediately after feeding, ruminal pH decreased, depending on the total feed intake and on starch and fibre content of the fed ration. It could be seen that additional feeding of concentrate

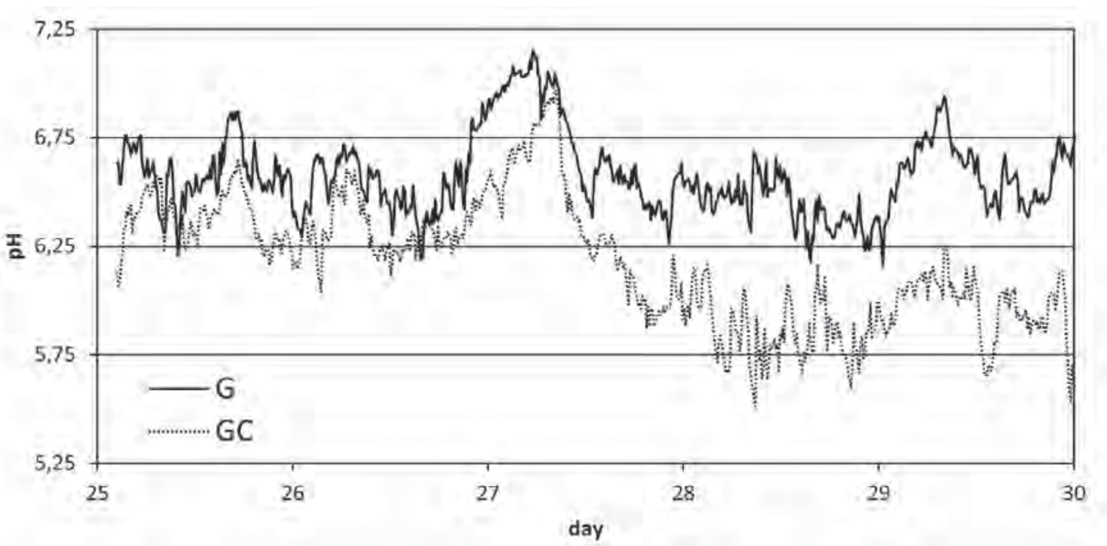

Figure 1. Course of the ruminal pH of 4 grazing cows (20 hours per day) between day 25 and day 30 with the changeover of cows 3 and 4 to additional concentrate feeding (GC) on day 27, whilst cows 1 and 2 receiving still only pasture (20 h/d). Group GH is not shown in this figure.

led to reduced ruminal pH (GC), whilst ruminal pH in G did not change when compared to the course prior the "off feeding" period.

Table 1. Effects of different dietary treatments (G, GH, GC) on ruminal pH, standard deviation, daily minimum (nadir) and time (min$^{-d)}$ pH was below 6.3; 6.0; 5.8 and 5.5

	Mean	Treatments			Statistics		
		G	GH	GC	*P*-value	SE	R²
pH	6.31	6.36[b]	6.56[b]	6.01[a]	0.000	0.181	0.538
Daily minimum	5.91	5.95[b]	6.2[b]	5.58[a]	0.000	0.202	0.576
t< pH 6.3	602	583[c]	97[b]	1126[a]	0.001	323.989	0.591
t< pH 6.0	241	91[b]	12[b]	621[a]	0.000	241.748	0.536
t< pH 5.8	125	26[b]	0[b]	347[a]	0.005	188.833	0.395
t< pH 5.5	35	3[b]	0[b]	101[a]	0.002	51.295	0.444

Mean ruminal pH varied but did not differ significantly between barn feeding, pasture (10 h/d), G and GH. Lowest daily minimum was found on GC, and also mean ruminal pH on GC (6.01) was significantly reduced and time below pH 5.8 was 347 min and time below pH 5.5 was 101 minutes. It can be concluded that the combination of pasture feeding and feeding concentrates (6 kg/day) did induce SARA in the present trial. Pasture feeding only, but also the combination with feeding hay did not cause SARA in this examination.

Conclusions

Ruminal pH was significantly influenced by the treatment. It can be concluded that SARA may occur under practical conditions, when pasture feeding is combined with feeding of concentrates. Continuous grazing (20 hours a day) was more comfortable for the rumen physiology because the rumen ecosystem was adapted better to the ingested ration when compared with grazing for just for 10 hours per day.

The described indwelling pH measuring device is a very helpful tool and can also be used for practical purposes in future.

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Seed colour index for red clover (*Trifolium pratense* L.) cultivars ‘Varte’ and ‘Ilte’

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Abstract

Tetraploid cultivars of red clover ‘Varte’ (early) and ‘Ilte’ (late), which are also cultivated in Finland, Sweden, Norway and Russia, have been released by Jõgeva Plant Breeding Institute. Single plant nurseries for maintenance breeding with these cultivars have been established for a number of years. Seed yields are determined for individually harvested plants, and the colour of the seed coat is assessed visually on a scale of 1-5. Mean seed colour indices of 10 seed harvests were calculated using these scores, and the dependence of the index on features of particular years and age of the stand is explained. Seed colour index was calculated in two ways: 1) the plants within a population were divided into classes according to the colour of the harvested seeds, the number of plants per class was considered by calculation - an equation *[∑ (no. of plants per class x number of seed colour class)]/total no. of scored plants)*; 2) the seed yields of plants divided into seed colour classes were determined and used in the calculation - an equation *[∑ (sum of seed weights per class x number of seed colour class)]/ total weight of scored seeds*.

Keywords: red clover, cultivar, seeds, colour index

Introduction

Red clover (*Trifolium pratense* L.) is characterised by bichrome seeds. A newly harvested seed lot is multicoloured. Although it contains seeds that are monochrome (whitish-yellow or purple), the majority of seeds are bichrome with various proportions of both colours. Bortnem and Boe (2003) have evaluated the colour of seed coats of red clover collections of the U.S. NPGS and, based on the results, have determined seed colour indices for the cultivars. The authors concluded that the colour index of red clover seeds depended on the cultivar, but it was also affected by the geographical location where it was grown and by the weather conditions of the particular year. The aim of this study was to determine seed colour indices and their variations by years for the tetraploid red clover cultivars ‘Varte’ (early) and ‘Ilte’ (late) released by the Jõgeva Plant Breeding Institute in Estonia.

Material and methods

Red clover was grown and harvested in single-plant nurseries. Seed yields were determined and the colour of seed coat was assessed visually on a scale of 1-5. Our trial results allowed the colour index to be calculated in two ways: 1) the plants within a population were divided into classes according to the colour of the harvested seeds, the formula: *[∑ (no. of plants per class x number of seed colour class)]/total no. of scored plants)*; 2) the seed yields of plants divided into seed colour classes were determined and used in the calculation - the formula *[∑ (sum of seed weights per class x number of seed colour class)]/total weight of scored seeds*. For the cultivar ‘Varte’ data from 10 harvest years (always the1st harvest year) of the same trial location (Jõgeva 58º45‘N, 26º24‘E) were used. For the cultivar ‘Ilte’ data from 7 trial years but from 10 nurseries were used with the aim of investigating also the possible effect of harvest year (I or II) on the seed colour index.

Results and discussion

The seed colour index of the cultivar 'Varte' calculated for plants was, on average for the trial years, 3.13 and varied from 2.73 (2001) to 3.70 (2007) (Table 1). Based on the data of seed yields, the seed colour index was 3.19 and varied from 2.77 (2001) to 3.70 (2007) (Table 2). The seed colour indices determined by the two methods were rather similar (differences only 0.01-0.06) or completely identical (2007). The same tendency was also observed for the cultivar 'Ilte', the seed colour index of which, when calculated for the plants, was 3.52 expressed as the average of ten trials 3.52 (difference by years from 3.22 (1997 I) to 3.89 (2006 II) (Table 3). Calculated by seed yields, the seed colour index was on average 3.55, and varied from 3.25 (2002 I) to 3.92 (2006 II) (Table 4). The methods resulted in a difference of 0.01-0.07, or they were identical.

Table 1. Seed colour index of cv. 'Varte' based on the number of plants per population

	Colour classes of seed coat						
	1	2	3	4	5		
Year	no./%	no./%	no./%	no./%	no./%	Total no.	Index
1994	19/2.7	249/35.6	251/35.9	170/24.4	10/1.4	699	2.86[efg]
1996	57/8.9	178/27.9	175/27.6	141/22.1	86/13.5	637	3.03[cd]
1999	87/10.0	249/28.6	212/24.4	234/26.9	88/10.1	870	2.99[de]
2001	100/10.6	350/37.2	257/27.3	170/18.0	65/6.9	942	2.73[g]
2002	76/7.9	299/31.0	348/36.1	204/21.2	37/3.8	964	2.82[fg]
2003	58/12.4	102/21.7	150/32.0	131/27.9	28/6.0	469	2.93[def]
2004	86/8.1	157/14.8	294/27.6	411/38.6	116/10.9	1,064	3.30[b]
2005	122/13.1	155/16.7	228/24.6	263/28.3	161/17.3	929	3.20[bc]
2006	37/5.5	84/12.5	152/22.6	241/35.8	159/23.6	673	3.60[a]
2007	60/5.6	126/11.9	211/19.8	339/31.9	327/30.8	1,063	3.70[a]
∑/x	702/8.4	1,949/23.5	2,278/27.4	2,304/27.7	1,077/13.0	8,310	3.13

The indices designated with the same letter do not differ significantly at $P = 0.05$

Table 2. Seed colour index of cv. 'Varte' based on seed weight

	Colour classes of seed coat						
	1	2	3	4	5	Total	
Year	g/%	g/%	g/%	g/%	g/%	g	Index
1994	217.7/3.2	2,377.1/34.5	2,445.2/35.5	1,747.9/25.4	94.3/1.4	6,882.2	2.87[ef]
1996	599.8/9.2	1,650.6/25.3	1,824.9/27.9	1,447.2/22.2	1,005.7/15.4	6,528.2	3.09[cd]
1999	980.4/10.2	2,586.7/26.9	2,329.2/24.2	2,663.8/27.7	1,053.7/11.0	9,613.8	3.02[de]
2001	1,450.6/10.0	5,397.0/37.1	3,869.2/26.6	2,783.9/19.1	1,053.8/7.2	14,554.5	2.77[f]
2002	1,799.7/7.8	7,018.9/30.6	8,183.3/35.6	4,994.9/21.8	959.9/4.2	22,956.7	2.84[ef]
2003	937.2/11.7	1,669.7/20.9	2,640.9/33.1	2,249.0/28.2	491.5/6.1	7,988.3	2.96[de]
2004	1,101.7/8.2	2,020.4/15.1	3,433.8/25.7	5,244.1/39.2	1,571.1/11.8	13,371.1	3.31[b]
2005	3,710.7/13.3	4,457.5/16.0	6,691.5/24.0	8,070.4/28.9	4,963.3/17.8	27,893.4	3.22[bc]
2006	1,144.5/5.6	2,531.0/12.4	4,405.7/21.6	7,277.9/35.6	5,072.5/24.8	20,431.6	3.62[a]
2007	966.7/5.7	2,038.9/12.0	3,407.3/20.0	5,304.8/31.1	5,330.6/31.2	17,048.3	3.70[a]
∑/x	12,909.0/8.8	31,747.8/21.5	39,231.0/26.6	41,783.9/28.4	21,596.4/14.7	147,268.1	3.19

(2005 I). The fact that two methods resulted in an identical seed colour index indicates that the seed yield of the plant does not depend on the seed colour. While comparing our trial results of many years with these of Bortnem and Boe (2003), it becomes evident that the tetraploid red clover cultivars bred in Estonia have a seed colour index that is more similar to that of Central-European cultivars ('Varte' in particular), or even to South-European cultivars ('Ilte').

Table 3. Seed colour index of cv. 'Ilte' based on the no. of plants per population

Year	Colour classes of seed coat 1 no./%	2 no./%	3 no./%	4 no./%	5 no./%	Total no.	Index
1995 I	29/3.4	117/13.8	220/26.0	322/38.0	159/18.8	847	3.55[b]
1995 II	33/4.7	139/19.9	160/23.0	216/31.0	149/21.4	697	3.44[b]
1996 I	17/4.1	72/17.2	97/23.2	119/28.5	113/27.0	418	3.57[b]
1996 II	27/6.1	77/17.4	88/19.9	125/28.3	125/28.3	442	3.55[b]
1997 I	59/4.8	328/26.4	315/25.4	358/28.9	180/14.5	1,240	3.22[c]
2000 I	21/2.0	106/10.0	317/29.8	476/44.9	141/13.3	1,061	3.57[b]
2005 I	49/5.0	101/10.4	257/36.4	400/41.1	166/17.1	973	3.55[b]
2006 I	2/0.5	31/7.8	102/25.5	176/44.1	88/22.1	399	3.79[a]
2006 II	7/1.5	34/7.3	91/19.6	205/44.1	128/27.5	465	3.89[a]
2007 I	29/3.4	117/13.8	221/26.1	321/37.9	159/18.8	847	3.55[b]
∑/x	273/3.7	1,122/15.2	1,868/25.3	2,718/36.8	1,408/19.0	7,389	3.52

Table 4. Seed colour index of cv. 'Ilte' based on seed weight

Year	Colour classes of seed coat 1 g/%	2 g/%	3 g/%	4 g/%	5 g/%	Total g	Index
1995 I	182.7/5.9	603.6/19.4	584.5/18.8	660.2/21.2	1,078.1/34.7	3,109.1	3.59[bc]
1995 II	379.2/4.7	1,527.1/18.9	1,740.0/21.6	2,563.4/31.8	1,856.3/23.0	8,066.0	3.49[c]
1996 I	290.4/5.3	948.4/17.4	1,155.8/21.2	1,555.2/28.6	1,501.1/27.5	5,450.9	3.56[bc]
1996 II	396.8/6.3	1,069.7/17.1	1,308.1/20.8	1,765.4/28.1	1,738.9/27.7	6,278.9	3.54[bc]
1997 I	604.3/4.7	3,231.5/25.2	3,244.6/25.3	3,765.1/29.4	1,971.5/15.4	1,2817.0	3.25[d]
2000 I	173.1/1.8	848.1/9.0	2,673.2/28.5	4,281.6/45.5	1,428.9/15.2	9,404.9	3.63[b]
2005 I	997.8/5.0	2,075.5/10.3	5,358.0/26.7	8,197.5/40.8	3,463.0/17.2	20,091.8	3.55[bc]
2006 I	18.4/0.4	290.8/6.5	1,091.5/24.2	2,022.9/44.9	1,081.5/24.0	4,505.1	3.86[a]
2006 II	77.3/1.3	415.6/7.1	1,042.1/17.7	2,719.1/46.2	1,634.1/27.7	5,888.2	3.92[a]
2007 I	212.4/3.3	885.1/13.7	1,630.0/25.2	2,425.4/37.5	1,319.0/20.4	6,471.9	3.58[bc]
∑/x	3,332.4/4.0	11,895.4/14.5	19,827.8/24.2	29,955.8/36.5	17,072.4/20.8	82,083.8	3.55

Conclusions

The seed colour index of the late red clover cultivar 'Ilte' was, as a rule, higher (i.e., seeds more purple; darker) than that of the early red clover 'Varte'. The weather conditions during the seed ripening period have an effect on the colour index, but the age of the stand (1st or 2nd harvest year) has no effect. The seed colour index cannot be regarded as a definite property for differentiating red clover cultivars. Based on the results of our additional plot trials it can be concluded that the colour index does not characterize the value of red clover seed from the viewpoint of either forage yield or herbage quality.

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Obliged permanent grasslands: main future of ruminant productions in Belgium?

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Abstract

A prospective exercise was initiated to identify the possible evolution of livestock farming systems in Belgium and especially in the Province of Luxemburg. After the definition of the current trend in farming systems, a scenario for the evolution of cattle farming systems was defined in a context of global markets, together with the adoption of a proactive posture to face society and environmental problems. It took into account the following trends: reduced consumption of animal products, a decrease of food waste, cattle production focussing on dairy production with meat becoming a by-product of these systems, use of sexed semen, cattle production concentrated on obliged permanent grassland, etc. The scenario, meeting national population needs together with a reduction in the environmental impact of this sector, was discussed with different stakeholder groups. The next step will be to define alternative scenarios and to identify political driving forces and supports necessary to orientate the sector in the shared direction.

Keywords: forecast, prospective, cattle systems, consumption habit, sustainability

Introduction

As in other European Countries, in Belgium the number of farms is steadily declining. Under this trend, coupled to an increase of farming-system size and a reduction of manpower, what is the possible place of grassland-based livestock farming systems? To explore the possible answers to this question and to identify the possible futures of livestock farming systems in Belgium, and especially in the Province of Luxemburg, with more than 85% of its Utilized Agricultural Surface (UAS) covered by grasslands, the Agriculture Deputy of the Luxemburg Province has initiated a forecast exercise. Its results are presented hereafter.

Material and methods

This exercise was driven by a group of seven experts (agricultural engineers, farm advisors, farm accountancy service, rural sociologists), based on forecasting methodology (Stassart *et al*., 2007). The first step focussed on the definition of the current trends of regional agriculture in the context of the Common Agricultural Policy (CAP) and globalisation. Historical data describing the evolution of the agricultural sector in the Luxemburg province from 1975 till now were assembled together with macro-economic data characterising agricultural product exports and imports at the Belgian scale. Finally, a seminar was organized, with 15 experts, with the aim of defining the main stakes our farming systems have or will have to face in the next 10 years, together with the major trends identified in term of CAP evolution.

On this basis and inspired by (1) the Millennium Ecological Assessment scenarios (Reid *et al.*, 2005) and (2) AGRIMONDE 2050 forecast exercise (Chaumet *et al.*, 2009), two contrasted evolutions of the general context (social, economical, environmental), at an horizon of 20 to 30 years, were drawn.
Based on this second general context evolution and AGRIMONDE2050 forecast results, a rupture scenario aiming to identify an alternative for the development of cattle production systems in Belgium was defined by the initial group of seven experts. The aim of this scenario, as contrasted as possible from the 'general trend' one, was, first, to lead to clear reactions from the stakeholders. Indeed it was, together with the general trends, debated and discussed in three work groups: the first included farm advisors (technical and financial), the second included young farmers, while the third one included staff responsible for the agricultural sector.

Results and discussions

The reduction in farm numbers in the Belgian Luxemburg Province, as in the rest of Belgium, is close to 3% per year. Thus, in this Province, farm numbers declined from from 7991 in 1978, to 2983 in 2007, with a parallel increase of their UAS from 19 to 49 ha per farm. In 2007, there were about 1.7 manpower units per farm. An extension of this trend indicates that in 2007 there was 25 young farmers taking over from 100 farmers that were stopping their activity; this will lead to fewer than 1500 and 800 farms, with, on average, around 100 and 175 ha of UAS per farm, respectively, by 2030 and 2050 in the Luxembourg Province. As the stocking rate is close to 2 LU ha^{-1}, ≈ one cattle and her calves per ha, this will lead to herd of 100 and 175 cows, in 2030 and 2050 respectively.
Macro-economic analysis underlined that Belgian cattle meat was, as in other European countries, produced at high cost (100-158 € 100 kg $liveweight^{-1}$) in comparison to imported meat (36 € 100 kg $liveweight^{-1}$ in Brazil or Argentine) but with a quality, lean and tender, specific to our country. Therefore, 77% of Belgian production is consumed in Belgium.
Major trends identified, in terms of CAP evolution, were (1) a pursuit of the suppression of market regulation tools with the development of revenue support measures (insurances); (2) a standardisation of the support, per ha, at a geographical scale to be defined. We will disconnect from the historical model. This highlights the necessity of a transition period and questions the way to implement such a standardised support, per ha, without risk of direct transfer from the farmer towards the land owner; (3) a reinforcement of the rural development support programme with more attention to environment protection. Nevertheless, this questions the ability of regional powers to co-finance these programmes.
On this basis and inspired by the Millennium Ecological Assessment scenarios (Reid *et al.*, 2005), the first evolution of the general context drawn included a full liberalisation of market exchanges, together with the adoption of a reactive posture to face emerging problems, while the second is based on a global orchestration of market exchanges together with the adoption of a proactive posture to face society and environmental problems.
Based on this second context definition, at local and global levels, we defined a scenario of evolution of cattle livestock farming systems in phase with the 'AGRIMONDE 1' scenario (more market exchanges regulation, pro-active response environmental and social problems, better distribution of food resources). This scenario also took into account the following leading trends : a reduction of animal products consumption, a decrease of food waste, a cattle production focussing on dairy production with meat becoming a by-product of these systems, a cattle production concentrated on obliged permanent grassland and/or on the valorisation of bio-industrial sub-products that can not be valorised by mono-gastric species, and national self-sufficiency.

Such a scenario, for 2030-2050, leads to a huge reduction in the number of cattle in Belgium, even if a stocking rate of 2 LU/ha of grassland is maintained (Table 1). Thus, the number of cows would shift from more than 1068,000 to fewer than 470,000 under such a scenario.

Table 1. Cow herds and stocking rate under the scenario defined 'in rupture' to the scenario 'market as usual', at the horizon 2050

	Market as usual	Rupture scenario
UAS (ha)	1370285	
Permanent grassland	507304	
Including grassland of high ecological value	50000	
Limitations	2 LU ha^{-1} UAS	2 LU of herbivore ha^{-1} grassland
Suckler cows	544516	40000 (on Natural grassland)
Dairy cows	523699	430000
LU of herbivore ha^{-1}grassland	3.6	2.0
Total LU UAS^{-1}	2.0	1.4

Such an evolution would be allowed by the emerging technique of semen sexing leading to the insemination of the best cows with female leading semen, of high dairy origin bulls, while the low performing ones would be inseminated with male leading semen, of bulls with a high value for meat production ("industrial crossing"). This strategy would cover meat and milk needs based on the dairy cow herd, following, also, a modification of our feeding habits.

The development of such a scenario would also reduce the environmental pressure exerted by cattle production systems, mainly through reduction in stocking rate and the beneficial impact of grasslands on biodiversity, nitrate leaching reduction and as a carbon sink (Peyraud *et al*., 2010). Nevertheless, this scenario will need to select, in order to supply our production of 3.10^9 litres of milk, dairy cows with good intake capacities able to produce 7000 litres per lactation, mainly from grass, and this in association with an adapted management of the resources offered by the grasslands.

Confrontation of the different stakeholders groups to this scenario, during the milk crisis of 2009, led to the following reactions. Young farmers focussed more on the definition of measures that would allow the development of multifunctional agriculture in connection with society, with rules that would facilitate the access to the land for farmers with innovative ideas. Farm advisors had more difficulties to detach themselves from the 'business as usual' trend. Nevertheless, they underlined the importance of the transition pathway from the actual to alternative systems; they also underlined the necessity to develop milk products with more added value than butter and milk powder that currently represent the main valorisation of Belgian milk. With municipal persons in charge of agricultural sector, we explored possibilities to mobilise land owned by municipalities to support innovative farming systems.

Acknowledgements

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Relationship between *in vivo* digestibility and *in situ* degradability of grass in grazing

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Abstract

During the grazing season three Friesian cows, fed on a grassland herbage diet dominated by Lolium perenne and *Trifolium pratense*, were studied in a metabolism house. A randomly blocked experimental design was used to test the efficiency of *in vivo* digestibility and *in situ* degradability values to estimate dry matter (DM) intake and nitrogen (N) excretion in faeces and urine. Significant monthly differences ($P < 0.05$) were found for N digestibility, degradability, intake and excretion. For each DM digestibility and degradability percentage unit increase, DM ingestion increased by1.77 and 1.91 g DM kg^{-1} $W^{0.75}$ for the ranges 58.6-77.2% and 60.3-82.3%, respectively. However, *in vivo* digestibility showed an over-estimation of faeces-N and urine-N excretion by 55% compared to *in situ* degradability. Overall, the obtained results show that both techniques are reliable for predicting N intake and excretion in dairy cows fed with a grassland herbage diet.

Keywords: grass, N intake, N excretion, estimation, methodology

Introduction

Grassland herbage is one of the most important constituents of dairy cattle rations. The nutritional value of forages is a function of nutrient content and voluntary consumption (Meissner *et al*., 1989). Grass intake and digestibility are the best index of forage nutritive value. The most important benefit of *in situ* evaluation of digestibility is that it evaluates the digestibility of feeds taking into account diurnal variation in rumen pH. *In situ* digestibility uses kinetic data, resulting in a good proximity to the *in vivo* digestion processes. Nevertheless, the *in situ* technique shows higher variability (Siciliano-Jones, 2002). The aim of the present work is to evaluate if *in vivo* digestibility and *in situ* degradability values can be used to estimate dry matter (DM) consumption and N excretion in faeces and urine of dairy cattle fed with a grassland herbage diet during different months and using feeds with different digestibility values.

Materials and methods

Three Friesian cows (two of them ruminally fistulated) were separated in a metabolism house for 15 days per month during six months (April, May, July, August, October and November). These animals weighed 608 ± 9.4 kg and had the last birth in January. The three metabolism-house dairy cows were fed with the same grassland herbage as the herd, dominated by *Lolium perenne* and *Trifolium pratense*.

The 15-day period in the metabolism house was divided into 10 pre-experimental days and 5 control days. Herbage on offer and rejected was weighed daily. Similarly, faeces and urine (withdraw by a Foley vesicle probe) were sampled and weighed daily. The samples were analysed the same day in the laboratory to determine DM and N content. A randomly blocked experimental design with three replications was used in the field experiments to agree with the following equation: $Y = \mu+M_i+V_k+\varepsilon_{ijk}$; where Mi are the months (1 to 6) and V_k

are the cows (1 to 3). In the ruminally-fistulated cows nylon bags were used containing the same grassland herbage (2 replications per cow and month) to determine *in situ* degradability (Mehrez y Ørskov, 1977) using an outflow rate of $k = 0.06\ h^{-1}$ in a Latin square with 2 cows×2 months (Salcedo, 2000). Grassland herbage DM and N degradability were determined by an orthogonal contrast test.

Results and discussion

Forage dry matter and organic matter *in vivo*, *in vitro* digestibility and *in situ* degradability are shown in Table 1. Results show that all parameters follow a quadratic trend with a concentration decrease in summer months ($P < 0.001$), which was probably due to the higher neutral detergent fibre content (Salcedo, 2000). Regarding ingestion and consumption prediction, Table 2 shows DM intake and N balance during the experiment period. Results show that each *in vivo*-digestibility percentage unit increase corresponded to a DM intake increase of 1.77 g DM $W^{0,75}$ (Figure 1). The lowest values were observed in summer whereas the highest values were obtained in autumn.

Table 1. Forage digestibility and degradability.

		April	May	July	August	October	November	SED	L	Q
OMD_{vivo}	g kg^{-1} DM	774	718	624	593	807	811	1.02	***	***
OMD_{vitro}	g kg^{-1} DM	749	707	608	573	793	813	1.06	***	***
DMD	g kg^{-1} DM	732	679	586	555	768	772	1.01	***	***
DMd	g kg^{-1} DM	699	658	631	612	781	813	1.17	***	***
Nd	g kg^{-1} N	714	679	677	650	831	857	1.24	***	***

OMD_{vivo}: organic matter *in vivo* digestibility; OMD_{vitro}: organic matter *in vitro* digestibility; DMD: dry matter *in vivo* digestibility; DMd: dry matter *in situ* degradability; Nd: nitrogen *in situ* degradability; SED: standard error of the difference means; L: linear effect; Q: quadratic effect; *** (P < 0.001).

Table 2. N intake, degradability and excretion.

	April	May	July	August	October	November	SED	Time	Time×Month
g DM kg^{-1} $W^{0,75}$	91^{c}	80^{d}	64^{e}	59^{f}	99^{a}	95^{b}	0.44	ns	ns
Intake N (g d^{-1})	418^{c}	384^{d}	323^{e}	298^{f}	527^{f}	560^{a}	43.4	*	ns
Faecal N (g d^{-1})	95^{a}	83^{b}	79^{bc}	75^{c}	94^{a}	96^{a}	3.79	ns	ns
Urine N (g d^{-1})	166^{d}	155^{b}	152^{bc}	146^{c}	166^{a}	165^{a}	3.52	ns	ns
F + U N (g d^{-1})	265^{a}	238^{b}	230^{b}	221^{c}	261^{a}	261^{a}	7.71	ns	ns
Milk N (g d^{-1})	77.4^{a}	73.6^{b}	58.3^{c}	59.9^{c}	55.9^{d}	56.6^{d}	3.86	ns	ns

$^{a, b, c, d, e}$ in the same row are significantly different at $P < 0.05$; ns: not significant. SED: standard error of the difference means

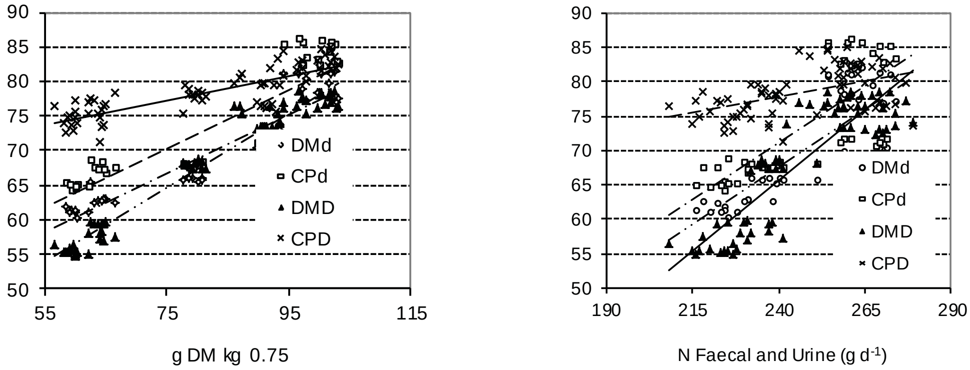

Figure 1. Relationship between dry matter and N digestibility and degradability with dry matter ingestion (left figure) and faeces and urine N excretion (right figure)

Table 3. Dry matter ingestion and N excretion (faeces and urine) prediction using *in situ* degradability and *in vivo* digestibility.

Independent variable	Y = a + bx	R^2	se	n
	In situ degradability			
g DM $W^{0.75}$	Y = -53.7 + 1.91 DMd	0.83	6.74	42
g DM $W^{0.75}$	Y = -43.7 + 1.72 CPd	0.73	8.51	42
	In vivo digestibility			
g DM $W^{0.75}$	Y = -39.4 + 1.77 DMD	0.95	3.48	72
g DM $W^{0.75}$	Y = 203.3 + 3.63 CPD	0.62	9.65	72
	In situ degradability			
g N d^{-1}	Y = 105.6 + 2.02 DMd	0.67	10.79	42
g N d^{-1}	Y = 118.2 + 1.75 CPd	0.57	12.35	42
	In vivo digestibility			
g N d^{-1}	Y = 117.6 + 1.88 DMD	0.77	8.84	72
g N d^{-1}	Y = 32.7 + 2.72 CPD	0.85	5.77	72

CPD: crude protein *in vivo* digestibility; see: standard error of regression

In a similar experiment in Galicia (Spain) Osoro and Cebrian (1986) obtained a slightly lower regression slope (1.22 *vs* 1.77) probably due to the use of a different animal species. However, crude protein digestibility showed a R^2 lower than these researchers (0.73 *vs* 0.83), probably because protein was not a limiting factor, ranging from 15.1 to 24.1%. Table 3 shows that the DM degradability equation slope is similar to degradability (1.91 *vs* 1.77).
Faeces and urine N excretion was significantly different ($P < 0.05$) with time, with minimum values in summer and maximum in autumn, due probably to lower forage protein content in autumn (significant at $P < 0.001$). In agreement with this, dairy cows have a lower nutritive need in autumn and grassland herbage has more protein content (+18.9%) than during the summer. Average percentages for faeces, urine and milk-excreted N relative to N intake were: 21.5 ± 3.4, 39.7 ± 8.3 and 15.9 ± 4.1, respectively. The reason to obtain higher (significantly different at $P < 0.001$) faeces-N in summer relative to autumn was probably due to the higher N concentration unit to acid and neutral detergent fibre (1.67 and 13.4%, respectively) in grassland herbage (Salcedo, 2005). Dry matter degradability gave a better prediction of faeces-N and urine-N excretion than crude protein degradability. The opposite was observed between *in vivo* crude protein digestibility and dry matter digestibility.

Conclusions

In situ degradability and digestibility can be used as a consistent method to estimate dry matter ingestion in grass. In contrast, N excretion (faeces + urine) is more consistent than the *in situ* methodology.

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The effect of cultivar on the crude protein fractions of fresh, wilted and ensiled red clover

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Abstract

The crude protein of red clover silage consists of lower contents of non-protein nitrogen than alfalfa. This may be related to the polyphenol oxidase (PPO) activity in red clover. However, most ensiling studies did not measure the PPO activity. Therefore, a laboratory ensiling trial with three red clover cultivars and one white clover cultivar as control grown in two management systems (with and without mechanical stress) over two consecutive years was conducted. Fresh, wilted and ensiled herbage was sampled at four cutting dates in both years to determine the crude protein fractions according to the Cornell Net Carbohydrate and Protein System. The specific PPO activity was photometrically measured in fresh clover leaves. The content of crude protein fraction A increased from fresh over wilted to ensiled herbage, especially in white clover. As a result, the content of true protein decreased. The most important source of variation for all crude protein fractions was generally the ensiling stage, except for fraction C. In conclusion, the protein fractions were less affected by the specific PPO activity. The stage of maturity at harvesting was the main factor explaining the differences in protein fractions among the silages made from the red clover cultivars.

Keywords: red clover, ensilage, proteolysis, polyphenol oxidase, stage of maturity

Introduction

Red clover represents an important protein source for ruminants in sustainable farming systems. For the winter feeding period, and particularly by year-round indoor feeding systems, it is necessary to produce well-fermented silages with minimal nutritional losses. However, extensive protein degradation occurs during the ensiling process leading to an increase in non-protein nitrogen compared to fresh forages. In general, red clover undergoes less proteolysis than alfalfa (Papadopoulus and McKersie, 1983). This is often attributed to the polyphenol oxidase (PPO) activity in red clover. Although numerous ensiling trials using field-grown red clover have been conducted, in the majority of cases the PPO activity was not measured. The objective of the present study therefore was to quantify the crude protein (CP) fractions of the Cornell Net Carbohydrate and Protein System (CNCPS) of fresh, wilted and ensiled red clover herbage over two consecutive years, compared to white clover. In this context, evaluating the influence of the PPO activity on the changes in CP fractions during wilting and silage fermentation was of special interest.

Material and methods

Three diploid red clover cultivars (*Trifolium pratense* L. cvs Milvus, Montana and Harmonie) and a tetraploid white clover (*Trifolium repens* L. cv. Vysocan) as control were used to carry out a laboratory ensiling trial. Clover herbage originated from a red clover trial with three replications, which was established in June 2007 at ‚Hohenlieth', northern Germany.The plants were grown in two management systems (without and with mechanical stress). In order to induce a higher PPO activity, the plots with mechanical stress were rolled twice with a Cambridge roller approximately three weeks before the planned cutting date. Eickler *et al.* (2011) have demonstrated that mechanical stress may increase the specific PPO activity of red clover. The experiment was conducted over two growing seasons (2008 and 2009) at four cutting dates per year with an interval of about 42 days. At each cut, the stage of maturity of the red clover cultivars (Fagerberg, 1988) expressed as mean stage by count (MSC) was determined. Furthermore, the specific PPO activity in fresh clover leaves was photometrically measured (Escribano *et al.*, 1997; Eickler *et al.*, 2011). For ensiling, clover herbage was chopped to a length of 2-3 cm and wilted to a target DM of about 400 g kg^{-1}. Each treatment was ensiled into 1.5 L glass jars with three replications. All jars were stored for 90 days in a dark room at 25°C. Fresh, wilted and ensiled herbage samples of each treatment were dried at 58°C and milled through a 1 mm screen, in order to estimate the quality parameters using near-infrared reflectance spectroscopy. As reference laboratory method for the determination of the crude protein fractions of the CNCPS the recommendations of Licitra *et al.* (1996) were used. The N content was measured according to the Dumas combustion method. Silage DM content was corrected for volatile compounds with a simplified equation afterwards. All data were statistically evaluated using analysis of variance based on a generalized mixed model (SAS 9.1), in which the DM content of each sample was considered as covariable.

Results and discussion

The analysis of covariance showed an interaction year x ensiling stage ($P < 0.0001$) for all CP fractions and, with the exception of fraction C, an interaction species/cultivar × ensiling stage (Table 1). There was an increase of fraction A from fresh over wilted to ensiled clover herbage at the expense of fraction B, irrespective of species, cultivar and year. This is in accordance with previous findings (e.g. Richardt and Steinhöfel, 2007). However, the proportion of fraction A in clover silage was lower in 2009 (382.4 g kg^{-1} CP) compared to 2008 (430.6 g kg^{-1} CP). White clover herbage had in all ensiling stages the highest proportion of fraction A and the lowest proportion of fraction B3. The silage protein of the red clover cultivar Harmonie contained more of fraction A and less fraction B3 than Montana (Table 1).

Table 1. Content of crude protein fractions of fresh, wilted and ensiled clover herbage as affected by cultivar.

		Crude protein fractions (g kg^{-1} CP)1					
Species/cultivar	Ensiling stage	A	B	B1	B2	B3	C
White clover	fresh	207.5aC	703.3aA	160.7aA	304.6aA	238.4bA	92.4b
	wilted	310.8aB	600.6bB	99.5aB	280.7bA	221.2bA	
	ensiled	525.0aA	376.4bC	49.9bC	224.3aB	103.6cB	
Milvus	fresh	149.4bC	715.8aA	110.1bA	314.3aA	290.9aA	126.8a
	wilted	208.1cB	648.9aB	63.0bB	335.2aA	252.1aB	
	ensiled	358.4cA	501.9aC	72.9aAB	234.9aB	195.7abC	
Montana	fresh	155.7bC	710.4aA	108.4bA	316.3aA	286.3aA	137.9a
	wilted	212.3bcB	648.3aB	67.4bA	335.4aA	246.6aB	
	ensiled	362.5cA	496.6aC	74.9aA	225.1aB	197.9aC	
Harmonie	fresh	158.1bC	716.3aA	117.6bA	302.6aA	294.2aA	126.8a
	wilted	226.0bB	653.5aB	73.5bB	321.5aA	259.1aB	
	ensiled	380.1bA	488.2aC	74.5aB	239.3aB	175.2bC	

[1] weighted annual averages, which were calculated by the DM yield of each cut; a,b,c indicate differences between cultivars within ensiling stage; A,B,C indicate differences between the ensiling stages within cultivar (Bonferroni-Holm; $P < 0.05$).

These differences were mainly related to the MSC of the red clover cultivars. In both years, fraction A was negatively correlated with the MSC (2008: $R^2 = 0.54$; $P < 0.0001$; 2009: $R^2 = 0.43$; $P = 0.0003$) and in case of fraction B3 a strong positive correlation was identified (2008: $R^2 = 0.74$; $P < 0.0001$; 2009: $R^2 = 0.70$; $P = 0.0003$). Considering both DM content and MSC as covariables revealed that the differences in fraction A and B3 among the ensiled red clover cultivars were not observed. The proportion of fraction C did not vary among the ensiling stages, but differences between white and red clover were observed.
Concerning specific PPO activity, white clover had, in all cuts, the lowest PPO activity. Differences among the red clover cultivars were only found in the third and fourth cut 2008 (Table 2). Although poorly correlated, there was an unexpected positive correlation between fraction A and specific PPO activity related to the leaf weight ratio ($R^2 = 0.22$; $P = 0.0126$), which was absent in 2009. However, this is in line with the poor negative correlation between fraction B3 and specific PPO acitivity ($R^2 \leq 0.32$). One reason for these outcomes might be the comparatively low range in specific PPO activity, particularly in 2009 (Table 2).

Table 2. Specific PPO activity in fresh clover leaves as influenced by year, cut and cultivar.

		Specific PPO activity (IU μg^{-1} protein g^{-1} DM)			
year	Species/cultivar	Cut 1	Cut 2	Cut 3	Cut 4
2008	White clover	0.08b	0.13b	0.25c	0.11c
	Milvus	1.72a	1.74a	1.66b	2.56b
	Montana	1.50a	1.00ab	2.77a	3.45ab
	Harmonie	1.89a	1.41a	2.11ab	4.27a
2009	White clover	0.07b	0.14b	0.25b	0.19b
	Milvus	1.64a	2.14°	1.45ab	1.90a
	Montana	1.19ab	1.69a	1.72a	1.50a
	Harmonie	1.75a	1.74a	1.50ab	1.98a

a,b,c indicate differences between cultivars within cut and year (Bonferroni-Holm; $P < 0.05$).

Conclusions

The course of the ensiling process has the greatest impacts on the changes in protein quality of clover herbage. The extent of proteolysis in silages made from field-grown red clover is mainly influenced by the stage of maturity at harvesting, whereas the specific PPO activity seems to be of minor relevance. Nevertheless, the silage protein of red clover has lower contents of fraction A and higher contents of fraction B3 compared to white clover, which may be more favourable for the protein utilization by ruminants.

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Lucerne silage fermentation characteristics when adding single strain inoculants

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Abstract

The trial was performed under laboratory conditions with forage that was moderately difficult to easily ensileable. The aim was to document efficacy of 7 lactic acid bacteria (LAB) strains as silage inoculants on dry matter (DM) losses and fermentation parameters compared to an untreated control. Efficacy data were used in a dossier submitted to the EU for registration. Three varieties of lucerne (*Medicago sativa* L.) from second cut were used. After wilting, the DM, crude protein and soluble carbohydrate concentrations of the lucerne were 313.9, 321.7 and 349.7 g kg^{-1}; 243.1, 275.7 and 275.3 g kg^{-1} DM and 36.7, 38.5 and 35.2 g kg^{-1} DM, respectively. Forage was harvested and chopped with standard field equipment. All LAB strains were applied at 1x 105 cfu g^{-1} of fresh crop. After inoculation, the chopped lucerne was ensiled in 3.0-L anaerobic glass jars at density of 434 g L^{-1}. The trial had 8 treatments (untreated control and 7 inoculants) with five replications per variety and per treatment.
The inoculants had a significant effect on lucerne silage quality characteristics in terms of lower pH and shifting fermentation towards lactic acid dominance with the homofermentative LAB. The heterofermentative LAB *Lactobacillus buchneri* resulted in fermentation towards acetic acid production. All inoculants significantly decreased butyric acid and alcohol concentrations, ammonia-N fraction and dry matter losses.

Keywords: lucerne, silage, inoculant, lactic acid bacteria, fermentation

Introduction

Obtaining good fermentation quality, high digestibility of nutrients and high energy and protein values in silages is sometimes difficult when the crop has high buffering capacity. Therefore, application of microbial inoculants that improve the fermentation is desirable. The advantages of the use of microbial additives, thanks to the suitable selection of lactic acid bacteria, have been stressed by many authors, and it is clear from the results that inoculants have a beneficial effect on the improvement of the fermentation quality of silages (Muck and Kung, 1997; Wrobel *et al*., 2004). It is well documented that silage inoculants can decrease protein breakdown measured as ammonia-N, and thus the level of intact protein remaining in the silages in turn leading to improved nitrogen utilization by animals and improved animal performance (Winters *et al*., 2001). Although the homofermentative and heterofermentative LAB take different approaches to directing fermentation in the silage, the principal goal of both is to preserve as much of the nutritive value of the crop at harvest as possible for the livestock consumption in the resulting silage (Filya *et al*., 2007). The aim of the present study was to evaluate the effect on fermentation characteristics of moderately difficult to easily ensileable lucerne, when using 7 LAB strains compared to an untreated control at laboratory scale. The generated data were used in dossiers submitted to the EU for registration of single LAB strains with the ultimate aim of using them in mixed formulations in the EU.

Materials and Methods

Three varieties of lucerne (*Medicago sativa* L.; ‚Europa', ‚Birute' and ‚Verko') from second cut were used. Three samples from each variety of untreated chopped lucerne were taken for analysis of chemical composition. After wilting, the dry matter (DM), crude protein (CP) and soluble carbohydrate concentrations of ‚Europa', Birute' and ‚Verko' were 313.9, 321.7 and 349.7 g kg^{-1}; 243.1, 275.7 and 275.3 g kg^{-1} DM and 36.7, 38.5 and 35.2 g kg^{-1} DM respectively, which was obtained by shading the plant before harvest. Lucerne was chopped by a forage harvester under farm conditions to ≈ 3 cm chop length and was ensiled in 3-L glass jars at a density of 414 to 453 g L^{-1}. One trial had 8 treatments (uninoculated control (T1) and 7 LAB strains: *Lactobacillus plantarum* DSM16568 (T2), *Lactobacillus plantarum* DSM16565 (T3), *Lactobacillus plantarum* BCCM/LMG P-21295 (T4), *Lactobacillus buchneri* CCM 1819 (T5), *Lactococcus lactis* NCIMB 30117 (T6), *Lactococcus lactis* DSM 11037 (T7), *Enterococcus faecium* NCIMB 11181 (T8) with 5 micro-silos per treatment. The LAB strains were provided by Chr. Hansen A/S. All inoculants were applied at 1.0×10^5 cfu g^{-1} of fresh forage by spraying it as a water solution on the crop. All inoculant solutions were analysed for LAB counts to document the correct inclusion (target +/-30%). Samples of ensiled material were collected from all glass jars included in the experiment after 90 days of ensilage. The statistical analysis was conducted separately on each forage cultivar assuming a completely randomized block design. Three x five replications were used per additive treatment. The SAS general linear model (GLM) procedure was used (SAS Institute Inc., Cary, NC, USA). A Student's t-test was used to separate inoculant treatments. Another analysis by using the SAS GLM procedure was conducted in which forage cultivars were analysed together in the statistical model in which a completely randomized block design was assumed. Significance was declared at $P < 0.05$.

Results and discussion

Lucerne crops can be difficult ensile because its high contents of organic acids, salts, proteins, and minerals result in a high buffering capacity (McDonald *et al*., 1991). In our experiment the opportunity for improvement in silage fermentation quality was great: a limited WSC content (37 g kg^{-1} DM), high protein concentration (265 g kg^{-1} DM) and a high buffering capacity, which would cause clostridial fermentation and butyric acid formation. The lucerne silage made without additive was poorly preserved: high pH value and butyric acid concentrations, fermentation acids not dominated by lactic acid and high breakdown of proteins to ammonia N; all factors typical for difficult or mediocre ensiling conditions. The fermentation quality of the tested silage is given in Table 1. All inoculant treatments reduced ($P < 0.05$) pH relative to the untreated control. The greatest reduction in pH was 0.40, a substantial difference for the homofermentative LAB treatment. The inoculant treatment improved lactate:acetate ratios compared with uninoculated control silage. The exception was the heterofermentative LAB Lactobacillus buchneri CCM 1819 (T5) treatment, which produced silage with lower lactate:acetate ratio. These findings are consistent with other studies (Kung *et al*., 2003; Filya *et al*., 2007). The LAB inoculants resulted in significantly lower butyric acid, alcohol and ammonia N concentrations compared with the untreated control. All additives reduced ($P < 0.05$) total DM losses. The high DM losses of uninoculated control silage reflect an inefficient fermentation.

Table 1. Fermentation quality of the lucerne silages and ensiling losses after 90 days of ensiling (results summarized from 3 fields)

Treatment	T1	T2	T3	T4	T5	T6	T7	T8
DM*, g desiled g kg^{-1}	313.0[b]	320.2[a]	320.3[a]	319.8[a]	319.4[a]	319.8[a]	322.1[a]	319.3[a]
DM loss*, g kg^{-1}	67.9[a]	43.2[c,b]	39.9[d]	41.2[c,d]	46.4[c,b]	42.9[c,b]	37.9[d]	46.6[b]
pH	5.35[a]	4.99[c,b,d]	4.97[c,d]	4.95d	5.03[b]	5.01[c,b]	5.02[b]	5.02[b]
Lactic acid, g kg^{-1} DM	16.4[e]	50.2[b,c]	55.9[a]	51.8[b,a,c]	39.4[d]	53.9[b,a]	47.8[c]	55.4[a]
Acetic acid, g kg^{-1} DM	33.7[c,d]	41.0[b]	36.2[c,b]	34.8[c,d]	49.0[a]	30.6[d]	29.8[d]	33.7[c,d]
Butyric acid, g kg^{-1} DM	13.9[a]	0.7[b]	1.3[b]	2.5[b]	0.9[b]	1.5[b]	1.5[b]	1.0[b]
Propionic acid, g kg^{-1} DM	0.8[c]	1.2[b]	1.1[b]	1.1[b,c]	1.2[b]	1.3[b,a]	1.5[a]	1.2[b,a]
Alcohol, g kg^{-1} DM	12.2[a]	5.2[c]	4.4[c]	5.7[c,b]	6.9[b]	4.7[c]	4.5[c]	4.6[c]
Ammonia N, g kg^{-1} total N	102.0[a]	77.0[d,c]	80.9[c]	74.1[d]	79.2[c]	85.8[b]	80.0[c]	86.1[b]
Lactate:acetate	0.49	1.22	1.54	1.49	0.80	1.76	1.60	1.64

$t_{0.05}$ = 1.982; Error df = 110

* Dry matter and calculated dry matter losses are corrected for volatiles

a, b, c, d, e - Means with different superscript letters in a line indicate significant differences at $P < 0.05$

Conclusions

All seven LAB strains used in the lucerne ensiling experiment improved the silage fermentation quality compared with the uninoculated silage, resulting in a significant increase in lactic acid production and significant decrease in pH, butyric acid, alcohol, and ammonia-N formation. Heterofermentative LAB *Lactobacillus buchneri* shifted fermentation toward acetic acid. Ensiling losses were also smaller in the inoculated silages than in the untreated. While the efficacy of the individual strains in this trial proved to be successful in moderately difficult to easily ensilable silage, it is anticipated that even greater effects would be seen when combining some of the strains.

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Effects of oven- or freeze-drying on protein fractions of red clover and relationship with specific polyphenol oxidase activity

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Abstract

Red clover is known to have high polyphenol oxidase (PPO) activity among forage legumes. Several studies indicate that the specific PPO activity may lead to a decrease in the extent of protein degradation in silo and in rumen. However, in literature, positive effects are often attributed to the PPO activity without measuring the enzyme activity or without quantifying the relationship between the PPO activity and the potential improved forage quality. Compared to freeze-drying (FD), oven-drying (OD) may allow PPO activity, quinone formation and complexation with proteins during the first hours of the drying process. Therefore, protein fractionation would reflect the variation in PPO activity after OD but not after FD. The aim of the study was to investigate the effect of OD or FD on the protein fractionation of red clover samples, and to relate the specific PPO activity with the crude protein fractions. In total 12 red clover cultivars of different origin were grown in pure stands in a four-cut system in two management systems (without/with mechanical stress). The results showed a poor or no relationship of specific PPO activity and protein fractions, either if samples were FD or OD. OD resulted in a few less-soluble crude protein (Fractions A and B1), probably due to the higher temperature, but not due to the PPO activity.

Keywords: red clover, polyphenol oxidase activity, protein fractionation, oven-drying, freeze-drying

Introduction

Among forage plants, red clover is known to have high polyphenol oxidase (PPO) activity. The enzyme oxidizes phenols to quinones, which are highly reactive, forming stable quinone-protein-complexes, and protecting protein from fast degradation. However, in literature, positive effects are often attributed to the PPO activity without measuring the enzyme activity. Compared to freeze-drying (FD), oven-drying (OD) may allow PPO activity, quinone formation and complexation with proteins during the first hours of the drying process. Therefore, protein fractionation would reflect the variation in PPO activity after OD but not after FD. The aim of the study was to determine the influence of method of drying red clover samples before protein fractionation, and to relate the specific PPO activity with the crude protein fractions.

Material and Methods

In total, 12 red clover (*Trifolium pratense* L.) cultivars of different origin and white clover (*T. repens*) as a control were grown in pure stands in a four-cut system with three replications in two management systems (with and without stress) in Hohenlieth/Northern Germany (soil texture: loamy sand, average temperature 8.9°C, average precipitation 804.5 mm). In one system (with stress) plots were rolled with a Cambridge-roller about 3 weeks before harvest to induce higher PPO activity under stress conditions. The phenological stage of the plants was monitored at each sampling date according to Fagerberg (1988) to calculate the mean stage by count (MSC). Yields and leaf weight ratio (LWR) were determined. Fresh red clover plants were harvested at six-week intervals in the years 2008 and 2009, and leaves for PPO analysis were immediately frozen at -27°C. Samples for protein fractionation were separated in two subsamples and either oven-dried (OD) at 58°C for 48h or freeze-dried (FD) and then ground to 1 mm particle size. The specific PPO activity was determined in frozen leaves according to Escribano *et al*. (1997) and related to the LWR. Protein fractionation was carried out according to the CNCPS, described by Licitra *et al*. (1996). All data were tested in a variance analysis (mixed procedure, ANOVA) using SAS 9.1. Effects were considered significant in all statistical calculations at $P < 0.05$. Cuts were treated as repeated measurements for the PPO activity data, and years for the protein fraction data. Regression analysis was performed by PROC REG to evaluate relationships between specific PPO activity and the protein fractions.

Results and discussion

The specific PPO activity was affected by the system×cut×cultivar interaction in 2008. In 2009 all three double interactions were observed (data not shown). Stress due to rolling induced mostly a higher specific PPO activity in 2008 for all cuts and in 2009 only at the first cut. White clover showed the lowest specific PPO activity at all times. Highest values in specific PPO activity were measured in the first year at the autumn growth, where the red clover plants were less developed in phenological stage expressed by a lower MSC. Among cultivar and system, the cut also plays a decisive role. However, specific PPO activity was poorly related with MSC or LWR (Weiher *et al*., 2010).

Crude protein (CP), affected by year ($P = 0.0050$), system ($P = 0.0024$) and cultivar ($P < 0.0001$) as main factors only, averaged 210 g kg^{-1} DM for red clover (averaged over two years, 12 cultivars, two systems and four cuts per year) in FD samples and 231 g kg^{-1} DM for OD samples. Fractions A, B2 and B3 were affected by the year×system interaction, and fractions B1 and C were affected by year and cultivar. Fraction B2 made up the largest proportion of CP independent of the drying method (OD: 303 g kg^{-1} N, FD: 372 g kg^{-1} N).

Levels of fraction A in FD samples accounted for 51% of the variation in fraction A in OD (Table 1), whereas the concentration of other protein fractions in FD samples were poorly related to the respective fractions in OD samples. No relationship was observed for fraction B2 (Table 1).

Table 1. Relationship between protein fractions in 12 red clover cultivars and white clover (Hohenlieth 2008 and 2009) when freeze-dried (FD) *vs*. oven-dried (OD) (RMSE = Root mean square error)

Protein fraction	Equation	adj. R^2	*P*-value	*RMSE*
Fraction A	OD = 109.50 + 0.59*FD	0.51	< 0.0001	27.90
Fraction B1	OD = -41.60 + 0.71*FD	0.31	< 0.0001	22.93
Fraction B2	OD = 272.58 + 0.08*FD	0.00	0.3419	50.19
Fraction B3	OD = 151.59 + 0.77*FD	0.26	< 0.0001	36.60
Fraction C	OD = 70.91 + 0.48*FD	0.13	< 0.0001	27.52

Grabber (2009) assumed that conservation as hay rather than FD enhanced protein protection by o-quinones in red clover, as FD would hinder o-quinone formation. However, the enzyme activity was not measured. Our results show that protein fractions and specific PPO activity in 12 red clover cultivars and white clover were poorly related (Table 2). Relationships were neither observed between PPO activity and Fraction B1 in OD samples, nor with Fraction B1 or B3 in FD samples. Probably the relationship was poor or absent, because the specific

PPO activity is not the main cause of variation for protein fractions, independently of drying method. So the suggestion of Graber *et al*. (2009) that the prevention of o-quinone building explained the shift in the protein fractions was not confirmed by our findings.

Table 2. Relationship between protein fractions and specific PPO activity in 12 red clover cultivars and white clover (*RMSE* = Root mean square error; Cor. = Correlation)

	oven-dried				freeze-dried			
Fraction	*P*-value	adj. R^2	RMSE	Cor.	*P*-value	adj. R^2	RMSE	Cor.
A	< 0.0001	0.10	37.82	-	< 0.0001	0.26	41.37	-
B1	0.8318	0.00	27.66	-	0.0515	0.01	21.66	+
B2	0.0003	0.06	48.75	-	< 0.0001	0.13	38.74	+
B3	< 0.0001	0.09	40.47	+	0.7915	0.00	28.32	-
C	< 0.0001	0.17	26.97	+	< 0.0001	0.09	21.40	+

Oven-drying shifted the proportions of CP fractions from buffer soluble (A and B1) to detergent extractable (B3 and C), just as observed previously by Grabber and Coblentz (2009). Goering *et al*. (1973) noted long ago, that with higher temperatures the acid and the neutral detergent insoluble nitrogen increased, forming Maillard products generated by heat damage. Probably the shift in our red clover protein fractions is due to the higher temperatures caused by oven drying. The PPO activity was absent during the OD drying process, or the consequences of the PPO activity were not detected using crude protein fractionation as measurement.

Conclusion

OD resulted in a few less-soluble protein fractions (fractions A and B1), probably due to the higher temperature caused by the drying method. The shift was not related to the PPO activity (and formation of quinone-protein-complexes), neither after OD nor FD. Furthermore the relationship between PPO activity and protein fractions was poor, suggesting that specific PPO activity was not the main cause of variation in protein fractions.

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Crude protein yield and quality of festulolium (×*Festulolium* Asch. & Graebn.) and hybrid ryegrass (*Lolium*×*boucheanum* Kunth.)

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Abstract

Festulolium hybrids are promising grasses used in many European countries, especially in adverse environments. The herbage quality of *Festulolium* cultivars and *Lolium*×*boucheanum* were tested under the agro-ecological conditions of Latvia in field trials established on a sod-gleyic soil with two (N) fertilisation rates (120 and 180 kg N ha^{-1}). The results of the experiments in 2003-2007 highlight the significant dependence of the crude protein (CP) yield on the variety used and the N fertiliser dose. On average over three years of sward use, an increase in N fertiliser from 120 to 180 kg ha^{-1} contributed to an increase in the CP yield of 98 kg ha^{-1} or 30%. Higher CP yields were achieved by *Festulolium brauii* cultivars. Differences between varieties in neutral detergent fibre, acid detergent fibre content and *in vitro* digestibility were highly significant, but no significant effect of different N rates on these parameters was observed.

Keywords: *Festulolium*, *Lolium*×*boucheanum*, nitrogen fertilization, herbage quality

Introduction

Rural development in Latvia is aimed at balanced development of efficient and sustainable production of agricultural commodities and farm produce. The genus *Festuca* has worldwide distribution in different climatic regions, including Latvia. Fescues have the advantage of longevity and resistance to unfavourable climatic conditions, and are also high yielding. However, they are less valuable than ryegrasses in terms of forage quality. Ryegrasses have the advantage of rapid growth, high productivity and excellent forage quality, but they are more suited to mild climatic conditions (Lemežiene *et al.*, 2004).

Festuloliums are acknowledged to be the most prospective herbage species in the context of sustainable agriculture development, combining high forage quality and resistance to climate stress (Thomas and Humphreys, 1991; Nekrošas and Sliesaravičus, 2002). Because of its competitive productivity *Festulolium* may be ranked equally with the main forage grasses, timothy and meadow fescue, when grown in the climatic zone of Latvia (Gutmane and Adamovich, 2008).

The objective of this research was to study herbage quality of varieties of *Festulolium* and *Lolium*×*boucheanum* during three years of sward use under the agro-ecological conditions of Latvia.

Materials and methods

Field trials were conducted in Latvia on a calcareous sod - gleyic soil (*Luvic Epigleyic Phaeozem (Calcaric): WRB 2006*), fine sandy loam (20-30 cm deep arable layer). Soil pH_{KCl} was 7.2, with high plant available phosphorus and good potassium content; humus content was 31 g kg^{-1}. The swards comprised: perennial ryegrass 'Spidola' (control); *Festulolium* pabulare'Perun' (*L. multiflorum*×*F. pratensis*), 'Punia' (*L. multiflorum*×*F. pratensis*), 'Saikava' (*L. perenne*× *F. pratensis*), 'Lofa' (*L. multiflorum*×*F. arundinacea*) × *LM*, *F. braunii* 'Felina' and 'Hykor'

(*L. multiflorum*×*F. arundinacea*)×*FA*; and hybrid ryegrass 'Tapirus' (*L. multiflorum*×*L. perenne*). Varieties represent the same middle early maturity group. The trials were sown in May 2002, 2003, and 2004 without a cover crop; the seeding rate was 1000 germinating seeds m^{-2}. The plots were fertilised with P_2O_5 at 90 kg ha^{-1} and K_2O at 78 kg ha^{-1} and at two N fertiliser treatments, N $120_{(40+40+40)}$ and N $180_{(60+60+60)}$. The dry matter (DM) yield was determined for three years of sward use.
The yield of first-cut herbage DM was analysed for the following quality indices: crude protein (CP), neutral detergent fibre (NDF) and acid detergent fibre (ADF) by method of van Soest, and *in vitro* digestibility of the organic matter (IVOMD) by De Boever *et al*. (1994). The experimental data were subjected to ANOVA analysis.

Results and discussion

The largest annual grass DM yields in Latvia were produced at the first cut, and average DM yield of the first cut over the three years of production accounted for 49% of the annual yield. The first-cut crude protein yield was significantly influenced by variety ($P < 0.01$) in all production years. Total CP yields in each production year were higher with festucoid-type festulolium varieties 'Felina' and 'Hykor'. For these varieties, the highest total CP yields were provided not only by their good yielding ability, but also by higher CP content in herbage DM as compared to other varieties. Among loloid-type festulolium varieties, 'Punia' produced higher total yields of CP in each production year.
CP content in herbage DM, as well as its yield obtained at the first-cut, were significantly ($P < 0.01$) influenced by the increase of N rate from 120 to 180 kg ha^{-1} in all production years of the sward. In the first production year, the average increase in CP yield was 88 kg ha^{-1} (20%). In the second production year it was 75 kg ha^{-1} (or 42%), but in the third production year it was 131 kg ha^{-1} (or 56%) (Table 1). The highest increase in CP yield in the three production years was recorded for the hybrid ryegrass 'Tapirus' and the loloid-type festulolium 'Punia' (respectively, 350 kg ha^{-1} or 48% and 363 kg ha^{-1} or 37%).
Acid and neutral detergent fibre (ADF and NDF) content in herbage, on average for three production years, was the lowest for perennial ryegrass 'Spidola' (24% for ADF and 43% for NDF). For the rest of the loloid-type varieties, NDF was in the range of 46-50%, but ADF content ranged from 27% to 30%. Both of the festulolium varieties of the festucoid type, 'Hykor' and 'Felina,' showed higher mean values for NDF (respectively 56% and 58%) and ADF (respectively 33% and 33%).
On average for the three production years, herbage of perennial ryegrass 'Spidola' was of higher DM *in vitro* digestibility (76%). For the rest of the loloid-type varieties, digestibility was in the range from 69% to 73%. On average for three production years, festucoid-type festulolium varieties 'Felina' and 'Hykor' were of lower DM digestibility (61% and 65% respectively). For the three production years, there was a significant negative correlation between the DM digestibility and CP fibre fractions NDF ($P < 0.001$) and ADF ($P < 0.001$).
Net energy lactation (NEL), a parameter of forage quality, is closely related to ADF content in herbage DM. On average for three production years, NEL was the highest for perennial ryegrass 'Spidola' (6.7 MJ kg^{-1} DM). For the rest of the loloid-type varieties, NEL ranged from 6.2 to 6.5 MJ kg^{-1} DM. For both of the festucoid-type festulolium varieties 'Felina' and 'Hykor,' NEL was lower (6.0 MJ kg^{-1} DM), on average over the three production years.
In all production years the NDF and ADF content in the herbage DM, the DM digestibility and indices of NEL were all significantly influenced by grass variety ($P < 0.01$). No significant influence of N fertiliser on NDF and ADF content in herbage DM, or on DM digestibility and NEL was detected ($P > 0.05$).

Table 1. First cut crude protein (CP) yield for three years of sward use, kg ha^{-1} (average for three sowing cycles).

	Crude protein yield at N120, kg ha^{-1} Year of sward use				Increase of crude protein yield at N180, kg ha^{-1} Year of sward use			
Variety	First	Second	Third	Total	First	Second	Third	Total
Spidola	385	173	169	727	111*	52*	140*	303*
Tapirus	394	131	208	733	126*	102*	122*	350*
Saikava	310	192	178	680	67	69*	48	184
Perun	493	157	241	891	125*	97*	106*	328*
Punia	559	192	220	971	113*	99*	151*	363*
Lofa	458	164	205	827	66	60*	134*	260*
Hykor	639	278	320	1237	80	85*	98*	263*
Felina	1170	330	330	1830	15	35	246*	297*
Mean	551	202	234	987	88	75	131	294
$S\bar{x}$	96	24	21	136	14	9	20	20

* yield increase for variety significant at the 95% probability level

Conclusions

Crude protein content in herbage dry matter, as well as its yield obtained at the first-cut, were significantly influenced by the increase of N rate from 120 to 180 kg ha^{-1} in all production years of the sward.

Festucoid-type festulolium, characterised by higher crude protein content in the herbage dry matter, and interaction with higher dry matter yield, provided higher first-cut crude-protein yield.

The dry matter digestibility, neutral detergent fibre and acid detergent fibre in the grass dry matter, as well as net energy lactation (NEL MJ kg^{-1}) were higher for loloid-type festulolium than for festucoid-type festulolium.

Acknowlegements

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Effects of sowing and fertilisation in the establishment of annual legume rich permanent pastures

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Abstract

A field experiment tested the effect of three fertilisation strategies (nil, mineral and organic fertilisation) on pasture establishment, measured by plant species composition in spring sward in the two first years after sowing two pasture types (simple annual, legume-rich mixture and complex annual legume-rich mixture) compared with unsown pastures. There was a positive effect of organic fertilisation on the spring floristic composition through the increase of sown annual legumes, without an increase of ruderal species. Farmyard manure substituted, with advantages, conventional sowing mineral fertilization in these conditions.

Keywords: sown biodiverse permanent pastures rich in legumes, *Trifolium subterraneum*, organic fertilisation, pasture ecology

Introduction

Since Portugal joined the EU in 1986, low cereal prices and high fertilizer and fuel costs have lead to extensive abandonment of agricultural land, and simplification of mountain mixed farming systems. In the 1970s, Portuguese agronomist David Crespo devised a Mediterranean pasture system - the Sown Biodiverse Permanent Pastures Rich in Legumes (SBPPRL) (Crespo *et al*., 2004) - often mixing 10-12 improved cultivars of 6-7 pasture species, with Trifolium subterraneum in preponderance (3-4 cultivars; > 50% of the seed mixture by weight). Former cereal fields are easily converted to pastures by sowing these mixtures. SBPPRL are now rapidly expanding in Portugal due to their superior productivity and C sequestration in soil organic matter (Teixeira *et al*., 2011). Current SBPPRL fertilisation recommendations at sowing propose soil pH correction and mineral P, and sometimes K, fertilisation. P fertilisation represents almost 20% of establishment costs (Teixeira, 2010). As manure is available on many cattle or sheep mountain farms, the substitution of conventional mineral fertilisation by farmyard manure is an option for reducing establishment costs and contributing to a desirable increase in P recycling on a farm scale. The main objective of this paper is therefore to assess the effects of nil, current mineral, and organic fertilisation in the spring botanical composition of Mediterranean legume-rich permanent pastures in the first two years after establishment, in a soil with a medium available-P content.

Materials and methods

In the autumn of 2008 a hierarchical split-plot experiment was established in a field of 2.1 ha, previously cultivated with oats, in Bragança, Portugal (41°46‘N 6°48‘W, 741 mm yr^{-1} of rainfall and 11.9°C of mean annual temperature). Parent rock was schist and the initial soil before sowing had a pH (water) of 6.0, 1.6% organic matter, medium available P (65 mg P_2O_5 kg^{-1}, Egner-Rhiem) and high available K (113 mg K_2O kg^{-1}, Egner-Rhiem). Three types of pasture were established (main plots): i) unsown pasture (UP); 2) simple seed mixture (SM); 3) complex seed mixture (CM). SM combined *T. subterraneum* ‘Denmark’ (61%), *T. repens* ‘Winterwhite’ (9%), *D. glomerata* ‘Prairial’ (13%) and *L. perenne* ‘Victorian’ (17%) with the

same grass/legume weight proportion as in the CM. In CM, there was used a SBPPRL mixture with eight legumes and two grass species, dominated by *T. subterraneum*. All treatments were tilled to 15 cm deep, harrowed and rolled. Three fertilisation (Fert) treatments at sowing were tested in sub-plots of ca. 0.23 ha, in each of the main plots: i) conventional, routinely recommended, mineral fertilisation (MF) - 1000 kg lime ha^{-1}, 53 kg P_2O_5 ha^{-1} (superphosphate 26.5%) and 30 kg K_2O ha^{-1} (potassium chloride 60%); ii) cattle manure (OF) (with 3.25% of N, 1.38% of P_2O_5 and 7.5% of K_2O), 40 t ha^{-1}, just enough to supply P_2O_5 of the MF - 130 kg N ha^{-1}, 55 kg P_2O_5 ha^{-1} and 300 kg K_2O ha^{-1}; iii) no fertilisation (NF). The plots were not fertilised in 2009 or 2010. The botanical composition data were recorded in four replications (quadrats) in each sub-plot, paired along a microtopographic gradient, in the springs of 2009 and 2010. Species relative cover was evaluated by the point-quadrat method (70×70 cm quadrats with 49 points) in the third week of May, in the centre of 1×1 m permanent quadrats. In 2010 these quadrats were protected from herbivory with an exclosure cage during the preceding two weeks to allow species flowering and posterior identification. The sown legumes were merged into one unique response variable (SownLeg). There was one cleaning-grazing event in June of 2009. The experiment was subjected to rotational flash grazing by a local village sheep flock in November of 2009 and from February to the end of June of 2010.
Species relative covers were assumed as response variables in a RDA (Redundancy Analysis) and in a PCA (Principal Component Analysis) carried out in the CANOCO package (Ter Braak and Šmilauer, 2002). The RDA consisted of eight dummy explanatory variables: the treatment levels of Year (2009 and 2010), Pasture (UP, SM and CM) and Fert (NF, MF and OF). For the PCA, besides the treatment levels, based in Iberian phytosociological literature (e.g. Rivas-Martínez *et al*., 2001) four supplementary (passive) variables were constructed adding the relative cover of poor soils cereal weeds (CereWeed, *Aperetalia spicae-venti*), Mediterranean fallow land and ruderal species (Ruderal, *Thero-Brometalia* and *Sysimbrietalia*), annual oligotrophic species (MAnnPast, *Helianthemetea*), and annual-hemicryptophytic species adapted to trampled soils and heavy grazing (MHemPast, *Polygono-Poetea* and *Poetea bulbosae*). Relative covers were compared with *t* tests.

Results and discussion

A hierarchical decomposition of community variation with an RDA with a split-plot design (Lepš and Šmilauer, 2003) produced the following explained variability of species data: Year 26.2% (ns), Pasture 21.7% ($P < 0.01$), and Fert 25.5% ($P < 0.004$). Constraining the decomposition of community variation to sown plots (SM and CM plots), Year, Pasture and Fert explained, respectively, 36.8% (ns), 3.1% (ns) and 31.8% ($P < 0.02$) of species variation. So, in the all-data (UP, SM and CM plots) analysis, pasture flora control by Pasture (21.7%) was due to a UP effect. Fert had a significant effect in pasture species assembling.
The PCA biplot of Figure 1 shows that between 2009 and 2010 there was strong reduction in CereWeed (e.g. *Papaver rhoeas*), less evident in UP plots, and an expansion of plants adapted to trampled soils and intensive grazing (MHemPast, e.g. *Trifolium glomeratum*), or of annual oligotrophic species (MAnnPast, e.g. *Vulpia* sp.pl. a plant genus avoided by grazers after flowering). *Lolium rigidum* (a ruderal) and *Anthemis arvensis* (a cereal weed) relative cover, the two most abundant undesirable species in the experiment, was promoted by UP and depressed by pasture sowing (SM and CM). Ruderal species appear split in two groups: more nitrophilous species (e.g. *B. hordeaceus*, *B. sterilis* and *H. leporinum*) were encouraged by OF while more oligotrophic ones (e.g. *A. arvensis* and *L. rigidum*) preferred NF and MF plots. The Ruderal variable was not correlated with OF ($R = -0.13$).

The PCA biplot (Figure 1) also suggests that OF and a second year (2010) favoured SownLeg in the sown plots. These hypotheses were supported by two-tailed *t* tests comparing SownLeg relative cover means: 18.1% in 2009 *vs.* 65.1% in 2010, 23 df, $P < 0.001$, *t* test; 66.4% in OF *vs.* 29.8% in MF plots in 2009, 7 df, $P < 0.001$, paired *t* test; 66.4% in OF *vs.* 31.8% in NF plots in 2010, 7 df, $P < 0.001$, paired *t* test. Soil P content before sowing probably explains why MF and NF had a similar effect in SownLeg and in the autochthonous flora. Pires *et al.* (2008) also found a significant positive effect of farmyard manure on legume dominance in similar pastures. *L. perenne*, the main sown grass, did not show a clear trend.

Conclusions

Cereal-associated weeds decreased rapidly in recently sown, annual legume-rich sown pastures. Species adapted to trampled soils and heavy grazing followed the opposite trend. Fertilisation exerted a significant control on spring flora of the sown plots. In spite of an important N input (130 kg N ha^{-1}), the OF treatment increased relative cover of sown legumes without an expansion of low-palatable ruderal species. The two most important undesirable species - *A. arvensis* and *L. perenne* - were depressed by pasture sowing and had a higher relative cover in NF and MF. In the studied soil fertility conditions, conventional mineral fertilization can be replaced without disadvantages by farmyard manure at sowing.

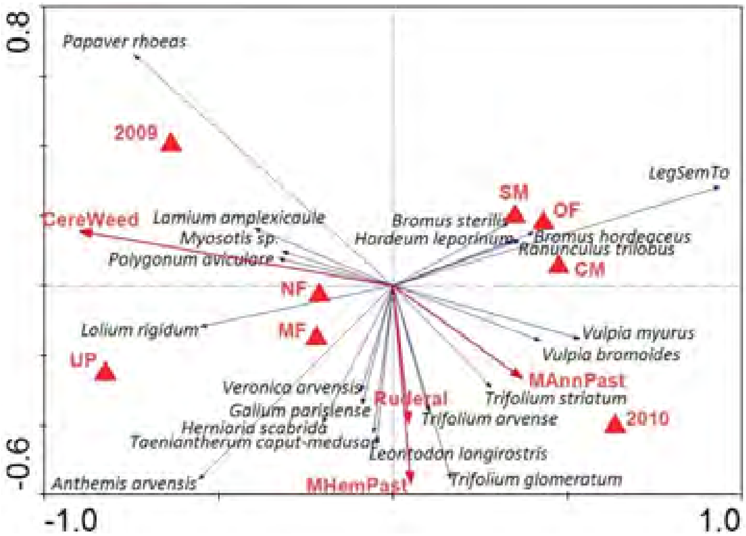

Figure 1. PCA species-treatment and supplementary variables biplot. All variables were passively projected. In the figure are represented the first twenty-one species with the highest fit with the first two axes.

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Session 2

Organic, low-input and alternative grassland farming systems

Merits of full grazing systems as a sustainable and efficient milk production strategy

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Abstract

The continuation of high input dairy production systems in areas and on farms where grazing is possible is becoming increasingly questionable in terms of sustainability. Areas north of the central European Alps are ideal grassland areas, with adequate temperature and rainfall which result in a high per-hectare pasture productivity. The multi-faceted merits of milk production from grassland have been overlooked in the quest for prestigious high per-cow performance. However, it is the authors' opinion that there should be prestige in achieving sustainability, profitability and efficiency, and in encouraging a positive image for dairying. By employing the use of a full grazing system these attributes are obtainable. In addition, these cows that have a high proportion of grassland-based feed, produce milk and dairy products of improved nutritional and sensory qualities over their predominantly concentrate-fed contemporaries. Although a grazing system is considered to be low input, this system type should not be associated with low managerial competence. Moreover, an increased quality of technical knowledge and support to full-grazing farmers from consultancy and research levels is needed. Redefining what constitutes an efficient and productive cow in a grazing system, and the appropriate selection tools to identify her, is also required. The qualities, nuances and the challenges of the implementation of a full grazing system are further developed in the body of the text.

Keywords: milk production system, milk quality, dairy cows, feed conversion efficiency

1. Introduction

Dairy production systems in Europe and North America have seen changes towards a total milk-output orientated cow (Holsteinisation) and feed-lot, stall-feeding systems, which utilise optimised total mixed rations (TMR), with the major components being maize and grass silage and concentrates. There are still grassland-based milk production systems in countries with alpine foothills, but the reputation and status of these systems have waned. However, this could change quickly in the near future because of the sharp decline of prized arable land availability. This is due in part to urbanization, industrialization and the corresponding expanding infrastructure, and increased demands on feed-grain production as a consequence of the rising meat consumption of emerging countries such as China. Also, the nuclear disaster in Fukushima will impact the demand for energy-producing land areas. In the light of these developments, the practice of high per-cow concentrate usage to achieve high annual per-cow production is increasingly questionable. Therefore, pastoral land and pasture-based milk production (especially in areas where pasture is a best-case land use) will become more economically relevant and will regain some of its current lost status and reputation. The role of grasslands from the perspective of global food production will become increasingly important, especially if the availability of prerequisite resources for long-term additional food production is uncertain, and combined with growing global food demand (Spiertz and Ewert, 2009; Nösberger, 2010). The core task of sustainable milk production lies in the pathway of the conversion of forage to a food that is of nutritive value for humans in the form of milk, dairy products and, to a lesser extent, meat. This is particularly relevant for regions such as the Alps and alpine foothills, where permanent pasture is the primary input resource. If we assume that the careful and efficient use of resources is becoming increasingly important, and furthermore that the era of extravagance is over, it is right that we, at this year's EGF Symposium can revert back to and employ the strengths of grassland-based milk production and show how these adaptations can be successfully implemented.

In recent decades, dairy farmers in the grassland areas sought huge increases in performance through advancements in breeding and feeding with maize and concentrates. They succeeded, yet it left dairy production systems stressed. However, it was viable - even on marginal land within mountain regions - to have high yielding cows and a high proportion of cheap concentrate in the cow's annual diet. But in terms of sustainability and resource efficiency, it is a moot point whether to continue with this system or not. To survive in the long term, milk producers in the grassland areas should shift their focus to using their own resources and realizing the potential of pastoral-based dairy production. To this point, the presentations at the EGF General Meeting in Kiel 2010 showed that efficient, region-specific usage and combinations of resources should be employed for herd and grassland management. This new grassland management model will incorporate the critical role of legumes, namely white clover, and its positive impact on intake from livestock (Peyraud *et al*., 2010). Moreover, not only should pasture be the main input resource for ruminants, but the awakening societal awareness of the exogenous advantages of grassland must be considered (Sanderson and Wätzold, 2010).

This paper aims to show primarily that the development and promotion of milk production in grassland areas requires a paradigm shift, particularly in countries and areas situated north of the central European Alps. Annual milk yield per cow as a key performance indicator is misleading and should be neither coveted nor necessary to achieve sustainability. It will also be shown that milk and dairy products produced from pasture have a unique composition with beneficial nutritive values (fatty acids), sensory properties and physical characteristics, which should be conveyed to the consumer.

2. The search for sustainability and social recognition

2.1. The value of milk production in small and mid-sized family dairy farms

In many regions north of the Alps, the topography and climate is not suitable for arable crops and the landscape is dominated by grassland. Where there is relatively even distribution of rainfall throughout the year and/or mild temperatures during the winter, the climatic conditions are favourable for grass growth, and the annual dry matter production can reach 15 t DM ha^{-1} y^{-1} (Jeangros and Thomet, 2004). Mountainous regions, in contrast have a shorter grazing period (5-7 months), and DM yields are lower. However those areas often benefit from frequent summer rainfall, allowing grass growth above 40 kg DM ha^{-1} d^{-1} whereas growth is nearly stopped in plains and hill regions, as observed in Franche-Comté in France

Table 1. Average data from dairy farms in 4 countries/regions: Bayern (D), Baden-Württemberg BW (D), Switzerland (CH) and Austria (A)

	D - Bayern	D - Baden-W.	CH	A
Agricultural effective area (Million ha)	3.22	1.43	1.09	3.19
Proportion grassland (%)	35	38	75	62
Proportion maize whole plant (%)	11.0	7.6	4.1	11.0
Size of herd (Cows.dairy farm^{-1})	37.2	32.2	18.5	11.2
Milk yield (kg ECM.cow^{-1})	7638	6198	6773	6828
Concentrates (kg cow^{-1}.yr^{-1})	2370	2079	883	1300

[1] Only milk controlled cows

(Delaby *et al*., 2010a). This grass growth potential contributes to the construction of a "green landscape". The aesthetic value of the pastoral landscape is especially important for tourism, and the farms' integral role at a societal level is recognised by the government via guaranteed direct payments. Permanent grassland-based milk production systems are indispensable for maintaining the typical landscape in these regions, ensuring biodiversity and fulfilling the various multifunctional tasks (Lobsiger *et al*., 2010). Thus it is important to communicate the positive image of grassland-based milk production systems. However, the figures in Table 1 show relatively small farms (in grassland areas) but using high amounts of concentrates, which is problematic if sustainability is considered.

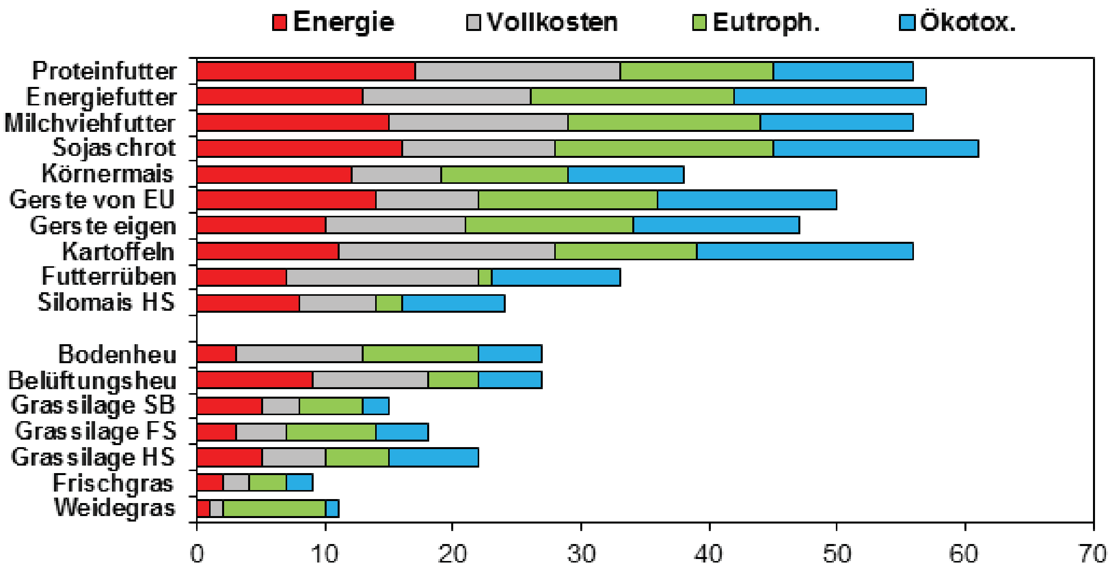

Figure 1. Ranking of the impact of 17 various dairy cattle feeds on full costs, energy efficiency, eutrophication risk and eco-toxicity risk (Zimmermann, 2006)

Figure 1 shows the various impacts of dairy cattle feeds, both economically and environmentally, under average production conditions. Unprocessed, freshly cut and fed feeds were the least expensive. The environmental effects of roughages are generally lower than those of concentrates, especially if the concentrate is dried and processed, or transported over long distances (Zimmermann, 2006). Basset-Mens *et al*. (2009) also support these findings of the decreased environmental impact by grazing mixed-type pasture sward systems. Moreover, grazing has positive effects through decreased labour demand and on improved animal welfare. However, a successful grazing operation places high demands on management and personnel competence.

2.2. Optimising the conversion of grassland biomass to food

In grassland-based dairy production, the cow's four-part stomach system (ruminant) enables it to be utilised as a bioreactor, in which cellulose energy (indigestible to humans) is unlocked to generate a food source digestible for humans. The cow does not suffer from decreased concentrate content in her diet, as pasture in itself is a natural total mixed ration. The timing of plant canopy harvest, the conservation system and the botanical composition of grassland swards determine milk production potential. The age of the plants is the main factor influencing their nutritive value (age effect): early utilization is necessary to obtain feed suited to the high requirements of dairy cows. Rapidly grown spring pasture has by far the highest nutritional value, both in terms of energy and protein supply. During this period, milk yields of 30 kg energy corrected milk (ECM) cow^{-1} day^{-1} are possible solely from forage. As the year progresses, the digestibility and energy concentration falls. However, the crude protein content remains and increases steadily. Therefore, spring production of milk from grazed pasture is the most lucrative, as values of feed conversion efficiency are over 1.5 kg ECM kg DM^{-1}. In the cut-and-carry regime, the forage is mostly older and therefore of lower energy content, but voluntary DMI could be increased through shorter and more evenly spaced ingestion and rumination sequences (Boudon *et al*., 2009). The age effect is less pronounced for legumes and forbs than for grasses. Therefore the presence of legumes in the pasture sward provides year-round ration-energy optimisation. Also, pasture utilisation is increased when feeds, high in legume content, are offered, in all forms (fresh, silage, hay) rather than pure grass monocultures, which also increases the milk production potential and feed-conversion efficiencies (Peyraud *et al*., 2010). The stall-feeding system with an optimized TMR has a distinct advantage in voluntary intake. With similar energy concentrations of the diet, the DM intake is higher in a TMR system than in a grazing system, primarily due to the faster rate of intake, thus allowing for annual milk yields of 10,000 ECM cow^{-1} or more, whilst full grazing systems achieved levels of 6,500 ECM cow^{-1} (Kolver and Muller, 1998). However, the economic result is strongly dependent on the cost of the feeds used.

3. Quality differentiation of grassland-based milk

3.1. Distinction between milk produced from either mainly grass-based feed or from TMR

Many studies have investigated the influence of farm feeding practices on the composition of cow milk in different production systems. The composition of the milk fatty acids (FA) is largely influenced by the cow's diet.

It was shown that an increased proportion of grass-based feed in the diet decreases the amount of saturated fatty acids (SFA) and especially the sum of C12, C14 and C16 (Leiber *et al*., 2005; Couvreur *et al*., 2006; Ferlay *et al*., 2008; Bisig *et al*., 2008; Collomb *et al*., 2008). The levels of mono-unsaturated fatty acids (MUFA) (Leiber *et al*., 2005 [at 2000 m]; Couvreur *et al*., 2006; Bisig *et al*., 2008; Collomb *et al*., 2008) and polyunsaturated fatty acids (PUFA) in milk fat increase with increased proportions of grass-based feed (Leiber *et al*., 2005; Couvreur *et al*., 2006; Bisig *et al*., 2008; Collomb *et al*., 2008).

For the n-3 PUFA, at least 9 studies showed an increase of between 51 and 330% with grass-based feed only, compared to the standard mixed diet in the respective studies (Table 2). The highest increase was observed when 100% grazing was compared to 100% maize silage rations. Another portion of the PUFA, the conjugated linoleic acids (CLA) are of important interest. At least 8 studies found an increase of CLA content between 77 and 244% with grass-based feed mainly, compared to the standard mixed diet (Table 2). The CLA-enriching effect of pasture

Table 2. Fatty acid content in milk of grass-based fed cows compared to milk of cows fed a mixed diet with high levels of concentrate and whole-crop maize silage

Region	Diet composition	n-3 g/100 g fat	up %	CLA g/100 g fat	up %	Reference, remarks
Zug, Switzerland, 400 m above sea l.	Hay, grass silage, maize silage 10:60:30	0.81		0.661		Leiber *et al*., 2005 per 100 g FAME
	Grass only (barn, pasture)	1.375	70	1.789	171	∑ CLA
Grisons, Switzerland, 2000 m above sea level	Hay, grass silage, maize silage 10:60:30	0.85		0.689		Leiber *et al*., 2005 per 100 g FAME
	Grass only (barn, pasture)	1.810	113	1.539	123	∑ CLA
Engadin, Rhinewald, Emmental, Lucernese-Willisau, Toggenbourg	about 75% feed grasses (winter: grass silage, hay), 2% (s_x= 2) maize silage, 12.5% (s_x = 3.3) concentrate	1.19		0.72		Bisig at al., 2008, Collomb *et al*., 2008 ∑ CLA
	Grass based feed only	1.89	59	2.03	182	
Wisconsin, USA	33% pasture, 25% alfalfa hay, 48.3% ear maize, 6% roasted soybean	0.81		0.89		Dhiman *et al*., 1999 per 100 g FAME CLA c9, t11
	66% pasture	1.46	80	1.43	61	n-3: C18:3
	100% pasture	2.02	149	2.21	148	
South Wales	Up to 50% concentrate, grass silage	0.54		0.75		Butler *et al*., 2009 ∑ CLA
	Low input not organic cert. (no or low levels of concentrate)	0.94	74	1.82	143	n-3: ALA
	Low Input organic (no or low levels of concentrate)	1.03	91	1.33	77	
Haute-Loire (Massif central), France	33% Maize silage, 66% grassland, 3.7 kg/d concentrate	0.65		0.73		Ferlay *et al*., 2008
	99% grassland, 1% maize silage, 2.6 kg/d concentrate	0.98	51	1.58	117	
Rennes, Bretagne, France	0% grass: maize silage, 3 kg soybean-concentrate	0.29		0.48		Couvreur *et al*., 2006 CLA c9, t11
	30% grass: maize silage, 2 kg soybean-c, 1 kg cereal concentrate	0.43	49	0.54	13	
	60% grass+1 kg soybean-c, 2 kg cereal concentrate	0.60	108	1.21	152	
	100% grass+3 kg cereal concentrate	0.73	153	1.65	244	
Six regions in France (Bretagne, Picardie, Lorraine, Franche-Comté, Auvergne, Aquitaine)	100% Maize silage	0.20		0.33		Hurtaud *et al*., 2010
	100% Grazing	0.86	330	1.10	233	
Southern Germany	50% Maize silage, other preserved forage	0.5				Weiss *et al*., 2005
	Grass silage, hay, little concentrate	1.1	120			
	Pasture only	1.3	160			

has been explained by the effects on biohydrogenation and the provision of α-linolenic acid as a lipid substrate for the formation of trans-vaccenic acid (C18:1 trans-11) in the rumen and its subsequent desaturation to CLA C18:2 cis-9,trans-11, the main CLA isomer in milk, in the mammary gland (Collomb *et al*., 2006).

3.2. Potential of quality differentiation of grass-based milk

The decreased SFA-C12, -C14 and -C16-content and the increased MUFA, PUFA, n-3 FA and CLA are nutritional benefits of grass-based milk. Of the SFA only C12, C14 and C16 adversely affect low-density-lipoprotein level (LDL) in human plasma. LDL is a risk factor for cardiovascular disease. In higher concentrations n-3 FA can lead to nutritional claims or even health claims. The European Food Safety Authority (EFSA) published their positive scientific opinion on a health claim related to the n-3 FA α-linolenic acid (ALA) for infants and children up to three years with the following wording: "Alpha-linolenic acid, an essential fatty acid, contributes to brain and nerve tissue development." and previously a positive opinion on ALA for normal growth and development of children (EFSA, 2011). To be able to make such nutritional or health claims, conditions of their concentration have to be met.
CLA were discovered by Pariza *et al*. (1979) as an anticarcinogen. Also in animal models, other effects such as a body fat lowering effect associated with an increase of lean body mass, an antidiabetic effect, antiatherogenicity, a positive modification of the immune system and influence on bone metabolism were found. Human studies are often contradictory. Recently EFSA published a negative opinion on several health claims for CLA (EFSA, 2010).
Branched chain fatty acids (BCFA) content in milk is positively correlated to the proportion of grass-based feed (Couvreur *et al*., 2007; Collomb *et al*., 2008; Hurtaud *et al*., 2010). BCFA have an anticarcinogenic effect on cancer cells (Vlaeminck *et al*., 2006).
It is still unsure whether trans fatty acids (TFA) of ruminant origin are neutral, positive or negative from a nutritional point of view. In Denmark and Switzerland maximum levels of 2 g/100 g fat for TFA are set. TFA of animal origin are excluded (EDI, 2008). CLA are mainly TFA and have the positive potential previously shown. An increase of TFA with increased proportions of GBF could be observed (Ferlay *et al*., 2008: from 3.96 to 6.94 g/100 g FA; Collomb *et al*., 2008).
The conclusion is that grass-based milk has positive nutritional benefits but none can be labelled and communicated on the product due to current EU regulations. However, it should be possible to communicate other non-nutritional values on the products.

3.3. Sensory changes with grass-based feed

The softness and spreadability of butter is improved when made from milk with increased grass-based feed (Couvreur *et al*., 2006; Mallia 2008). A softer cheese body texture is also observed, especially with fresh grass in the cow's diet (Bisig, own observations; Martin *et al*., 2009). Butter made of milk produced with more grass-based feed was less rancid than butter made with milk produced with maize silage (Couvreur *et al*., 2006). Other odour and flavour attributes were unchanged (Couvreur *et al*., 2006) or were creamier (Mallia, 2008). Maize silage feeding results in whiter and less appreciated cheese and butter (Martin *et al*., 2009). Even a small proportion of fresh grass (15% of the diet) led to cheeses which were judged more yellow, less firm and with a more intense and partly more grassy and flowery aroma (Martin *et al*., 2009).

4. A cow to suit the system

4.1. Defining the cow's efficiency: from the cow to the system

In many countries, selection pressure was placed on total milk production per cow per year. We must admit that this selection increased the cows' ability to transform feed into milk, for example: gross feed conversion efficiency (kgECM per kgDMI). Cows also became larger; small efficient cows being predictably discarded. More worrying was the fact that other total farm-profit drivers, such as health and reproduction, were left unchecked and declined, owing to antagonistic genetic correlations with milk yield (Windig *et al*., 2006). This reminded us that the evaluation of a dairy cow's efficiency depends certainly on the ratio of output (quantity and quality of milk) per input (quantity and environmental cost of feed), but also on the time scale we use (lactation or life length) and the constraints of the system (feed quality and availability, seasonal pattern). A cow which is best suited to a grazing system must not only possess a high forage conversion efficiency of kg DM consumed to saleable product (including quality) but must also have high fertility, longevity, robustness, intake capacity and willingness to graze. A compact calving pattern further strengthens the importance of the reproductive process, namely cyclicity, oestrus and fertility.

4.2. Genotype × environment interactions: which cow for low input grazing systems?

Efficient cows in one system are not necessarily efficient in another. Indeed, interactions between feeding system and cow type have been reported for both production and reproduction traits (Fulkerson *et al*., 2001; Kolver *et al*., 2002; Horan *et al*., 2004; Beerda *et al*., 2007; Delaby *et al*., 2009; Cutullic *et al*., 2011). Although Delaby *et al*. (2010b) suggested that high genetic merit dairy cows are compatible with low input systems, it is clear that the widespread North-American Holstein type cow currently has a suboptimal reproductive performance, which renders it unsuited to a pastoral compact calving system. However, the recent results of Coyral-Castel *et al*. (2009) and Coleman *et al*. (2010) suggest that selection for both high milk yield efficiency and fertility is possible, as successfully done in New Zealand and Irish dairy breeding programmes. In a recent study conducted on Swiss commercial pastoral, seasonal calving farms, New Zealand-type Holstein cows were not only as efficient as Swiss Holstein cows for milk production, but had improved reproductive performance and thus appeared more suitable for the system (Figure 2; Piccand *et al*., 2011, in these procee-

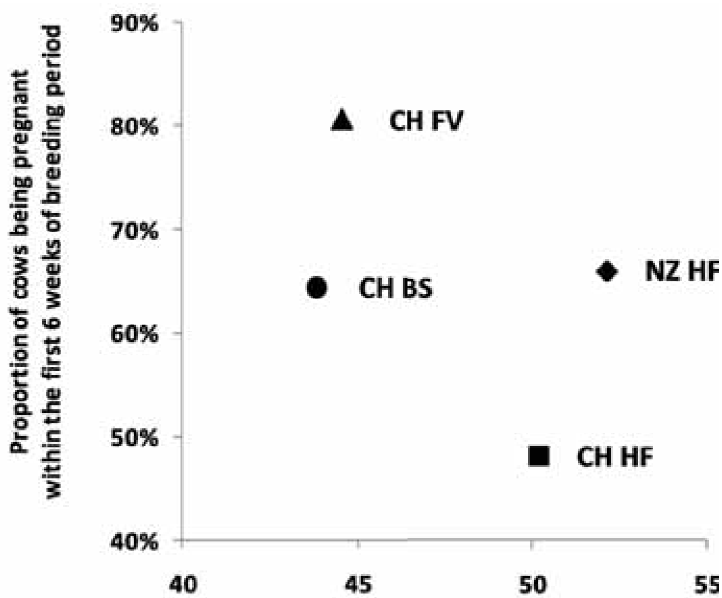

Figure 2. Average milk efficiency over 270 days of lactation and average proportion of pregnant cows within 6 weeks of the breeding season for New Zealand Holstein Friesian (NZ HF; n = 131 lactations), Swiss Holstein (CH HF; n = 40), Swiss Fleckvieh (CH FV; n = 43) and Swiss Brown Swiss (CH BS; n = 45) dairy cows managed in seasonal-calving pasture-based systems (from Piccand *et al*., 2011, in these proceedings).

dings). Between New Zealand type Holstein cows and Fleckvieh cows, we may wonder which type is the more appropriate, since, on the one hand, Fleckvieh cows produced less milk but on the other hand produced more meat and had better reproductive performance.

4.3. Selecting and breeding for the future

In addition to the previously mentioned classical breeding traits (milk production efficiency, reproductive performance, health, meat production), other traits should retain attention, for example: milk composition. If the main final product is cheese, especially high added-value cheese as in many Alpine regions, milk processing characteristics should be considered. Flexibility, i.e. capacity of the cow to switch from one system to another, should also be of increasing importance: either in a context of fluctuating milk prices to quickly produce more milk efficiently through increased concentrate usage when milk price is high, as suggested by Peyraud *et al*. (2010) - although this may be questionable in the context of sustainability. Or, flexibility could also encompass the cow's ability to adapt to temporary feed restriction or high temperatures in the climate change context (Hayes *et al*. 2009). Behavioural components of efficiency may also be emerging criteria (Prendiville *et al*., 2010; Kunz *et al*., 2010). The incorporation of genomic selection will aid in this holistic approach, through increased reliabilities and decreased generation interval, with an increased confidence to include any one trait in any given decision. The main difficulty now relies on the definition of pertinent criteria, each defined according to the production system objectives.

5. The search for the optimal full grazing system

5.1. Learnings from on-farm grazing research projects

The culture of full-time grazing is missing in Switzerland, southern Germany and Austria. Yet a pioneering effort of likeminded farmers with the support from research institutes was formed. The goal was to completely abandon confinement feeding and convert their farms to a full-time grazing system. Table 3 shows which research institutes, and with how many farms carried out this initiative.

Table 3. On farm research projects with full grazing systems in the four areas of Bayern, Baden-Württemberg, Switzerland and Austria

	D - Bayern[1]	D - Baden-W.[2]	CH[3]	A[4]
Number of full grazing farms (≤ 10% Supplementary feed during vegetative period)	6	7	10	4
Of those: organic farms	3	6	2	4
Of those: mountainous zoned farms	-	5	1	4
Project duration	2006-10	2005-07	2001-03	2006-08
Produced milk per farm (kg ECM dairy farm^{-1})	220000	307164	134330	161272
Proportion grazing of annual feed ration (%)	50	36	59	50
Concentrates (kg cow^{-1} yr^{-1})	950	823	504	581
Milk yield (kg ECM cow^{-1} yr^{-1})	6200	6312	6032	5539

[1] Steinberger (2011), [2] Elsässer (2010); [3] Blättler *et al*. (2004); [4] Steinwidder *et al*. (2009, 2010)

The results of these projects show that full grazing systems in the alpine foothills can be implemented with success. In summation, the following statements can be made:

1. The health and fertility of the cows was as good, but in most cases better than those of typical farms.
2. Depending on the duration of the growing season, farm structure and planned start of calving, pasture made up 40-70% of total feed ration.
3. The proportion of concentrates in the annual ration was reduced by up to 70%..
4. The continuous grazing system (set stocking) was found to be suitable for the initiation of farmers to full-time summer pasture feeding. It also resulted in optimal per-area productivity, per-cow yield, labour efficiency and pasture sward performance
5. A complete conversion to a full-time grazing system resulted in decreased labour input, and consequently, the farmer's lifestyle was dramatically improved.
6. The financial results are difficult to compare due to the different direct payment systems, although the annual milk yield per cow of full grazing was much lower. In all four areas, farm management personnel agreed that the final economic outcome had improved.
7. Grassland helped to cultivate a positive image for agriculture amongst the general population.
8. Problems for the dissemination and application of the full grazing systems:
   - Lack of knowledge, competence and empathy for successful grazing management at research, consultancy and farm levels.
   - Land availability: farm growth is hindered because additional area immediately surrounding existing farm infrastructure is very difficult to acquire.
   - There are still entrenched attitudes solely orientated toward high cow performance.
   - Unavailability of best suited dairy cattle genotypes and a lack of relevant breeding indices as selection tools.

5.2. Should seasonality be the rule?

Synchronisation of feed demand with feed supply is the backbone of the seasonal calving pastoral-based system. In Figure 4, it can be seen that pasture growth increases rapidly in spring in all regions, although the timing of growth rate incline is region-specific. As the farmer has

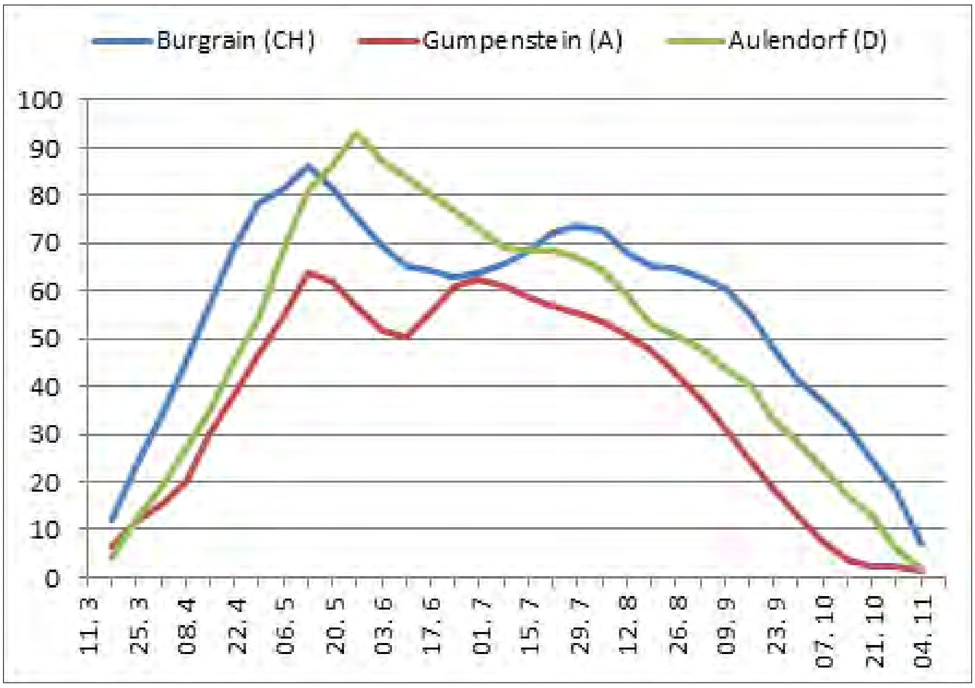

Figure 3. Grass growth at different sites (averages from at least 3 years, measured after the method Corrall and Fenlon, 1978)

no bearing on the onset of spring, the feed demand can be manipulated to meet supply and this will dictate the onset of calving. This ensures a best-case scenario of feed cost minimisation to the farmer, since milk is mainly produced through cheap grazed grass and because peak energy content of grass corresponds to cows' peak energy demand. However, to minimise cow wastage, high reproductive performance (as described in section 4) is imperative to ensure continued synchronicity in successive years (cows which fall out of the seasonal rhythm).

To optimize the system further, other classical management tools of grazing systems can be used, such as stocking rate or grazing pressure. In a grazing system, output must be considered at the herd level, not at the individual cow level. Indeed, an increase in stocking rate decreases individual cow performance but strongly increases biomass utilisation and milk output per hectare (Delagarde *et al*., 2001; McCarthy *et al*., 2011). Milk production per hectare will only decrease once optimal stocking rates are exceeded (King and Stockdale, 1980).

In the future, the dairy industry should take advantage of higher milk production potential during grass growth peaks, instead of imposing disincentives via decreased milk prices. As discussed in section 3, this milk is the best quality milk a cow can produce, from which high quality products can be derived. Originally, the purpose of hard cheese production was to store superfluous milk and enable year-round dairy product consumption. Why now should the farmer store feed to produce milk all year round? How and why has this apparent regression occurred? However, we consider it relevant and sustainable to ensure basal winter milk production. Although, if farmers intentionally produce surplus winter milk (provocatively said, is it not the same as producing tomatoes in winter?), it is clear that complementary systems to seasonal calving pastoral-based systems are also needed. However, research is still required to evaluate the performance of those low-input grass-based winter producing systems.

6. Conclusions

The success of a grazing system is reliant on its simplicity, meeting feed demand with feed supply, and coordinating peak demand with peak nutritional value. Grazing systems are generally considered 'low input'. However, this term is not synonymous with 'low competence'. Although simple in its founding principles, whether seasonally calving or not, a successful system relies on a high degree of managerial competence.

Expertise in this area has diminished and should be rectified. With improved consultancy and on-going research, farmers willing to convert existing confinement TMR systems can improve their economic outcome whilst also fostering a positive image for agriculture. However, not only should human proficiency be improved to meet the demands of a grazing system, but the animal must also be best suited. This should include the establishment and measurement of relevant performance indicators and will include improved selection tools to help identify optimal genotypes. Animal breeding programmes should relinquish per cow production as the primary selection objective and should consider other key profit drivers for farmers (fertility, longevity and kg ECM per kg metabolic BW). The lower per cow yield in a low input system does not mean low output, as it has been shown that there is high per-area productivity (kg ECM ha^{-1} grassland) in grazing systems, whilst also decreasing environmental impact and improving sustainability.

Nutritionally positive differences of grass-based milk have been demonstrated when compared to TMR milk. Although health-benefit claims cannot be made via labelling due to EU regulations, potential differentiating factors can still be communicated to both the public consuming dairy products and conventional dairy producers.

There is no better vector for change at a production level than clear, unobstructed signals from the consumer. Where possible, the choice of milk production system should be sensitive to market preferences, and in the regions north of the Alpine boundary such systems are possible. Moreover, considering the merits outlined in this paper which positively affect consumer, producer and the environment, a change to a full grazing system is highly justified.

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The future of organic grassland farming in mountainous regions of Central Europe

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Abstract

8 % of the total EU population lives in mountainous areas which represent a particularly important eco-region in Central Europe. Because of ecological, climatic and economic reasons an increasing pressure is imposed upon agriculture. Hence in large parts of European mountainous areas drastic changes in agricultural structure and land use systems can be observed in terms of emigration and land abandonment. Due to disadvantaged production conditions, and the high ecological sensitivity, organic farming is an important option for a sound regional development. In alpine regions organic farming does not proceed in a homogeneous way. One essential reason for that could be seen in the differences of national and regional “traditions and orientations” and supporting tools. For a positive development it is necessary to work on further integration of organic farming in regional development concepts (e.g. organic regions) and on the development of the “quality leadership” through cross-regional production, marketing and merchandising concepts. Undisputedly, further positive development of organic farming in mountainous regions depends on ongoing financial, research and advisory support.

Keywords: oganic farming, alpine regions, agriculture, regional development, quality leadership

1. Introduction

Mountainous regions play an important role in terms of biological and cultural diversity. They provide valuable habitats, opportunities for recreation and tourism and they supply a substantial part of the European Union’s drinking water. Their ecosystems are, in most cases, fragile and highly sensitive to environmental alteration.

Various definitions of mountain areas on regional, national and international level exist. Article 18 Regulation (EC) No 1257/99 defines mountainous less-favoured areas as “those that are characterized by considerable limitation of the possibilities for using the land and an appreciable increase in the cost of working it due:

1) to the existence, because of altitude, of very difficult climatic conditions, the effect of which is substantially to shorten the growing season;
2) at a lower altitude, to the presence over the greater part of the area in question of slopes too steep for the use of machinery or requiring the use of very expensive special equipment, or;
3) to a combination of these two factors, where the handicap resulting from each taken separately is less acute but the combination of the two gives rise to an equivalent handicap”.

Areas north of 62 degrees of latitude in Finland and Sweden are assimilated into mountain areas since, even in the absence of high altitude, low temperatures limit crop growth and development and therefore severely affect the agricultural activity (EC, 2009).

In 2006, around 39.5 million people representing 8% of the total EU population lived in mountainous regions. Economic development in mountainous regions is significantly below the EU-27 average. In 2006, the level of GDP (Gross Domestic Product) per head in mountainous regions corresponded to 77% of the Union's average. This gap tends to widen slightly over time, increasing by 1.3 percentage points from 2000 to 2006 (Monfort, 2009). The relative importance of mountainous areas at the national level varies strongly in the EU, from dominant (more than 50% of farms and utilised agricultural area (UAA) in Finland, Slovenia and Austria) to marginal (less than 5% of farms and UAA in Germany and Poland) (EC, 2009). The land cover and the topography of the European mountains distinctively differ from the high mountains (Alps, Pyrenees, Carpathians, southern Norway) to the lower middle mountains, which are far larger in their extent. Land-use systems and farm management methods have developed through a long-term process, and thus have shaped and modified the natural and cultural landscapes according to the specific climatic, historical and socio-economic conditions. There is a close link between the natural environment and the cultural and lifestyle patterns of the population in mountainous regions (Dax and Wiesinger, 1998).

Today permanent grassland and meadows with low stocking density dominate the agricultural land use in mountainous regions. The most important agricultural sectors are dairy farming and beef production. Mountainous areas are not isolated from the development of the modern urban societies. Hence, in large parts of European mountainous areas, drastic changes in the agricultural structure and land use systems can be observed in terms of emigration and land abandonment, agricultural intensification in valleys, changing livestock densities, decrease of traditional farming methods etc. These changes are frequently accompanied by a decline of biodiversity, loss of natural and cultural landscapes, an increase of natural hazards, forest degradation, negative ecosystem processes, eutrophication problems, water pollution and soil degradation (Dax and Wiesinger, 1998; Zervas, 1998; Olsson *et al*., 2000; Cozzi and Bizzotto, 2004; Marriott *et al*., 2004; Nordregio Report, 2004;Tasser *et al*., 2005; Marini *et al*., 2009; Marini *et al*., 2011 ; ;). Permanent handicaps (altitude and temperature, slope, soils, low productivity, limited agricultural and business sectors, long distances, loss of infrastructure and agricultural services), natural hazards, climate change, the competition for the use of land by different users (urbanisation in valleys, tourism) and long distances to the market are weak points and threats to agriculture in mountainous regions. On the other hand, traditions and know-how in specialist food production, the positive image of agricultural products, the importance of tourism, the high proportion of many valuable habitats and wild species, the specific and not transferable values of the landscape, the combination of income sources from different sectors (agriculture, tourism) are strengths and potentials.

To support socio-economic development, infrastructure and environment both on national and European level, different funding tools exist (Pillar 1, rural development, quality policy). Whereas worldwide, the situation in most mountain ranges is dramatic (few economic dynamic, weak ecological development) the situation in Europe especially in the Alps is more differentiated (Dax and Hovorka, 2004). Figure 1 shows the strong variability of total public support per AWU (Annual Working Unit) and the farm net values added per AWU of mountain farms as well as the mountainous area percentage in selected EU countries and Switzerland. Due to various agro-political, economic, cultural and operational factors the development of mountainous regions strongly differs between countries and regions. Therefore, one example is the development of agriculture in the Alps.

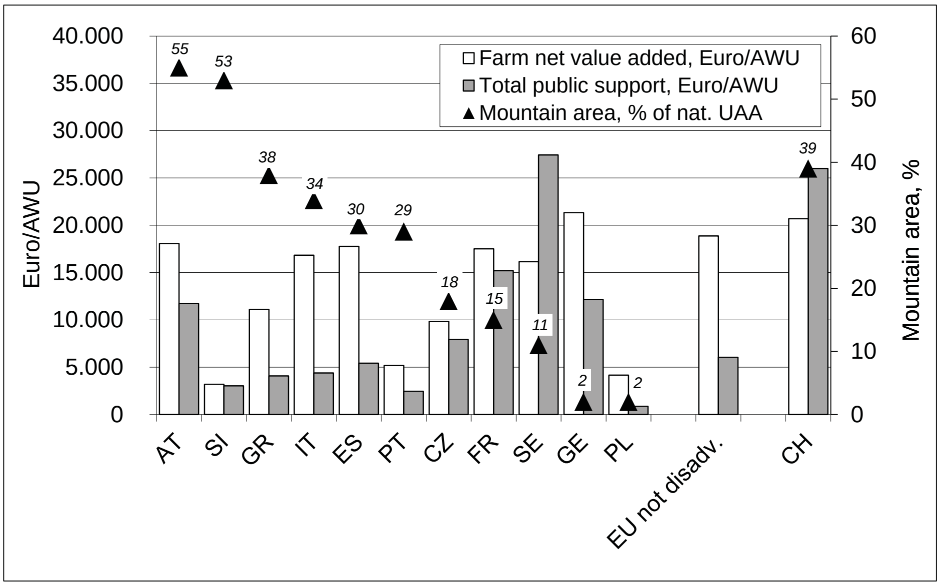

Figure 1. Farm net value added, total public support and mountainous area of farms in mountainous less favoured areas in the EU (FADN average 2004-2005) and of mountain farms in Switzerland (2009) (adapted EC, 2009; BLW, 2010)

2. Agriculture in the Alps

From 1980 to 2000 the farm abandonment rate in the Alpine Convention area accounted for approximately 36% (Streifeneder and Ruffini, 2007). Relatively stable situations were found in the Alps of Austria and Switzerland, whereas high farm abandonment rates appeared in Italy and Slovenia (Table 1). In Austria and Germany the farm abandonment rate proved to be lower than the respective national average. In comparison with the Alpine-wide average, the Alpine areas in Austria, Germany and Switzerland underwent moderate changes, whereas in Italy and Slovenia it was dynamic, and in France divergent changes regarding the number of farms and the utilized agricultural area occurred (Streifeneder and Ruffini, 2007). Nevertheless, between 2000 and 2007 the farm abandonment rate also increased in those regions that had been only moderately affected before, and regional differences within countries increased. Between 2000 and 2007 the farm abandonment rate resulting from the agro-structural change rose once more, even exceeding the 1980-2000 trend line (Streifeneder, 2009; Hoffmann *et al.*, 2010). In Austria, France and Slovenia the proportion of part-time managed farms is still traditionally high, but in all Alpine areas the share of full-time farms decreases whereas the agricultural area per farm increases (Streifeneder, 2009).

Table 1. Characteristics of mountain farms in the Alpine convention area (Streifeneder, 2009)

	Farm abandonment from 1980-2000, %			Changes in agricultural area farm^{-1} from 1980-2000, %				Full-time farms, %	
Country	Alpine area	Country	average AA, ha	< 5 ha	5-10 ha	10-20 ha	> 20 ha	Alpine area	total country
AT	-12	-32	18	-39	-20	-19	+18	35	41
CH	-34	-31	12	-62	-39	-10	+90	59	70
GE	-24	-45[1)]	20	-30	-39	-42	+17	59	44
FR	-47	-47	39	-50	-70	-65	+10	43	62
IT	-44	-24	8	-34	-42	-15	+5	62	44
SI	-56	-28	6	n.a.	n.a.	n.a.	n.a.	46	48
LI	n.a.	-47	18	-75	-70	-57	19	n.a.	n.a.

[1)] old federal states

3. Organic farming in Alpine Regions

As already mentioned in the introduction, mountain regions are disadvantaged because of the harsh climatic conditions, higher altitude and of other geomorphological conditions. Therefore in these regions productivity and intensity of land use is naturally limited, with the farming system playing a minor role. This is also based on economic reasons, as the management is much more expensive concerning specialized machinery and higher workload. Additionally, comparisons between organic and conventional farms are difficult from a methodological point of view, as different farms have different preconditions and the variance between organic and conventional farms in mountain regions is, in general, smaller than in favoured areas.

Due to the high sensitivity of mountainous regions in terms of changes in agricultural systems, well-balanced and site-specific management practices are of great importance. In this context organic farming can play a key role to support agriculture in mountainous regions so that it can be maintained. Organic farming plays a dual societal role. On the one hand it provides products for a specific market responding to consumers' demand for organic products and regionality, and on the other hand, it delivers public goods contributing to the protection of the environment and animal welfare, as well as to rural development. Organic farming can be seen as an integrated holistic agricultural approach aiming at the provision of high quality products that nurture consumer health, by respecting high animal welfare standards, by establishing sustainable management systems for agriculture which support and enhance the health of soil, water, plants and animals and the balance between them and by contributing to high levels of biodiversity and guarantying the responsible use of natural resources (EC 834/2007). Important positive effects of organic farming on the nominated protection targets of water, soil, climate and biodiversity could be proven in the current evaluation of the Austrian programme of rural development, but there is still some room for improvement (BMLFUW, 2010). Concerning structural changes in agriculture, alpine farms are increasingly faced with difficulties to remain economically viable. Organic farming presents a promising alternative for alpine farmers on the market (positive image, diversification etc.) and receives considerable financial support to compensate for disadvantages due to environmental constraints. In 2009, approximately 17% of the total remuneration of the Austrian agri-environmental programme ÖPUL (€ 548 billion) was spent for the measure of organic farming.

In the EU the growth of the organic sector was influenced by common regulation for organic farming in 1991 (EC, 1991), the inclusion of organic farming in the agro-environmental programme of the common agricultural policy in 1993, and by the growth of the consumers' demand for organic food (Padel, 2008). In 2007, the area under organic farming accounted 4.1% of the total utilized agricultural area and the proportion of organic producers in total agricultural holdings was 1.3% in the EU-27 (Eurostat, 2010). The organic area is still increasing in the EU-27 and in Norway. Denmark, Austria, and Switzerland have the highest market share of organic food with around 5-7% of the total national food market. The largest market for organic food exists in Germany (€ 5.8 billion), followed by France (€ 3.0 billion), the UK (€ 2.1 billion) and Italy (€ 1.5 billion). While organic land has expanded rapidly in many new EU Member States as well as in candidate and potential EU candidate countries, consumption levels have remained at a very low level (< 1%). With the economic crisis, market growth in 2009 has slowed down in some countries; in the UK there was even a decrease of 12.9 percent and in Germany the market stagnated. On the other hand, an increase of half a billion Euros (or +17 percent) was noted for France. For 2010, many companies have reported growth and it is expected that the overall growth rate was higher than in 2009 (Padel, 2010).

On average, organic farms receive higher subsidies in absolute terms and per hectare than conventional farms (€ 324 against € 225 per hectare in the EU-10 and € 438 against € 355 in the EU-15 in 2007). This is partly due to higher agri-environment payments (€ 127 per hectare in the organic sector in the EU-15 against € 24 in the conventional sector in 2007). Organic farms benefit from higher lessfavoured area (LFA) payments (more than twice as high as the conventional sector in the EU-10 in 2007) because they are more likely to be located in disadvantaged rural areas where extensive production systems are more predominant (EC, 2010). The size of organic area and the share in organic area as well as the number of producers differ considerably from country to country also within the Alpine countries (see Table 2). In the German-speaking Alpine regions (including Switzerland) organic farming is traditionally of great importance and shows a high proportion in all farms and land areas.

Table 2. Alpine areas and organic farming in selected Alpine States (Streifeneder and Ruffini, 2007; Streifeneder, 2009; Willer and Kilcher, 2009; BLW, 2010; BMLFUW, 2010)

	AT	CH	GE	FR	IT	SI
Alpine areas (year 2000)[1]						
Alpine area, km²	54,620	24,862	11,103	40,802	51,466	7,864
Alpine area, % of total area country^{-1}	65.1	60.2	3.1	7.4	17.1	39.3
Farms, N	96,205	19,968	22,017	28,128	93,046	23,149
Farms, % of total farms country^{-1}	33.5	28.3	7.7	9.8	32.4	8.1
Organic farming (year 2008, 2010[2])						
Organic area, ha×1000	518.2[2]	120	907.8	583.8	1002.4	29.8
Organic area, % of UAA country^{-1}	14.7[2]	11.1	5.1	1.9	9.0	6.0
Organic producers, farms	20,870[2]	5,935	18,703	11,978	45,231	2,000
Organic producers, % of farms country^{-1}	18.5[2]	11.1	5.7	2.4	2.6	2.5

[1] Note: alpine area < mountainous area
[2] Year 2010

Austria has always played a leading role in the field of organic farming and was the first country in the world to set official guidelines for organic farming in 1983. Since the end of the 1980s, the number of organic farms has increased from 1,200 in 1989 to 20,900 in 2009 (BMLFUW, 2010). The number of organic farms grew considerably after Austria entered the European Union (EU) in 1995. In total 390,000 ha AA are nowadays managed organically in Austria of which 230,000 ha are grassland. The EU still subsidizes agriculture to a high extent, and one way for small-scale farmers to obtain higher subsidies is to convert to organic farming. Other reasons for the increase in the number of organic farms in Austria are the political support, high consumer demand for organic products, consumers' interest and trust in organic production, marketing and the high availability of organic products in supermarkets (Milestad and Hadatsch, 2003). In mountainous regions of Austria organic farming is well accepted by farmers and the proportion of organic farms on the total of farms is higher than the Austrian average (see Table 3). In mountainous regions climatic and geo-morphological restrictions are the limiting factors to production, and high-output strategies are not economically common. Therefore, high-input farming systems are rare in disadvantaged regions and a lot of farms take part in the Austrian agro-environmental programme ÖPUL. In addition to organic farming, around 65,000 grassland farms contribute in special measures, which require an abdication or reduction of yield-increasing substances such as mineral nitrogen, easily soluble fertilizer and pesticides (Pötsch, 2007). These listed reasons were and are even beneficial in conversion to organic farming, which also can be an explanation that differences between organic and conventional farms cannot always be found.

Table 3. Number of mountain farms and organic mountain farms in Austria (BMLFUW, 2010)

	2002	2005	2009	Change in % 2002-2009
Number of mountain farms (with MFC[1)] points)	75,066	72,340	67,485	-10.1
Number of organic mountain farms (with MFC points)	14,408	15,183	15,214	+5.6
Organic mountain farms, % of total mountain farms	19.2	21.0	22.5	

[1)] Mountain Farm Cadastre; Increasing handicaps of management and public support in mountainous areas from MFC group 1-4

The growth of organic farming in Switzerland has been considerably slower than in Austria despite the fact that the origins of organic and biodynamic farming can be traced back to Switzerland. Since the economic and bioclimatic conditions in the two countries are also similar, the differences are likely to be caused by agricultural policy. During the years of guaranteed prices in the 1980s, there were little incentives for farmers to opt for higher returns from organic products. In 1990, the conversion of the Swiss agricultural system to direct payments with regulations for nutrient balance and ecological compensation areas boosted the share of organic agriculture. Between 1994 and 2006 the area under organic farming increased each year, but stagnated thereafter. Between 2004 and 2009 the number of organic farms in mountain regions decreased by about 12%, in line with the general decrease of farm numbers (Table 4).

Table 4. Number of mountain farms and organic mountain farms in Switzerland (BfS, 2010)

	1997	2004	2009	Change in % 1997-2009	Change in % 2004-2009
Number of mountain farms (Zone 1-4)	29,812	26,473	24,801	-16.8	-6.3
Number of organic mountain farms (Zone 1-4)	3,350	4,505	3,982	+18.9	-11.6
Organic mountain farms, % of total mountain farms	11.2	17.0	16.1		

Comparable to Austria and Switzerland, in Germany a high proportion of the country's total of organic farms can be found in mountainous regions. More than 55% of all organic farms are located in South Germany (Baden-Württemberg and Bavaria).

4. Organic farming in mountainous regions - opportunities, risks and contraints

Due to disadvantaged production conditions and the high ecological sensitivity, organic agriculture is an important option in terms of reducing the risks of farm abandonment or intensification in mountainous regions. It can support agriculture to maintain or become more environmentally and economically sustainable. What is the future of organic farming in alpine regions and how can it be developed further? Although outcomes cannot be predicted, there are trends that influence the development of organic farming.

4.1. Opportunities

Regional organic mountain quality products: There is an increasing market for quality products which are typical for different regions. The organic sector will be able to profit from this trend if it is possible to link high-quality production with tradition and innovative marketing strategies. There is a trend towards further diversification in marketing of organic products within a product group. But there is still some uncertainty for consumers by confusing labels and indications (close to nature, environmentally friendly, controlled-integrated, alternative, not containing chemicals etc.) which pretend to be organic but are definitely not! In the eyes of consumers, mountain areas and the mountain image are associated with goods of certain added value that opens up chances. On the other hand, there is still a remarkable discrepancy between declaration of intent and real purchase behaviour of consumers, and this has to be overcome. Specific promotion of ecological services by organic agriculture: So far, the existing regulations in organic agriculture only indirectly promote grassland biodiversity or other services (e.g. by limiting animal numbers on the farm, by banning mineral fertilisers and by prescribing organically produced concentrates). These constraints act at the farm level and only diffusely at the local level of ecological processes (e.g. competition between plants). More target-oriented action of organic farmers for biodiversity (such as the Swiss programme "Scoring with biodiversity") may considerable increase the willingness of the public to support this mode of production. In general more specific information is needed, which highlights the benefits of organic farming without bashing conventional farming.

4.2. Risks and constraints

Less money for rural development and agri-environmental programmes

The Common Agricultural Policy is due to be reformed by 2013. Mountain support schemes (part of the rural development programme) and organic farming support (part of agri-environmental programme) have great implications on mountain organic farms. For example, the Austria agricultural-policy aid to the mountain areas has succeeded, in part, in compensating for the production disadvantages of mountain farms (Dax and Hovorka, 2004). The dynamic development of organic farming in Europe is a positive outcome of the CAP.

Higher returns may not always be realised

A recent review among 484 farms (Ferjani *et al*., 2010) reveals that financial aspects are the main driver for abandoning organic farming. The lack of higher returns under organic agriculture was the main reason for reconversion, but also changing regulations, difficulties to obtain concentrates and weed problems were often mentioned. There is also a considerable influence of the farming type on the choice of farming system. Dairy producers were more frequently abandoning organic farming than herders of suckler cows or sheep.

Restrictions and regulations for organic farmers

It is evident that organic farming has to fulfill numerous requirements and rules, which are adopted occasionally. Beyond controversy the renunciation of yield-increasing substances (e.g. mineral nitrogen, pesticides) will always be an essential part of organic farming. Restrictions and rules are necessary for a clear and traceable differentiation but should be developed in cooperation with the organic stakeholders. For example, a challenge in organic grassland management is the availability of organic reseeding mixtures. In this special case, site-specific seeds are necessary for alpine grassland, which are often not available in organic quality.

Sometimes evidence for ecological benefits in mountain grassland is missing

A recent investigation by Lüscher *et al*. (2011) on 19 farms in a Swiss mountain region found no difference in plant species diversity in grasslands. They found that plant diversity at the farm level depended significantly on habitat diversity and farm size. The results are understandable by considering that the local management intensity is one of the primary driving forces of grassland biodiversity, and this intensity can be high or low in both organic and conventional systems. Other constraints of organic agriculture such as the ban of herbicides, mineral fertilizer or antibiotics were of little relevance to farmers in the investigated region.

As shown by the presented results the development of agriculture and organic farming in alpine regions does not proceed in a homogeneous way. One essential reason for that could be seen in the differences of national and regional “traditions and orientations”. Therefore, different tools to support organic mountainous farming are required. Undisputedly, further positive development depends on future financial support. Beside this it is necessary to work on further integration of organic farming in regional development concepts (e.g. organic regions). In this context, efforts in relation to processing and marketing of organic products are necessary as well, in spite of (or right because of) the dynamically developing organic market. A further development of the “quality leadership” needs a cross-regional marketing and merchandising concept beside the regional concept for expansion. Principally, both the term ‘mountainous agriculture’ as well as ‘organic agriculture’ have a positive image for consumers. The combination of them can essentially contribute to the hedging of mountainous agriculture. However, special support is especially needed by those regions, where the organic proportion is still low and the rate of abandoned farms is high.

5. Tasks for research

Development of organic farming in mountainous regions requires the integration of different sources of knowledge (research, policymakers, advisory services, politics, farmers, processors, marketing experts, consumers etc.). The most successful innovations arise from approaches that engage all main actors as well as the end users in the research (Padel *et al.*, 2010). There are many aspects of agriculture and organic farming in mountainous regions which require special research work and innovation. In this regard it has to be considered that mountainous agricultural area is not only a resource of fodder for animal production but also a complex agro-ecosystem. This requires a system approach in scientific work and cooperations between different sciences. Due to more standardized production systems, even in mountainous regions traditional agricultural management systems become less important. This development endangers mountainous ecosystems, the highly specific and not transferable values of the landscape and the products and therewith the sustainability of the regional production. For a sound development the research focus has to be set on qualitative issues rather than quantitative expansion. Furthermore a “one size fits all” approach is not a good recipe. Organic farming is based on traditional methods but innovations are an important complementation of this system. Therefore, organic farming research is especially necessary for a sustainable rural development in the Alpine area. The following research topics are of great interest:

- Site-adapted sustainable agriculture: There is a need to identify and develop improved management measures which are better able to integrate biodiversity and agronomy targets of species-rich farming. To improve functional biodiversity, further investigations are needed. Climate change, world population growth and uncertainties concerning supplies of fossil energy and water are research challenges. On the farm and regional level, innovations are needed to increase the efficiency of use of resources and to minimize negative impacts on the environment. Innovative nutrient recycling systems have to be developed, especially for the limited resource of phosphorus. The increasing gap between requirements of intensive livestock production (and breeding) and fodder resources available in mountain farms requires alternative low-input livestock systems. In general, the need for external feed is expected to increase with an increase in the performance level, as the demands for high forage quality also increase, especially with respect to the protein quality, and often can be covered to a lower degree by home-grown feedstuffs (Sundrum *et al.*, 2008). Therefore, it is often necessary to use some external feed materials, even though this conflicts with the principle of closed nutrient cycles. On the other hand, field studies clearly show that there is still an unused potential to improve the quality of home-grown forage, which very often could be realized without any extra costs (Pötsch *et al.*, 2010). To improve this situation both specific research and concerted advice is necessary.

Taking these different and partly conflicting objectives of organic farming into account, the principle in relation to the use of external and non-organic inputs should be: to use as few external inputs as possible and as many as necessary (Sundrum and Padel, 2006). Due to the renunciation of conventionally produced feedstuffs in the long run, the limited availability of nutrient resources is a characteristic of organic farming, and it is an on-going challenge for organic farmers to maintain a balance between nutrient demands for livestock and the organic resources available. One option may be to improve animal breeds adapted to grazing and low levels of external input. The development of herd management guidelines in which the requirements of the animals are better synchronized with the availability of the local feed sources and their introduction into farming practice will be an on-going challenge. Due to decreasing ruminant stocking rates on mountain pastures, research activities to reactivate these grassland areas are necessary. Because housing and indoor feeding of livestock are costly, innovations are necessary (co-operations, concerted production strategies etc.). Animal welfare is important both on the farm and on the market level (consumer demand) - the special production situations in mountain regions require practical and individual solutions. Through documentation of traditional management systems it will be possible to enhance modern and site-adapted agricultural systems and to design new support-instruments (economic, social etc.). There is also a need on socio-economic research to support decision makers and politicians by means of models to simulate and evaluate founding and support tools. Additionally, results of these investigations can assist farmers in their decision-making process and farm orientation (diversification, marketing of their products etc.).

- Meeting consumer`s and public demands: The advantages of organic farming in mountainous areas will only be maintained if organic farms are viable. Therefore a higher (premium) price for the products is important, but at the same time the consumers' willingness to pay must be stimulated. Trans-disciplinary research and innovations must help the food sector to meet consumer´s demand and acceptance, including the aspects of "terroir" food products that add a cultural experience beyond food as a provision (Hopkins, 2009). There is a need to document traditions and know-how in special food production, which could be the basis for cross-regional marketing and merchandising concepts. There is also a need for further research to quantify and valuate non-market "public benefits and goods". Not in all cases consumer´s, public and ecological demands are optimally fulfilled by organic regulations and farming methods - therefore a further development of the "quality leadership" of organic farming is necessary.

Conclusions

Mountainous regions play an important role in terms of biodiversity, valuable habitats, water, energy and fresh air supply, recreation sites, tourism areas and cultural heritage. Agriculture and its related activities are key components of the mountain rural economy and of land use. Although the development of economy and agriculture in mountain regions is heterogeneous, it can be concluded that farm abandonment or intensification of agriculture lead to substantial ecological and rural problems. In this regard organic farming can undertake a key role in the task to support agriculture in mountainous regions to maintain or become more environmentally and economically sustainable. A further development of the "quality leadership" needs targeted actions to promote ecological services as well as regional and cross-regional concepts in research, dissemination, marketing and further financial support.

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Oral Presentations

Which types of farms for managing mountain grasslands in the future? A prospective approach

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Abstract

Looking to the future in mountain areas, and changing agricultural markets and policies, local managers need specific tools and datasets in order to project how macroeconomic changes will affect their local livestock conditions. In response to this challenge, we worked on an approach for modelling a local-level outlook with particular focus on the various types of mountain farms. The objective is to succeed in harnessing local expert knowledge with technic-economic modelling output in order to test scenarios integrating both general and local changes. Preliminary testing of this approach focused on a grassland region in the French Massif Central. Results indicate that in such mountain areas the local impacts of CAP reform and price changes are more significant for the livestock economy than for land-use patterns and landscape management.

Keywords: CAP reform, livestock farms, grassland management, local approach

Introduction

Future changes and trends in European agricultural policies and markets will particularly affect grassland mountain farms (Chatellier *et al*., 2009), but specific evaluations taking into account the local conditions of mountain regions are difficult to produce and hard to find. For mountain regions, abandoning milk quotas and market regulations would have major consequences on the numerous small and medium-size livestock farms and their potential expansion, income and/or renewal capacities. At the territorial level, these changes could compromise certain ecological and social services as well as certain economic activities (Gibon, 2005). Given the low population density of mountain areas, local decision-makers are focused on maintaining and supporting permanent populations, such as farmers (McDonald *et al*., 2000). Local and territorial analyses and forecasts are needed in help initiate and target adapted actions in order to preserve these local livestock and grassland activities. In response to this challenge, we developed an approach for predicting the potential local effects of macroeconomic changes for a grassland mountain area and all its present farm types (Rapey *et al*., 2010; Veysset *et al*., 2010).

Materials and methods

The approach was developed and tested in a territorial community of communes which is included in a livestock area of the French Massif Central (the Mezenc plateau). The area studied is upland at over 1000 m asl, with 1200 mm of annual rainfall, and covers 23,000 ha, 75% is farmed area and totally permanent grassland. All 172 livestock farms located in this area have only permanent grasslands. These farms are differentiated according to their type of livestock farming (milk, calves, beef or lamb production) and farm size (from small, at ~35 ha, up to very large, at ~350 ha).

The main challenge to be tackled in the approach was to co-integrate the new Common Agricultural Policy (CAP) 'Health Check', evolutions in products and input prices, and new possibilities for farm enlargement as other farmers move into retirement, all during the same period, and in all farm types. Influenced by these goals, the method features five main steps: 1) to define hypotheses on the new CAP and supporting conditions (to 2015) as well as for future prices; 2) to identify the farms types that significantly reflect local agriculture (multivariate cluster analysis); 3) to formulate hypotheses on renewal and land reallocation for each farm type during the period (participatory method); 4) to model the technical-economic characteristics of each farm type today and for 2015 (economic optimization model); and 5) to extend the results from farm level to local-region level. Fifteen local experts, including decision-makers, advisors and farmers, were included on some steps (s.1, 2, 3 and 5) and thus contributed to validating or adapting hypotheses and farm types to local conditions. The approach combines modelling tools and local expertise, farm-scale and territorial-scale outlooks as well as structural and economic changes and European and local conditions.

Results and discussion

This approach is able to clarify present (called *Ref*) and future (called *2015*) local characteristics of livestock farming. Multivariate cluster analysis on the farm data (compiled from an exhaustive 2009 in-field survey) ended up with 10 cattle farm types (3 with suckler cattle: *SC1*, *SC2*, *SC3*; 4 with dairy cattle: *DC1*, *DC2*, *DC3*, *DC4*; and 3 with mixed suckler-dairy cattle: *MC1*, *MC2*, *MC3*). These 10 types cover 94% of the farm area used by the 172 farms. For the present, despite similar agronomic conditions, the 10 farm types are contrasting in terms of income, structure (farm size and workers), products and productivity (Table 1). There were no significant between-type differences in management of the farm area: stocking rate ranges from 0.7 to 0.9 LU ha^{-1}, and 40% to 48% of the area is cut for hay and wrapped-silage.

Table 1. Technical and economic results of the 10 farm types studied for Ref and 2015

	Dairy cattle farms (DC)				Mixed dairy-suckler cattle farms (MC)			Suckler cattle farms (SC)		
	DC1	*DC2*	*DC3*	*DC4*	*MC1*	*MC2*	*MC3*	*SC1*	*SC2*	*SC3*
Ref observed situation per farm-type (from surveys and typologies)										
Number of farms	3	25	4	12	8	11	3	27	24	32
Workers per farm (US)	3.80	1.40	2.30	1.20	1.25	1.75	2.30	1.00	1.50	1.30
Area per farm (ha)	180	70	101	27	74	73	118	33	133	75
Livestock Units per farm (LU)	140	49	77	22	64	62	96	30	111	65
Stocking rate (LU ha^{-1})	0.78	0.70	0.77	0.80	0.87	0.85	0.81	0.90	0.83	0.87
Ref estimated situation per farm-type (local adaptation of regional references)										
Purchased feedstuff per farm (tonne)	78.05	25.65	56.83	9.81	34.51	20.42	65.12	13.84	51.92	30.76
N fertilizers per ha (kg)	6	5	5	0	27	21	28	19	8	22
Income per worker (€ US^{-1})	12100	8715	13325	3743	17523	7701	18558	6414	19724	14713
2015 estimated situation per farm-type (percent change from *Ref* to 2015)										
Area per worker	=	+19	=	=	+16	+18	=	=	+9	+16
Purchased feedstuff	+3	-9	-6	-1	-9	-8	-8	-27	-29	-25
N fertilizers	=	=	=	=	-74	-67	-64	-100	-100	-100
Stocking rate	-1	-14	=	-3	-11	-6	-7	-7	-6	-9
Income per worker	+5	+10	+7	+53	+11	+30	+4	+11	-13	+7

An economic optimization model (*Opt'INRA*) allowed us to produce a set of technical and economic variables for these 10 farm types for the economic start-date of our study (*Ref*, validated by local experts). We used this model for each farm type to move ahead and forecast the 2015 conditions (*2015*). The *Ref* to *2015* changes of the farm types varied in terms of structure, productivity, and income (Table 1). Two main reasons explain this variability. First, the experts estimated that area and premium reallocation of retiring farmers would mainly go to medium-sized farms. Second, the consequent changes in size and labour productivity, coupled with CAP reform and price changes, increase the necessity to reduce the operational costs, particularly feedstuff and fertilizers. N application per ha was 24 kg and 14 kg for the mixed farms and suckler cattle farms in Ref, but fell to 8 and 0 kg N ha^{-1} in *2015*. Thus, stocking rate decreased from 0.85 to 0.79 LU ha^{-1}. N application remains low for the dairy cattle farms (5 kg ha^{-1}), but their stocking rate decreased from 0.74 to 0.66 LU ha^{-1}. Despite this, there was no change in management of the area (grazing and cutting). The changes on farm income per worker varied from -13% to +29%. On the whole, average annual income per worker increased by 8% (€12,681 to € 13,646 for *Ref* to *2015*) but remained low (< € 20,000/worker). The income of the smallest farms (*MC2*, *DC4*) increased but remains the lowest in real terms (< €10,000/year/worker). The largest suckler cattle farm (*SC2*) lost income due to fixed costs. Therefore, in these mountain conditions where food self-sufficiency and grassland productivity are limited, the economy of the various systems is highly sensitive to input prices and subsidies. In consequence, CAP reform and price changes should have more immediate effects on the livestock economy than on land-use patterns and landscape management.

Conclusion

The method presented in this paper has opened various possibilities for analysis at both farm and local levels. Discussions of the results with professionals and local actors have helped to select and study some possibilities. This interactive approach to the future is helpful to researchers, professional officers, farmers and local councillors in anticipation of the 2015 CAP horizon.

Acknowledgments

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Designing sustainable systems for dairy farming - a flexible approach to modelling multifunctionality in agriculture

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Abstract

The objective of this study is to explore and evaluate multifunctionality of dairy farming systems. Both current and potential new farming systems are examined using a model that combines ideas from mathematical programming and multi-criteria analysis. The first step is identifying variables with importance for multifunctionality. The different combinations of these variables are then examined using an algorithm that steps through the different combinations and generates a set of farming systems that are compared using multi-criteria analysis. This approach makes it possible to compare different farming systems with respect to several criteria. Examples of criteria are net farm income, labour input, N loss from soil, and ecological impacts. The ecological impacts of a farming system are quantified as an index using expert opinion. Sensitivity analysis will be used to examine how the weight assigned to each criterion affects the choice of farming system. The sensitivity analysis can thus provide valuable insight into how the preferences and values of individual farmers and stakeholders influence their perception of the ‚optimal' farming system. The model is flexible, new aspects of multifunctionality can easily be integrated, and the model can be scaled up from the farm to the landscape or regional level.

Keywords: biodiversity, dairy farming, environment, system modelling, multi-criteria analysis, multifunctionality

Introduction

In this study bio-economic modelling is used to describe dairy farming systems, both existing and potential, and to evaluate these systems with respect to a set of criteria for a multifunctional agriculture. One of the main advantages of a modelling approach is that novel systems which cannot be observed in real life today can be explored and evaluated (at least to some extent and based on certain assumptions). However, there are a number of challenges when modelling complex systems, such as a dairy farm with its economy, animal and plant production system, and its environmental impacts. To approach the complexity of the system, we chose to start with a simple but flexible model that can be developed step by step to improve its representation of reality. The model is written in the general programming language Python which adds flexibility and makes it easy to include new modules that enables the study of more specific questions. This paper gives an outline of the conceptual approach and the basic structure of the model. The model is still under development.

Outline of the model

The first step in the modelling process was to make a generalized outline of the farming system on a Norwegian dairy farm. A set of variables which define the farming system with respect to economic outcome and environmental impact were identified and included in the model. A livestock module and a plant-soil system module constitute the main structures in the model. In the livestock module, milk quota and either milk yield or number of dairy cows are fixed input parameters. The livestock module determines the requirements for concentrates and stored and grazed forage. These requirements are important input to the plant-soil module.

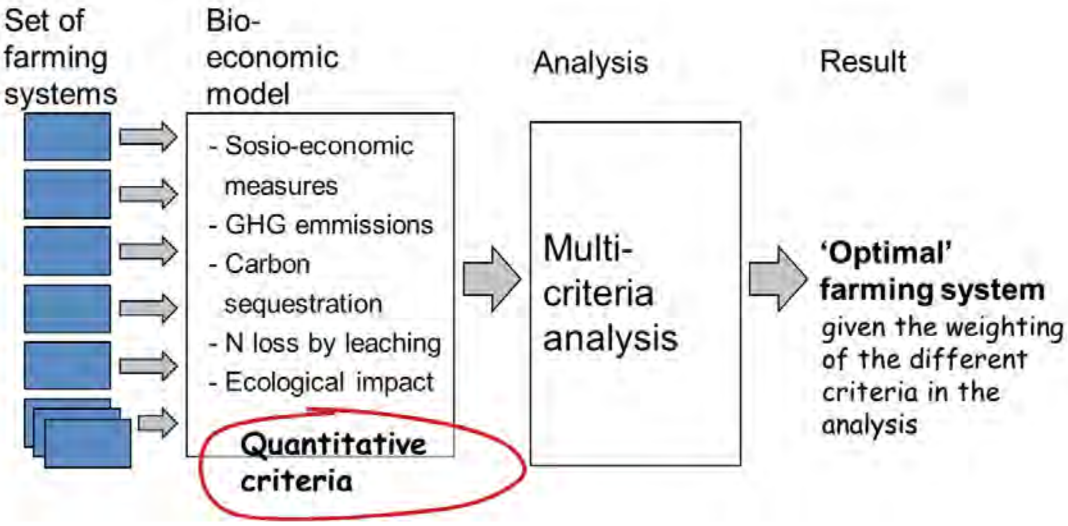

Figure 1. Conceptual outline of the approach.

The model takes some ideas from mathematical programming but should not be considered as a traditional optimization model. In our approach, an algorithm steps through the different combinations of key variables which defines the farming system (all key variables are viewed as discrete variables for this purpose). This generates a set of farming systems and the model is then used to calculate the performance of these systems with respect to different criteria for multi-functionality. In this process some farming systems will be sorted out as they do not satisfy specific requirements, e.g. there is an upper limit for the ratio of concentrates in diet. It is also possible to specify a farming system without using the algorithm above.

Criteria of multifunctionality

The criteria of multi-functionality include criteria related to socio-economic factors, climate load, clean water and biodiversity. The socio-economic criteria are in this first version of the model limited to net income and labour input. Emission of the greenhouse gases methane and nitrous oxide, and ammonia from livestock and plant-soil system are estimated using an accounting approach that builds on IPCC standards. Some adaptations are included to better describe Norwegian conditions. For livestock, N excretion per animal is calculated based on production intensity. Methane emissions are estimated from gross energy intake and a methane conversion rate, depending on livestock category, milk yield of dairy cows and feeding plan as described by Volden and Nes (2010). Emissions from livestock depend on technical solutions for housing and manure handling, and the grazing period. Emissions from the plant-soil system depend on sward and crop type, use of fertilizer and other factors such as time between ploughing and reseeding of swards. N loss by leaching and carbon sequestration in soil is also estimated in the model but these modules are still quite crude and need further development.

To evaluate the ecological impact of different management options, an ecological impact index is under development (for a similar approach, see Jouven *et al*. 2006). The vegetation is described by classifying each field according to a set of main ecological gradients, including soil moisture, nutrient status, and time since last ploughing and application of mineral fertilizer. The classification of fields also includes a simplified soil classification using a small number of soil type categories (mainly based on the proportion of organic matter in the soil). The description of the vegetation is adapted from the new system for classification of nature types in Norway (Halvorsen *et al*., 2009) and also includes a simplified description of soil type. For each field, the ecological impact index is given a value between 0 and 1, where 1 indicates that the management is considered to be ‚optimal' with respect to conservation of biodiversity in this vegetation type. The ecological impact index is related to a set of simple but also fundamental relationships in ecology like the ‚hump-shaped curve' relationship between plant diversity and productivity and the intermediate disturbance hypothesis (Grime, 1972).

Multi-criteria analysis

The final step is to compare the different farming systems in a multi-criteria analysis (Figure 1, the approach is outlined in Cooke *et al*., 2009). An advantage of this approach is that the weights assigned to each criterion in the analysis will be explicitly stated. It is therefore possible to examine how the preferences and values of individual farmers and stakeholder will influence their perception of the ‚optimal' farming system. Sensitivity analysis will be used to discuss how robust different policy instruments are towards individual preferences. The model will also be used to study how changes in agricultural policy and environmental schemes, income from farm products and costs of inputs can influence different aspects of multifunctionality in agriculture.

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Environmental impacts of Swiss milk production in the mountain region

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Abstract

70% of the agricultural area in Switzerland is covered by grassland which can be exploited only by ruminants. Milk is the most important product of Swiss agriculture - it contributes 24% to its economic output (2008). In the present study we assessed the environmental impact of Swiss milk production using life cycle assessment (LCA). Data of two years from 66 dairy farms in the plain, hill and mountain region were analysed.
The environmental impact per kg milk varied widely. The highest variation was found for terrestrial and aquatic ecotoxicity. Farms in the mountain region had significantly higher energy demand and global warming potential than farms in the plain region, mainly due to the more difficult climatic conditions in the mountain region. But there were also farms in the mountains which performed as well as the farms in the plain region. Those farms could show ways how to optimise Swiss milk production in the mountain region.

Keywords: Life Cycle Assessment, milk production, Switzerland, mountain region

Introduction

70% of the Swiss agricultural area is covered by grassland (BfS, 2010) which can be exploited only by ruminants. In addition there are alpine pastures which are not counted as agricultural area. 27% of the usable agricultural area (UAA) in Switzerland is situated in the mountain region (BfS, 2007). In this region, arable farming is - if at all - only possible on a very limited scale; and thus animal production plays an important role. Milk is the most important product of Swiss agriculture; in 2008 it contributed 24% to the total economic output (BLW, 2009). For meat production there is a lively discussion about its environmental impacts. But also the production of milk is associated with methane emissions and other impacts on the environment. In the present study we assessed the ecological impacts of Swiss milk production, particularly with regard to milk production in the mountain region.

Materials and methods

In the LCA-FADN project (Gaillard *et al*., 2008) data were collected on more than 100 farms during three years. The sampled farms were distributed over all production regions in Switzerland (plain, hill and mountain region). Each participating farm was equipped with a farm management software for collecting the required technical data, which provided the basis for calculating the individual life cycle assessment (LCA) (Hersener *et al*., 2011). In this study, data from all milk producing farms in the sample (66 farms) were analysed. In order to exclude single-year effects, the averages of the years 2007 and 2008 were used. The environmental impacts of the milk production were calculated with the Swiss Agricultural Life Cycle Assessment (SALCA) methodology (Nemecek *et al*., 2010). The functional unit was 1kg of milk. The following five environmental impacts were analysed: Non-renewable energy demand, global warming potential (100 years), eutrophication, terrestrial and aquatic ecotoxicity (assessed with the CML method, see Guinée *et al*., 2002). The statistical analysis was done with the program R (www.r-project.org). For the comparison of the three production regions the Mann-Whitney-Test was used in which the level of significance was reduced to $\alpha/3$ according to the Bonferroni correction (Stahel, 2002).

Results and discussion

The environmental impacts per kg milk varied widely (see Table 1). The variability was highest in the mountain region - except for ecotoxicity, where the variability was highest in the plain and hill region.

Table 1. Average results per kg milk and coefficients of variation for the five environmental impacts for all 66 farms (AEP = Aquatic Ecotoxicity Points, TEP = Terrestrial Ecotoxicity Points).

	Energy demand (MJ-Eq.)	Global warming potential (kg CO_2-Eq.)	Eutroph-ication (g N-Eq.)	Terrestrial ecotoxicity CML (TEP)	Aquatic ecotoxicity CML (AEP)
Average over all regions					
(Coefficient of variation)	5.6 (35%)	1.4 (20%)	15 (30%)	0.0016 (81%)	0.022 (71%)
Plain region (n = 30)	5.0 (22%)	1.3 (16%)	16 (19%)	0.0019 (106%)	0.027 (81%)
Hill region (n = 20)	5.3 (26%)	1.4 (16%)	13 (25%)	0.0016 (119%)	0.020 (52%)
Mountain region (n = 16)	7.0 (51%)	1.6 (26%)	17 (48%)	0.0011 (55%)	0.018 (79%)

The comparison of the different production regions (plain, hill and mountain region) showed a significantly higher energy demand and global warming potential for milk produced in the mountain region (Figure 1). For the other environmental impacts no difference was found between the production regions.

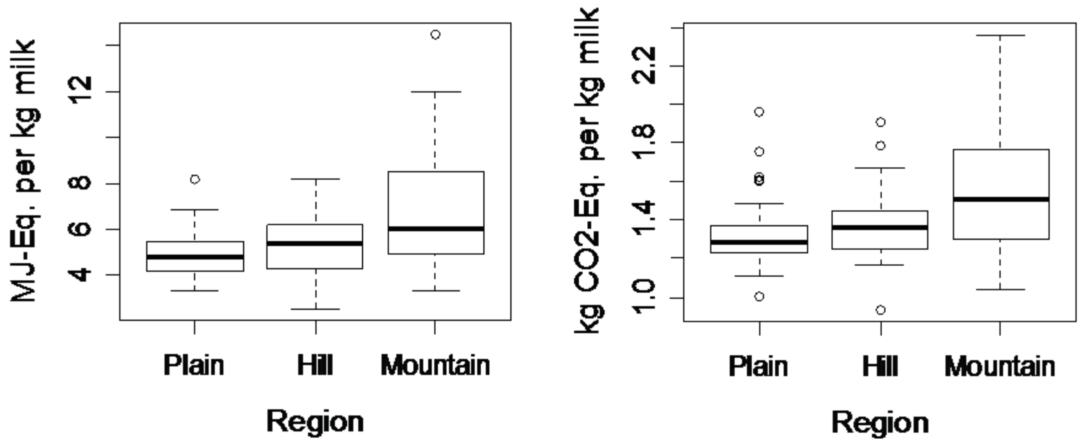

Figure 1. Energy demand and global warming potential per kg milk in the different production regions. The Mann-Whitney-Test showed a significant difference between the plain and the mountain region for both environmental impacts ($P = 0.01$).

The higher energy demand and global warming potential of farms in the mountain region could be due to the location of the farms or to their size. The farms in the mountains were generally smaller, had fewer dairy cows and accordingly produced less milk per farm than farms in the plain region. Since it is often assumed that smaller farms cannot produce as efficiently as big farms, a regression analysis was made in order to distinguish the influence of the production region and the production volume of the farm. In this analysis only the production region had a significant influence on the energy demand ($P = 0.02$). On the global warming potential only the output of milk had a significant influence ($P = 0.0009$). A closer examination showed that it was the milk yield per cow and year which mainly dominated the global warming potential per kg milk produced.

For the energy demand, the results showed that - independent from their production volume - farms in the mountain region used more energy to produce one kilogram of milk than farms in the plain region. This can be explained by the environmental conditions in the mountain region: the topography leads to higher fuel consumption. Because of the altitude the crops have a lower yield and for the same amount of fodder a larger area needs to be cultivated. In addition, the longer winter period increases the energy input for fodder conservation. This is underlined by the fact that farms in the mountain region have on average only 0.58 dairy cows per ha UAA, whereas farms in the plain region keep 0.84 dairy cows per ha UAA. Moreover, farms in the mountain region need 27% more diesel and 50% more electric current per dairy cow than farms in the plain region.
Nevertheless, the variability among farms within one production region was higher than the difference between the production regions. The higher energy consumption in the mountain region is therefore not an imperative implication of unfavourable natural conditions. Figure 1 shows that there are farms in the mountain region which perform as well or even better than the average of the farms in the plain region.

Conclusions

Farms in the mountain region generally have a higher energy demand and global warming potential than farms in the plain region. For the other impacts assessed there was no difference found between the production regions. It is not the smaller production volume but rather the more difficult climatic conditions which play the decisive role for the higher energy demand of farms in the mountain region. Nevertheless, there was a remarkable variability between the single farms, even within the same production region. Some farms in the mountain region can produce one kilogram of milk with the same amount of non-renewable energy carriers as farms in the plain region. This indicates a potential for optimisation. As a next step, those farms have to be analysed and the crucial factors for their lower energy demand have to be derived in order to improve the environmental performance of milk production in the mountain region. The results also highlight the importance of detailed single farm LCA studies. As stated by Van der Werf *et al*. (2009), inter-farm variability has not been subject to many papers yet, although it can be more important than the variability between production systems or regions. This should not be neglected when trying to improve the environmental impacts of agricultural systems.

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Feather production responses of farmed geese to diets containing *ad libitum* fresh chopped grass

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Abstract

In a feeding trial, growing geese were raised on diets containing different levels (100%, 75%, 50% and 25%) of complex grain pellet ration (CGPR) and *ad libitum* fresh chopped grass. Lower levels of complex grain ration resulted in significantly lower feather production (96.10 g, 85.97 g, 79.60 g, and 65.76 g feathers per animal of 100%, 75%, 50% and 25% CGPR respectively, $LSD_{5\%}$ = 8.26). In contrast, feather quality showed less pronounced differences among different treatments of feeding intensity. We concluded that slightly lower incomes from feathers, and remarkably lower production costs of feed, may compensate for farmers' losses attributed to reduced live-weight gains in grass-based farming systems.

Keywords: geese, feather production, feeding, chopped grass, feather quality

Introduction

The domestic goose is a multi-purpose farm animal. It can be farmed primarily for meat, but its fatty liver and feathers are valuable additional products, as well. As a relatively large bird, a goose can produce remarkable quantities of feathers at each moulting, which first occurs at about 10-11 weeks of age and every 6-7 weeks thereafter, when feathers mature.

Of the different types of feathers, soft feathers and goose down are valuable commercial materials and can be sold at a relatively high price. They are obtained by partial manual plucking of live birds. Both fine feathers and down are used to manufacture high quality bedding, especially pillows, blankets, duvets and mattresses. Items, such as winter clothing articles, quilted coats and sleeping bags are also made using goose feathers and down.

In existing farming systems, farming targets (for meat, fatty liver, feathers) are typically combined. Among these systems, there are range-type conditions based on grasslands and grazing (Buckland and Guy, 2002). Technically, these farming systems can be considered as alternative uses of grassland resources. Instead of cultivated grasslands, they are mostly practised on rangelands (e.g. China, Chile), on semi-natural grasslands (e.g. Poland, Hungary) or on less-favoured areas (e.g. mountain pastures; Habovstiak, 1987). Goose-farming systems including nutrition are adapted to the bird's physiological digestive system. Its digestive system can utilize grains and concentrates efficiently and has the capability to utilize high-fibre feedstuffs due to the microbial breakdown in the caecum and large intestine. The goose not only utilizes fibre, but even requires 4-10% fibre in its diet, depending on the age of the animal (Anrique *et al*., 1982).

In general, there are strong correlations between animal performances and animal nutrition. Meat and egg production responses of geese to different nutrition systems have been investigated for decades (Bielinska, 1977; Bielinska *et al*, 1984; Okhrimenko and Padalka, 1988); however, there are only limited results available in the literature on the feather-production responses of geese to different diets. This knowledge gap was the reason why feather production and feather quality investigations were included in feeding trials focused on diets containing different levels of daily concentrate dietary requirements supplemented with *ad libitum* fresh chopped grass.

Materials and methods

This paper presents the results of a feeding trial using the Andocs breed of goose, begun after the brooding period (4 weeks) and ending at the animals reaching 10 weeks of age (6-weeks growing period). This breed was selected from the White Hungarian Breed under hygienic conditions and is known as SPF (specific pathogen free). It is a broiler type breed with a relatively high growth rate and final live weight.

Goslings included in the experiment had been raised under intensive confinement conditions during the brooding period and fed with commercial waterfowl starter ration in the form of small pellets *ad libitum*.

During the experimental period, geese were housed indoors in an animal stable, with free access to open yards. To protect the goslings from predators, iron net fences were built around and above the open yards.

Goslings included in the experiment were separated into four groups, representing the following treatments:

1. 100% of complex grain pellet ration (CGPR) according to the typical dietary nutrient level (TDNL) for growing geese
2. 75% of CGPR according to TDNL+*ad libitum* fresh chopped grass
3. 50% of CGPR according to TDNL+*ad libitum* fresh chopped grass
4. 25% of CGPR according to TDNL+*ad libitum* fresh chopped grass

Both pelleted feed and chopped fresh grass were offered twice a day, in the morning and in the evening, which is the regular schedule for feeding geese. Grass was cut beforehand with a self-propelled rotary motor scythe, which was able to cut, chop and collect the grass. The grass was harvested from a mixed sward of 98% ground cover (gc) consisting of valuable grass species (*Festuca pratensis* gc 30%, *Festuca arundinacea* gc 30%, *Poa pratensis* gc 25%, *Lolium perenne* gc 2%, *Festuca pseudovina* gc 2%, *Trifolium repens* gc 5%)and some herbs (gc 4%), including *Achillea millefolium* (gc 2%). Drinking water was evenly available for the animals in each treatment throughout the experimental period. The feeding trial started in early summer and lasted for 6 weeks. The grass cut for the experiment had a leafy structure, as it was harvested from the second growth of the season. Each treatment consisted of 30 head of geese (n = 30). At the end of the experiment, 10 geese from each experiment were randomly selected and plucked by hand (n = 10 for feather production). Harvested feather yield per animal was measured on a precise electronic scale and was packed into a plastic bag. Bags were labelled and taken to feather-quality classification. The feather-quality classification was made by a big commercial trading company, FBZ Investment LTD (Kecskemét), which is specialized in buying, processing and selling the majority of the Hungarian feather production. The fractions of feather included in the classification system are as follows: down (% in dry weight = dw%), mature fine feather dw%, immature fine feather dw%, coarse feather dw% and sediments dw%.

Results and discussion

Harvested feather production per animal in the treatments was between 65.76 and 96.10 g on average (Table 1.) This yield is comparable (approximately 80 g per animal) to producers' expectations from a first plucking with geese at about 10 weeks of age (Buckland and Guy, 2002). Yields for treatments 1, 2, 3 and 4 were 96.10 g, 85.97 g, 79.60 g, and 65.76 g feathers per animal, respectively. Differences in feather production per animal between treatments are significant ($LSD_{5\%}$ = 8.26 g per animal) except for differences between treatments 2 and 3. The decreasing tendency of feather production per animal between treatments 1 and 4 indicates that *ad libitum* inclusion of chopped fresh grass in the diets targeted to replace growing proportions of complex grain ration reduces feather production of animals. Consequently, it seems that less intensive feeding systems in goose farming may result in lower feather production from the first plucking.

In contrast to feather production, the proportion of the most valuable fractions of feather (down and fine feathers) showed much less differences among treatments. The content of down ranged between 18.17 dw% and 20.76 dw% ($LSD_{5\%}$ = 2.62 dw%) and mature fine feather content ranged between 48.17 dw% and 52.56 dw% ($LSD_{5\%}$ = 6.14 dw%). These results were also similar to that (down 15-20 dw%, fine feather about 50% of the total weight) which producers can expect during first plucking (Buckland and Guy, 2002). Regarding the lack of any significant differences in feather quality between treatments, it seems that the intensity of the feeding system in goose farming may have no remarkable influences on feather quality and, consequently, on feather prices.

Table 1. Feather yield and quality from geese during the first plucking

Treatments	1	2	3	4	$LSD_{5\%}$
Complex grain pellet in the ration	100	75	50	25	
Feather production g goose^{-1} (*n* = 10)	96.10	85.97	79.60	65.76	8.26
Mean feather quality					
Down (dw%)	20.64	20.76	18.17	18.14	2.62
Mature fine feather (dw%)	52.56	48.47	50.88	50.95	6.14
Immature fine feather (dw%)	25.09	29.27	29.71	29.92	4.82
Coarse feather (dw%)	0.98	0.79	0.48	0.23	0.47
Sediments (dw%)	0.73	0.71	0.76	0.76	0.16

Conclusions

One practical conclusion of this experiment may be that the additional income of goose farming from feather production may depend on increased feather yield rather than on feather quality. Less-intensive feeding of geese may result in lower additional incomes (-15, -26 and -48 HUF per goose, calculated on recent feather prices, for treatments 2, 3 and 4, respectively) for farmers from feather production. However, there are remarkable savings in costs of feed per goose (170, 340 and 510 HUF for treatments 2, 3 and 4, calculated on the basis of recent food prices, respectively). The positive balances of these figures finally may improve the profitability of goose farming, even in the case of reduced live-weight gains from grass-based feeding systems (Buckland and Gay, 2002).

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Bio-energy from semi-natural grasslands? Socio-economics and risk assessment of alternative grassland utilisation in disadvantaged areas

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Abstract

In areas less favourable for agricultural production grasslands are usually managed extensively. The profitability of dairy or suckler-cow farming is often insufficient, however. In order to preserve seriously threatened semi-natural grasslands *and* small scale farming enterprises, alternative management solutions are needed. The recently suggested IFBB-technique (Integrated Generation of Solid Fuel and Biogas from Biomass) may exhibit a new alternative by using biomasses from extensive grasslands for the generation of renewable energies. This paper presents results of expert interviews amongst several stakeholder groups in the low mountain ranges of Vogelsberg, Germany, and Wales, UK, as well as of model calculations and risk modelling for different procedures of grassland processing, based on the gathered data. The expert interviews identified incentives and objections for an implementation of the IFBB technology at single-farm, local and regional level. Calculations of processing values of grassland management in different land-use alternatives and a risk modelling approach indicate that the utilisation of extensively managed grasslands in alternative bio-energy systems could exhibit the most favourable land-use option for semi-natural grassland preservation.

Keywords: competing grassland uses, Monte Carlo-simulation, expert interviews, biodiversity

Introduction

Grassland management in agriculturally disadvantaged areas such as low mountain ranges is currently often struggling to achieve economic profitability. An anticipated middle-term decrease of grassland use for feed of almost 25%, e.g. in some regions of Germany (Rösch *et al*., 2009) is to be seen alongside an ever growing demand for sustainable energy from renewable energy resources (Wachendorf *et al*., 2009). As a bio-energy procedure newly developed at Kassel University, Germany, the Integrated Generation of Solid Fuel and Biogas from Biomass (IFBB) may exhibit a promising alternative regarding the utilisation of biomasses from semi-natural grassland sites, as it is - unlike conventional biogas plants - able to use biomass low in digestibility for the generation of biogas (electrical power) and grass pellets for combustion purposes. The aim of this paper is to identify prospects for land-use systems based on semi-natural grassland use by means of model calculations and risk assessment, as well as the compilation of generally valid criteria for the suitability of a regional implementation of the IFBB procedure - applicable for any grassland region in less favoured areas or low mountain ranges.

Materials and methods

Model calculations of processing values and risk assessment for the comparison of extensive grassland management are based on the results of a survey amongst twelve conventionally and organically operating farmers in the grassland-based Vogelsberg region, Germany, as well as on expert interviews with representatives from local administration, NATURA 2000 site management, agricultural counselling and science in the Vogelsberg region, Germany, and in Wales, UK. The data were complemented and operationalized with standard data (KTBL, 2010). The calculation of costs was conducted in accordance with the standards of full cost accounting. Economic yields of landscape maintenance solely consist of single farm and compensatory payments. Factor costs were assessed with a wage rate of 15 €/h and opportunity costs for land with 75 €/ha year^{-1}. Investment costs (cost of capital) are included in the calculations for each procedure. Risk modelling was performed applying Monte Carlo-simulation (*@risk 5.5*) by allocating triangular distributions to the parameters grassland yields (t/ha), grassland production costs (€/t dry matter) and market prices for meat (€/kg) and grass pellets (€/t). The probability simulation was carried out with 10000 iterations.

Results and discussion

Based on the expert interviews, parameters which are crucial for assessments of the suitability of extensive grassland regions for the IFBB approach were identified. Parameters positively influencing the IFBB implementation process were detected as listed below: (i) At farm level, a strong personal interest in renewable energy production and involvement in the IFBB implementation process, a high 'pressure for change' (low income situation of farmers, few alternative job opportunities), the personal willingness to invest and to carry risks, as well as low path dependencies in customary agricultural practices and alternative uses for NATURA 2000 grassland (e.g. as bedding material); (ii) at local level, sufficient harvest yields and availability of NATURA 2000 or extensive grassland sites (acreage), coherent site location (reducing transport costs), good site accessibility with tractor technique, as well as average rainfalls that allow for at least one harvest per year; (iii) at regional level a strong involvement in the IFBB implementation process of different stakeholder groups (e.g. administration, machinery syndicates, consultants, potential investors), a growing infrastructure of pellet burning ovens and the availability of fixed feed-in tariffs for electrical power.
Processing values for the economic evaluation of semi-natural grassland were calculated for two animal husbandry, two bio-energy and two landscape preservation procedures. These model calculations indicate that grass from semi-natural grassland sites by trend is used especially efficiently in the examined bio-energy procedures (Table 1).

Table 1. Characterisation of extensive grassland use in several land use systems (€/t DM)*

	Suckler cows	Dairy	IFBB	DF**	Mulching	Composting
Dry matter needs from grassland, t DM yr^{-1}	223	137	3747	3420	-	-
Calculatory farming branch result, € yr^{-1}	8829	4228	326016	175598	180	-112
Processing value, €/t DM	40	31	87	51	45	-28

* Net yields 4 t DM/ha, one bio-energy unit each, stock sizes: suckler cow 60, dairy 64, ** Dry Fermentation

Dry matter needs refer to the yearly amount of feed or substrate from extensive grasslands and were presumed to be considerably lower for small-scale animal husbandry systems than for bio-energy units, referring to the local conditions in extensive grassland regions. Increase in size of animal husbandry units leads to cost degression - following the rule of the economies of scale - resulting in processing values even above the IFBB procedure. However, low-input systems such as suckler cow husbandry rely on extensive grazing, which can hardly be realized in large animal husbandry units in the investigated agriculturally small-scale and disadvantaged regions. Therefore, one solution for small-scale farms based on forage production could be the use of higher quality grassland sites in the existing decentralized animal husbandry pro-

cedures, whereas extensive surplus grassland could be used as substrate for a collaborative, locally centralized bio-energy plant.
The feasibility of the IFBB procedure considerably depends on the varying rates of future price increases of solid fuels. Influencing factors on the profitability of composting the grass are the distance of composting facilities and the disposal costs of 'green waste'. Since mulching is often prohibited under agro-environmental schemes, risk modelling subsequently was conducted for the two most likely bio-energy and animal husbandry land-use systems, suckler cow husbandry and the IFBB procedure. A comparison shows that under optimal conditions (direct marketing, low fixed costs e.g. for buildings) suckler-cow husbandry can achieve - with low probabilities - a more profitable grassland use, but reveals a broader risk potential. Although attaining moderately lower processing values, the IFBB procedure reveals a considerably lower distribution of probable results, which implies a substantially lower risk in using extensive grassland within the IFBB procedure (Figure 1).

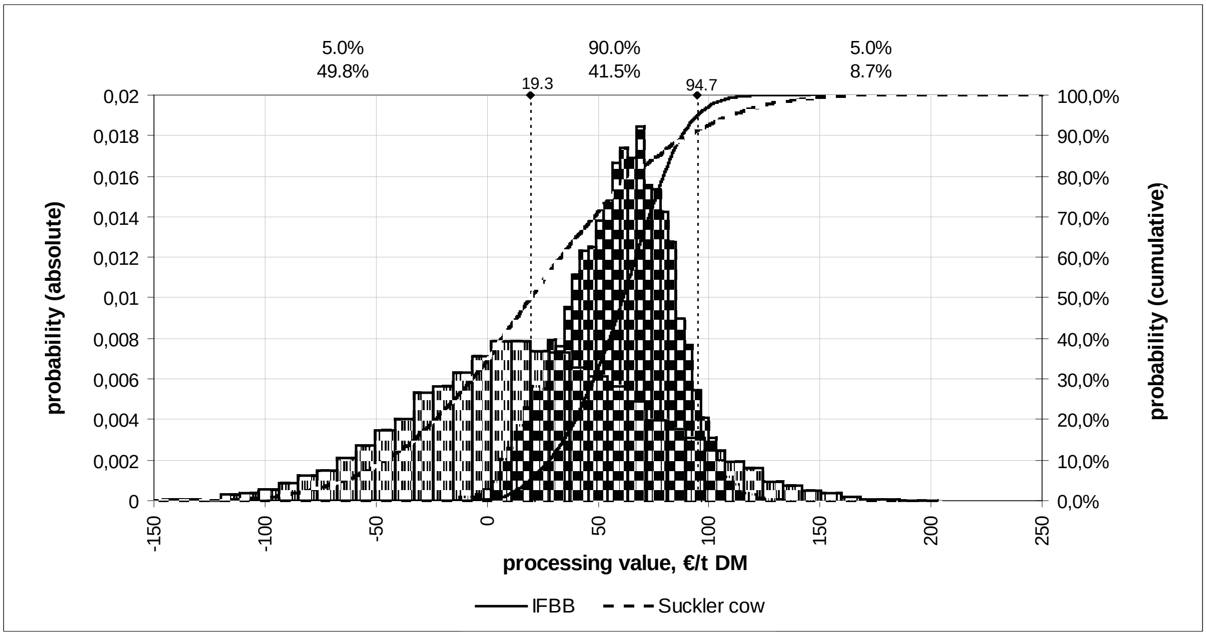

Figure 1. Risk assessment by means of probability (p) calculations of processing value (€/t DM) of semi-natural grassland used in suckler-cow husbandry and the IFBB procedure

Conclusions

The presented results indicate the favourable suitability of a regionally centralized usage of semi-natural grassland within bio-energy production (IFBB) compared to other land use systems, capable of securing valuable grassland habitats *and* additional income for small-scale farming enterprises in agriculturally disadvantaged regions, also bearing a lower risk potential.

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Poster Presentations

A new forage to be used in marginal lands with low input: *Bituminaria bituminosa* (L.) Stirt.

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Abstract

Bituminaria bituminosa, which can be grown in dry, stony and sloping marginal lands with shallow soil, can stay green throughout summer months and is resistant to high temperature and severe droughts. Different *B. bituminosa* populations were collected from Northern Anatolia. Analysis of ADF, NDF, CP, K, P, Mg, Ca and morphological traits (plant height, lateral shoot number and leaflet number) were used to monitor diversity in the collected populations. Principal component analysis was carried out using morphological and quality traits. Populations collected from Zonguldak and Sinop provinces were categorized in two main groups. Populations collected from Ordu Kumru3 district and Samsun Sarıyusuf district showed different morphological and quality characters compared to populations collected from other locations.

Keywords: *Bituminaria bituminosa*, morphological traits, quality traits

Introduction

Bituminaria bituminosa (*Fabaceae*), a perennial species widely distributed in the Mediterranean Basin and Macaronesia, has been used as a forage crop (Mendez and Fernandez 1990; Mendez, 2000). It has been cultivated in the Canary Islands and Morocco, but it is not domesticated yet, despite its high intraspecific variability and good adaptation to different Mediterranean habitats (Muñoz and Correal, 1998). It can be grown on dry, stony sloping marginal lands with high ground water level and shallow soil, and is resistant to high temperature and severe droughts. Northern Anatolia is natural growing area of *B. bituminosa* (Davis, 1970). The objective of this study was to determine some agronomical and nutritional traits of different *B. bituminosa* populations collected from Northern Anatolia.

Material and methods

Collected seeds of 24 different *B. bituminosa* populations were germinated in seed trays and transplanted into experimental fields in autumn 2009. During the experiment, no plant care treatments such as irrigation and fertilization were applied. Plant height, lateral branch number and leaflet number were investigated. To determine crude protein and the other quality traits of their hay (at the 50% flowering stage) experimental field forage samples were dried at 68°C for 24 hours. Hay samples were then ground (particle size 2 mm) and analysed using NIRS (Foss 6500)^R. Crude protein (CP) and the other quality traits were analysed from the forage samples consisting of leaf and flowers. The data, given Table 1, are the mean of 10 plants in the morphological characters and mean of 4 analyses in the quality traits.
Statistical analysis: Principal component analysis (PCA) was carried out using SPSS Version 13.0. This analysis is the two-dimensional visualization of the position of investigated exemplars relative to each other. The principal components represent the axes which are the orthogonal projections for the values representing the highest possible variances, in this case

the first and the second principal components. The obtained data were used to create scatter plot diagrams (Backhaus *et al.*, 1989). Therefore, a factor analysis was performed, whereby each variable was used to calculate relationships between variable and investigated factors. Based on the obtained data, a dendrogram (cluster) was created (Backhaus *et al.*, 1989) showing the relationship of investigated samples regarding their morphological and quality traits.

Results and discussion

It was observed that all plants kept their greenery throughout the summer months in 2010. At the end of the study, the results showed significant differences between the investigated characters and quality traits among the populations (Table 1). Plant height ranged from 47 to 108.2 cm and leaflet number varied between 260 and 1442. CP contents varied from 206.9 g kg^{-1} to 257.6 g kg^{-1}. According to other studies CP content of stem changed between 113.7 and 140.6 g kg^{-1}, regarding the average of locations. Not surprisingly, leaf + flower samples had higher CP content than stem samples (223.5-56.7 g kg^{-1}) (Gulumser *et al.*, 2010).

Table 1. Morphological and quality traits *Bituminaria bituminosa* accessions

Location	ADF g kg^{-1}	NDF g kg^{-1}	Ca g kg^{-1}	K g kg^{-1}	Mg g kg^{-1}	P g kg^{-1}	CP g kg^{-1}	LN	PH cm	LBN
Bolaman	207.3	272.2	20.80	18.30	5.20	3.70	224.5	600	92.25	20
Orencik	217.9	281.9	20.50	17.20	5.60	4.00	245.0	1010	97.00	14
Kumru 6	213.2	27.43	19.60	19.10	4.70	3.90	248.9	1234	100.00	23
Kumru 3	208.7	273.7	22.80	13.90	5.80	3.30	217.5	1080	88.80	13
Caybasi	211.0	276.2	21.40	15.10	5.70	3.60	241.9	1198	103.80	16
OMU 2	183.0	269.9	21.70	11.10	6.90	3.50	241.2	260	72.00	5
Zonguldak	193.2	289.1	21.10	15.70	6.10	3.70	234.5	484	66.75	6
Sarıyusuf	197.9	283.0	23.90	7.80	6.80	3.20	232.1	271	64.80	5
Ayancık	199.7	256.8	20.80	15.30	5.10	3.50	217.0	1297	95.00	14
Bacanak	209.9	264.5	20.80	16.70	5.80	4.00	247.7	1067	91.40	21
Cataltepe	189.0	294.2	22.00	12.10	5.90	3.40	243.2	382	56.00	9
Nebyan 2	182.5	289.3	21.30	12.20	6.20	3.50	237.3	387	58.75	7
Tıngıroglu	219.2	276.4	19.50	21.50	4.60	3.70	229.1	1240	98.00	13
Atakent	175.0	279.5	21.10	13.50	6.20	3.60	249.5	452	72.40	8
Mesudiye	201.4	248.0	20.10	17.90	4.50	3.60	230.3	1020	67.60	13
OMU 1	221.7	275.1	20.40	18.90	5.80	4.20	243.8	977	108.20	12
Gerze	231.4	286.5	21.70	13.90	5.30	3.50	229.7	789	85.00	14
Yarimada	196.2	256.0	21.40	21.30	5.80	3.80	206.9	1383	96.00	20
Kulak	219.8	285.1	20.90	16.70	5.20	3.70	240.9	1442	105.60	18
Nebyan 1	183.9	291.9	20.50	13.60	6.00	3.70	243.3	369	69.60	7
Havza	171.8	281.3	21.80	12.40	6.30	3.40	243.5	339	47.30	6
Çakalli	205.2	302.8	21.20	12.50	5.90	3.40	217.4	492	53.75	9
Tangal	197.5	242.3	20.40	16.00	4.90	3.70	257.6	821	96.00	11
Kavak	189.1	302.9	20.70	12.60	5.90	3.50	234.7	439	47.00	7

LBN: lateral branch number; LN: leaflet number; PH: plant height

The calculated first two principal components correspond to 68.1% of the present variation regarding investigated characters. PC1 corresponds to 53.3% of the total variation and PC2 to 14.8% (totally 68.1%). The obtained scatter plot using these first and second principal components is shown in Figure 1. Considering that all collected samples belong to the same species, *B. bituminosa*, it can be concluded that the genotypes collected from different locations exhibited remarkable differences regarding their morphological and quality traits.

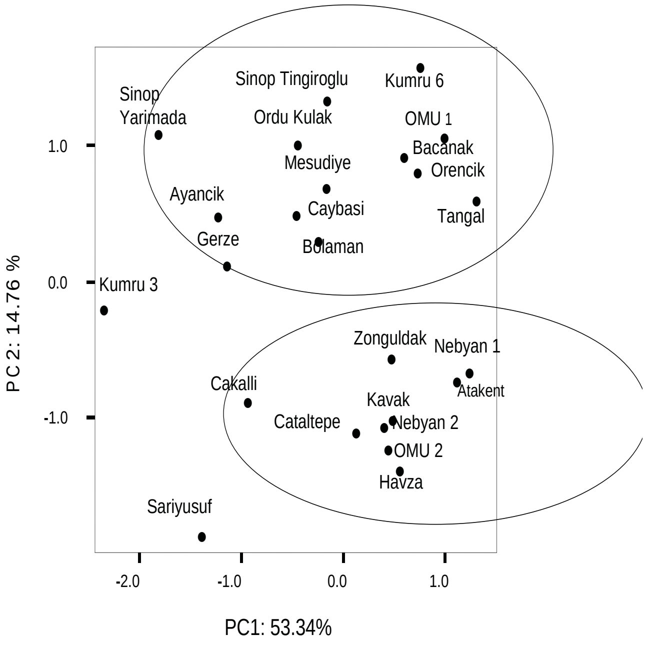

Figure 1. Scatter plot of *B. bituminosa* accessions.

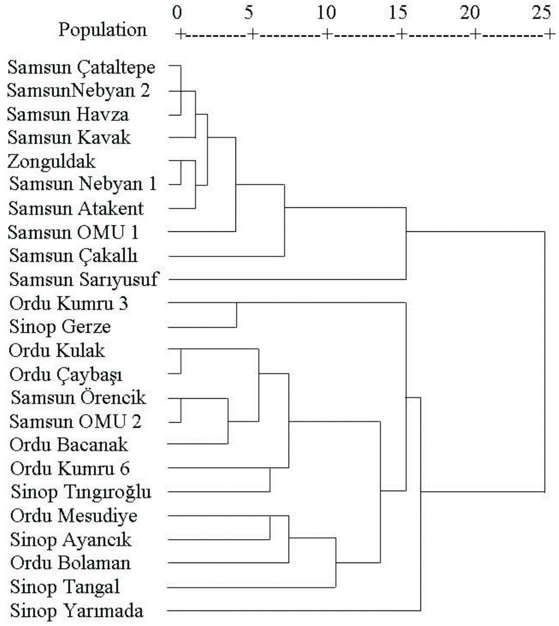

Figure 2. Results of cluster analysis of *B. bituminosa* accessions

The collection sites could be differentiated into two main groups (Figure 1). The populations collected from the vicinity of Samsun could be separated from the populations collected from Ordu Province. Populations collected from Zonguldak and Sinop provinces were categorized over the two main groups. Populations from Ordu Kumru3 and Samsun Sarıyusuf showed different morphological and quality characters compared to the other collection sites.
The dendrogram showed differentiation compared to the created scatter plot diagram (Figure 2). Figure 2 shows that populations collected from the locations Zonguldak and some districts of Samsun provinces represent a main group and include two subgroups. Ordu and some districts of Samsun and Sinop provinces represent a second main group and cover three subgroups.

Conclusion

According to morphological traits, there are differences amongst the accessions. Using morphological and quality data the investigated *B. bituminosa* accessions could be categorized into two groups. Identifiable morphological traits, such as plant height, lateral branch number and leaflet number etc. are helpful to categorize different groups to facilitate future breeding selection of the species.

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Impact of different management practices on the occurrence of some biotic disorders in turf grasses

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Abstract

The impact of different practices (type and rate of mineral fertilizers, cutting, mulching) on the occurrence of snow moulds (*Monographella nivalis*, *Typhula incarnata*), red thread (*Laetisaria fuciformis*) and graminicolous rusts (*Puccinia* spp.) was investigated in field trials (monocultures of perennial ryegrass, red fescue, Kentucky bluegrass, grass mixture and grass mixture with legumes) at three sites (Rousínov, Vatín, Zubří) in the Czech Republic. The five-times mulching system reduced the incidence of snow molds and red thread, compared with cutting. The type and rate of fertilizer did not influence the incidence of diseases.

Keywords: turf, diseases, mulching, cutting

Introduction

Extensively managed turf areas, often used as urban green spaces, are an integral part of grassland. Their functional and aesthetic values in the growing period can be adversely affected by some fungal diseases, predominantly snow moulds (*Monographella nivalis* (Schafnit) E. Müller and *Typhula incarnata* Lasch. ex F.), red thread (*Laetisaria fuciformis* (McAlp.) Burdsall and graminicolous rusts (*Puccinia* spp.) (Cagaš and Macháč, 2005). These turf areas are treated with fungicides only exceptionally. The objective of the study was therefore to find out whether some non-chemical management methods (fertilizer application, cutting or mulching) may have an effect on disease occurrence and turf damage.

Materials and methods

The occurrence of red thread, snow moulds and graminicolous rusts was studied in a turf trial with the following turf grasses: monocultures of *Lolium perenne* (a mixture of the cultivars Ahoj, Jakub, Kelt), *Festuca rubra* (a mixture of varieties Barborka, Blanka,Viktorka), *Poa pratensis* (a mixture of varieties Bohemia, Harmonie, Moravanka), a grass mixture (consisting of above-mentioned species and cultivars) and a grass mixture with legumes (the above-mentioned grass species and cultivars plus *Cynosurus cristatus* ´Rožnovská´, *Anthoxanthum odoratum* ´Jitka´, *Festuca ovina* ´Jana´, *Trifolium repens* ´Klement´ and *Lotus corniculatus* ´Lotar´). This turf trial (experimental plot size of 3.24 m^2, 3 replications) was established in the year 2006 (sowing rate of 25 g m^{-2}) at three sites in the Czech Republic - Rousínov, Vatín and Zubří. Studies were made regarding the effect of the following factors on the intensity of disease occurrence: type of N fertilizer (a very soluble form - Nitrophoska perfect, with a N-stabilizer - Entec perfect, and long lasting slow release form - Floranid permanent), annual rate of fertilizer (50 kg N ha^{-1}, 100 kg N ha^{-1}) and utilization treatments (cutting system and mulching system - each five times per year, on the Rousínov site only two cuts per year were made). The trial also involved a control treatment without any fertilizer application. The intensity of occurrence of red thread, snow moulds and rusts was evaluated using a scale from 1 to 9 (Cagaš *et al*., 2010, Schubiger *et al*., 2010). The evaluation of the occurrence of these diseases was carried out in the years 2009-2010. For statistical analyses the Statistica 9.0 program was used and ANOVA was applied for determination of differences between fertilizer types and rate and intensity of diseases. To determine differences between treatments and intensity of diseases in turf the Kolmogorov-Smirnov test was used.

Results and discussion

Large turf areas, usually part of urban green spaces, have to meet high requirements, especially from an aesthetic point of view. These can be adversely affected by some mycoses, at the beginning of the growing season, predominantly by snow moulds and later on by red thread and rusts. The expense for treatment of large turf areas are mostly limited and pesticide application is not desirable because it does not comply with the requirements of the integrated pest management. Moreover, there is a lack of registered pesticides in the local portfolio (Cagaš and Macháč, 2005). Therefore, it is necessary to find another type of treatment that can minimize the negative effects caused by biotic stress agents. In the trial no significant effects of type of N fertilizer and different rates of fertilizer on the intensity of diseases were observed. Even the highest rate of 100 kg ha^{-1} in the trial was most likely too low and the occurrence of diseases on the treated plots did not differ from disease occurrence in the untreated control. However, a five-times mulching system significantly reduced the occurrence of red thread both in the third and the fourth year of observation, compared with cutting, predominantly in red fescue and perennial ryegrass monocultures. In other cases (grass and legume/grass mixture) a similar, though non-significant, tendency was observed (Table 1, Figure 1). The same treatment also reduced the intensity of infestation with snow moulds in all types of turf in the third and the fourth harvest year. A favourable effect of mulching was observed on all sites. In the two-cut system (only in Rousínov) there was lower infestation with rusts than in the five-cut system. Mulching, which is often considered an alternative treatment, showed very good protective effects in grass monocultures and mixtures on more sites. A favourable protective effect of a similar treatment against mycoses *Cochliobolus sativus* and *Puccinia coronata* was reported by Colbaugh and Gonzales (1977).

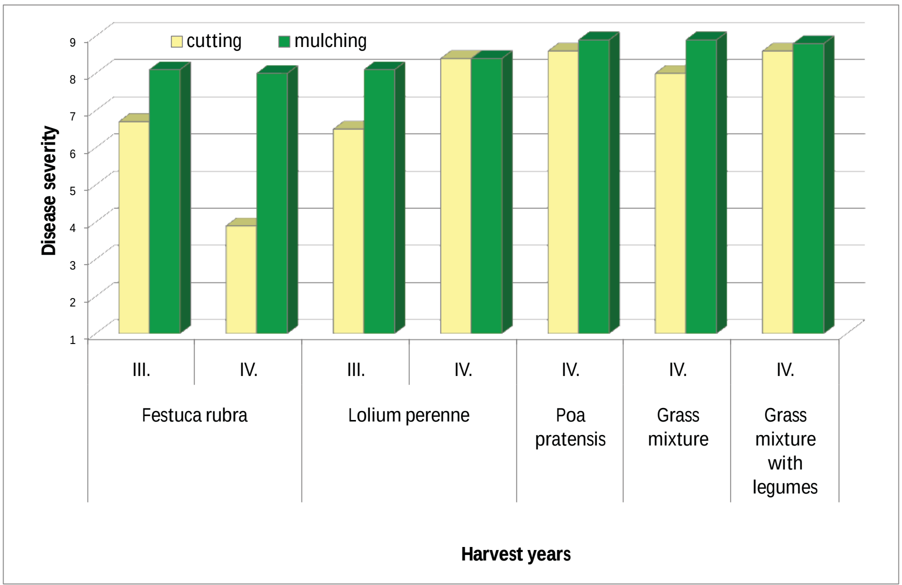

Figure 1. The impact of different treatments on the incidence of red thread in extensive turf in the locality Zubří (3rd and 4th harvest years)

Table 1. The impact of different treatment on the incidence of red thread in extensive turf in the localities Vatín and Zubří (3rd and 4th harvest year)

Turfgrasses	Locality/ observation	Harvest year	Treatment †5C	5M	Significance
Festuca rubra	Vatín	4	7.6	9.0	**
	Zubří/1	3	7.9	8.3	ns
	Zubří/2	3	6.7	8.1	*
	Zubří/1	4	3.8	6.9	**
	Zubří/2	4	3.9	8.0	**
Lolium perenne	Zubří/1	3	6.5	8.1	*
	Zubří/1	4	7.0	7.1	ns
	Zubří/2	4	8.4	8.4	ns
Poa pratensis	Zubří/1	4	7.7	8.6	ns
	Zubří/2	4	8.6	8.9	ns
Grass mixture	Zubří/1	4	8.0	8.9	ns
	Zubří/2	4	8.9	8.4	ns
Grass mixture with legumes	Zubří/1	4	8.6	8.8	ns
	Zubří/2	4	8.8	9.0	ns

†5C: 5-cut system, 5M: 5-mulching system. * ($P < 0.05$), ** ($P < 0.001$), ns (non-significant)

Conclusion

A polyfactorial turf trial on three sites in the Czech Republic confirmed that mulching five-times in the course of one season's growth can reduce the occurrence of red thread in extensively managed turf. This treatment could become part of integrated turf protection.

Acknowledgements

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Effect of live weight and walking distance on milk yield in Austrian Alps

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Abstract

Mown grassland at higher altitudes is decreasing thereby resulting in more areas available for grazing. Simultaneously, dairy herd size is increasing due to rationalization of farm management. This field study investigated the effects of cattle breed and of walking distance from the grazed area to the milking parlour on milk yield. Braunvieh had a higher milk yield than the native breed Grauvieh. However, it developed higher rates of hoof problems. The live weight of Grauvieh had no influence on milk yield per cow. Walking distances from grazing to the milking parlour alone did not influence milk yields of the herd. Grazing of some pastures near the milking parlour as well as some further away from it yielded higher than average milk. On average over the five year study the milk yield between the lowest and the highest yielding alps showed an 8% difference.

Keywords: Alps grazing, milk yield, cheese yield, cattle breed

Introduction

Grazing of alps not only serves agricultural purposes, but it also serves landscape protection, tourism (Buchgaber *et al*., 2010) and the protection of the people living there. However, conditions of farm management are changing, resulting in changes in the landscape utilization. Also, herds are increasing in size and the management of alpine grasslands is changing. This study investigated whether cows of the breed Braunvieh or Grauvieh are better suited for grazing alps and the influence of the walking distance to the milking parlour on the milk yield.

Material and methods

The study was done on the Komperdel Alp at Serfaus in the upper Inn valley of Tyrol in Austria at altitudes between 1,450 and 2,300 m above sea level. 150 to 180 cows are grazing here in one herd for three months from June to September. The cattle breeds tested were Braunvieh and Grauvieh, the latter being well adapted to the Alps. From 2005 to 2009 daily milk yield and constituents of the herd as well as cheese production were recorded. The distances from the pasture to the milking parlour, which the cows had to walk two times per day, were also measured. In addition, once a month the milk yield per cow was registered. In 2006 the live weight of 120 Grauvieh cows and 30 Braunvieh cows was recorded three times during the season.

Results and discussion

As shown in Figure 1, Grauvieh yielded a little less milk than Braunvieh. However, Grauvieh developed less hoof problems, especially during the grazing period 2006, when 12% of cows were treated or developed lameness, whereas 35% of the Braunvieh developed hoof problems. The live weight of the Grauvieh (spread: 430 to 680 kg cow^{-1}) had no influence on the milk yield per cow (Figure 1). On the other hand, the breeding of the Braunvieh in this region has resulted in higher variation between the cows. In this investigation, cows of the traditional

Braunvieh breed as well as Brown Swiss cows and crosses of the traditional Braunvieh with Brown Swiss were present. Differences between the Braunvieh breeds can therefore be also explained by different breeding practices. A trend has therefore not been calculated in Figure 1.

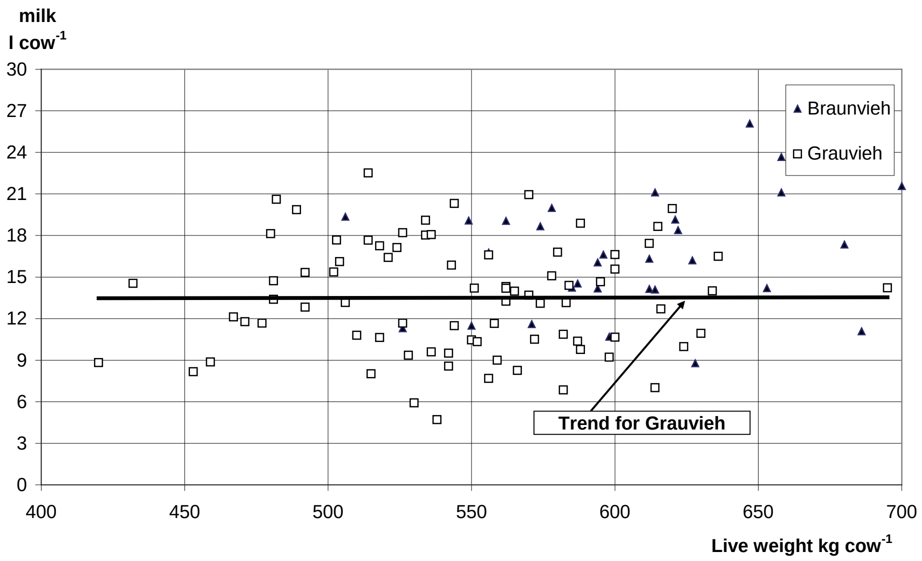

Figure 1. Comparison of live weight and daily milk yield per cow. (Only cows in milk during the whole season were considered, mean of 3 milk test records during the season)

Milk and cheese yields can change within a few days, especially when pastures have been changed. The amount of cheese produced from an individual pasture or alp can therefore be estimated. Within the grazing season this can be demonstrated each Sunday, when cows usually graze on paddocks near the milking parlour. In the evening and the following morning the milk yield of the herd is normally higher than average. Also, the urea content of the milk shows higher values, independent of the values of the previous days.
Cheese is the product that is produced from the milk of the alps. Therefore, the amount of cheese determines the value of the pastures and they can be evaluated accordingly.
Some alps near the milking parlour, so called Gampen, as well as some alps further away from the milking parlour produced higher than average cheese yields (Table 1). These alps often produce young and nutritious forages, because they are frequently grazed. The amount of cheese produced from the other alps was often found to be lower than the average. When comparing the highest and the lowest yielding alps, the differences of a 5year-average were 77 g cheese or 0.69 litre milk per cow and day, or about 8%.

Conclusions

Braunvieh produced higher yields than Grauvieh but showed higher rates of hoof problems. The bodyweight of Grauvieh had no influence on the milk yield. Some paddocks near the milking parlour as well as those further away produced higher than average yields.
Recorded over five years, the yield difference averaged 8% between the highest and the lowest yielding alps.

Acknowledgements

Thanks are due to the team of the Komperdel Alp in Serfaus and the farmers there, the Braunvieh Cattle Association and the Milk Test Association in Tyrol for help and support.

Table 1. Comparison of sites and amount of cheese

Site	No. grazing days 2005-2009	Amount of cheese above average No of days	% days	Deviation from mean (g cheese cow^{-1} day^{-1})	Distance (treading path in min.)	Site characteristics, forage conditions	Orientation	Altitude (m above sea level)
Gampen	35	23	66	+27	0	1× grazing $week^{-1}$ always young forage	All	1800-2000
Laustal	9	6	67	+10	10	a lot of herbage, good yield and quality	S, O, W	2000
Scheid	20	11	55	+8	70	Early bite with heifers in early summer; late growth if dry: good forage	S, O	2100-2300
Trya	14	7	50	+4	40	Early and often grazing, ski track, seeded grass, partly very good growth (*Trif. hybr*., *Dact. glom*., *Phleum pr.*, *Fest. rubra*)	SO	1450-1700
Seabla	9	4	44	+2	20	Even sites: good forage	SO	1750-2000
Lechar Wiesa	24	10	42	-10	15	Even sites: good forage	SO	1750-2000
Plansegg	38	15	39	-15	10	Changing sward quality	SO	2000-2300
Malfrist	12	4	33	-13	15	Changing sward quality	W	2100-2300
Kiastand Seabla, Reich	32	7	22	-36	25	Dominant species: *Nardus stricta*	SO	2000-2200
Kearb	5	1	20	-50	70	Changing sward quality	W	2150-2300
Rifa	10	1	10	-44	20	Changing sward quality, partly many sedges and much *Nardus stricta*; several years unused	SO	1750-2000

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Diet preferences of Koniks horses in disadvantaged areas: a case study from the Biebrza National Park

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Abstract

Grazing studies conducted in disadvantaged areas are restrained due to large space, environmental conditions (high water table; topography) and constraints associated with nature protection. The aim of the study was to evaluate diet preferences of free-ranging horses (Koniks) grazing on wetlands in the Biebrza National Park, N.E Poland. The research was assessed in three periods (spring, early and late summer) in 2009 and 2010 by direct visual observation, at 5-minute intervals, of randomly chosen horses grazing on a *Carex panicea*-dominated community. From 23 plant species horses selected especially the 3 most abundant. In early spring and late summer, horses mainly selected *C. panicea*, which was the most available species in the community. However, during early summer the most frequently eaten species was *Molinia caerulea*, whereas *Carex flava* became gradually more selected during vegetative season. Selectivity ratio, calculated on the basis of percentage of bitten species and their proportional share in cover of plant vegetation, showed that in summer *M. caerulea* was the most preferred species, while sedges were less preferred.

Keywords: koniks, diet preferences, wetlands, *Carex panicea*

Introduction

Konik horses, as free-ranging animals that are well-adapted to difficult environmental conditions, are useful in environmental protection in e.g. Poland, Belgium, France or Holland. Although there has been research about grazing preferences of Koniks at coastal meadows (Cosyns *et al*., 2001; Musielak and Rogalski, 2006) or forest (van Wieren, 1996) there is little knowledge about their influence on wetlands communities. Studies conducted at such disadvantaged areas as Biebrza National Park are restrained due to the large area, environmental conditions (e.g. high water table, topography) and constraints associated with different types of nature protection. Traditional field methods for grazing research (‘t Mannetje and Jones, 2000) are often impossible to apply. The aim of the study was to evaluate diet preferences of free-ranging horses (Koniks) grazing on wetlands in the Biebrza National Park by using direct visual observation method.

Materials and methods

The studies were conducted in Biebrza National Park in north-eastern Poland. The research was assessed in three periods: April (beginning of vegetation), late June (the grasses stem elongation of grasses) and the end of August (regrowth of the sward after cutting) in 2009 and 2010. Assessments were by direct visual observation at 5-min intervals of randomly chosen horses grazing a *Carex panicea* community, the species most often grazed by animals (Chodkiewicz and Stypinski, 2009). For each interval the first 10 bites per plant species were noted. The community was described in each term by noting every species and visually estimating relative cover in the vegetation. For each part of vegetative season within a year the relative number of bites per plant species and group of plant were calculated. Selectivity ratio (SR) according to Bokdam (2001) for the most-often bitten species was estimated:

$$SR = \frac{\textit{relative number of bite per plant species}}{\textit{relative cover of plant species in vegetation}} \times 100$$

The data were analysed for the whole group of bitten plants (Table 1) and also for particular species (Table 2) by using two-factor (months as a part of vegetative season and years) analysis of variance (ANOVA) using the t-Tukey test in Statgraphics Plus 4.1.

Results and discussion

The diet of Koniks grazing a *C. panicea*-dominated community consisted mainly of monocotyledons, of which sedges were the most frequently selected (Table 1). Grasses were significantly more often selected in early summer. This was related to the proportion of grasses in the sward (13% in 2009, and 5.5% in 2010). In 2010 - a year of extremely high water table in Poland - Koniks grazed significantly more sedges and other monocotyledons (*Juncus articulatus* and *Eleocharis palustris*) than in 2009. These species are associated with wet areas and they achieved good growing conditions. In contrast, the proportion of *Molinia caerulea* was much smaller, probably due to its poor development under waterlogged conditions (Gore and Urquhart, 1966). From 23 species in the community, horses preferred especially the 3 most abundant. In early spring and late summer horses mainly select *C. panicea* which was the most available species in the community (Table 2).

Table 1. Two-factor ANOVA for the average percent of bites per group of plants

Group of plants	April	June	August	LSD*	2009	2010	LSD*
	Number of observed horses				Number of observed horses		
	4	5	8	(months)	9	8	(years)
Monocotyledons within it:	99.86a	99.25a	98.12a	3.53	98.49a	99.66a	2.26
Grasses	4.13b	42.44a	16.98b	21.10	31.37a	10.99b	13.50
Sedges	95.20b	54.08a	80.15b	21.47	67.11a	85.84b	13.74
Others monocotyledons	0.52b	2.76a	1.00b	1.62	0.0a	2.83b	1.03
Dicotyledons	0.15a	0.76a	1.88a	3.53	1.51a	0.34a	2.26

*average for each factor; different letters in a row mean significant difference at the 5% level

This species was chosen in early phase of growth, when it has good feeding value (April to beginning of the vegetative season and August to the re-growth after cutting). However, *Carex flava* became gradually more selected during vegetative season. In early summer the most frequently bitten was *M. caerulea*. SR showed that in summer this species was the most preferred, whereas in other phases of the vegetative season it was grazed proportionally to its availability. *Molinia caerulea* is considered a poor grass but in early stages of growth it is characterized by good digestibility (Taylor *et al*., 2001). Within the sedges, only *C. panicea* was preferred in April and August. Values of SR below 1 show that *C. flava* was avoided. Further research connected with digestibility of preferred species is being conducted.

Conclusions

Horses mainly chose species, especially grasses and sedges, in early phase of growth. Weather conditions had a significant influence on the diet of Koniks. The method of direct visual observation of grazing animals is useful in field research in disadvantaged areas in communities with small number of species and short vegetation. *Carex panicea* seems to be the most often grazed by the animals.

Table 2. Two-factor ANOVA for the average percent of bites per particular species. B - average number of bites per species; S - selectivity ratio. Values of S between 0 and 1 show not preferable species

Species		April	June	August	LSD* (months)	2009	2010	LSD* (years)
		Number of observed horses				Number of observed horses		
		4	5	8		9	8	
Carex panicea	B (%)	87.58[a]	33.15[b]	55.08[c]	16.63	53.64[a]	63.56[a]	10.64
	SR	1.34[b]	0.66[a]	1.25[b]	0.35	0.98[a]	1.19[a]	0.22
Carex flava	B (%)	6.85[a]	11.93[ab]	21.94[b]	14.00	12.79[a]	14.36[a]	8.96
	SR	0.31[a]	0.72[a]	0.91[a]	0.75	0.66[a]	0.63[a]	0.48
Molinia caerulea	B (%)	1.74[b]	34.14[a]	9.44[b]	18.44	27.38[a]	2.83[b]	11.80
	SR	1.1[b]	3.24[a]	1.07[b]	1.40	1.93[a]	1.67[a]	0.90
Agrostis canina	B (%)	0.4[a]	4.44[a]	3[a]	6.57	1.02[a]	4.21[a]	4.20
	SR	0.2[a]	1.28[a]	0.81[a]	1.87	0.51[a]	1.01[a]	1.20

[*] average for each factor; different letters in a row mean significant difference at the 5% level

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Milk production from grazed pasture in mountainous regions of Austria - impact of calving season

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Abstract

The influence of calving season on milk yield, lactation length, composition of the diet, reproduction and nutrient supply for pasture-based systems in a mountainous region of Austria was examined with thirty-three dairy cows on an organic farm. Three groups of cows with a mean calving date of 17 November (group 1), 25 December (group 2) and 20 February (group 3) were compared. During winter periods the cows were housed and fed with grass silage, hay and a restrictive amount of concentrate. Cows were on pasture for 202 days in 2008 and 203 days in 2009 (177 day and night grazing days). The pasture area was continuously grazed at an average sward height of 4.7 cm. Calving in February (group 3) significantly depressed lactation length and milk-fat yield and tended to decrease energy-corrected-milk yield. From group 1 to 3 the amount of concentrate fed per cow decreased from 669 to 373 kg DM y^{-1} and the grazed pasture proportion increased from 43 to 50% of total feeding ration per year. Calving date had no effects on reproductive performance and frequency of veterinary treatments. However, at the beginning of the grazing season live weight loss and contents of βHBA, FFA and AST were highest in blood samples of group 3.

Keywords: grazing, dairy cows, seasonal milk production

Introduction

Seasonal dairy production of pastoral systems aims at implementing a site-adapted low-cost strategy. Both the season and calving distribution have major effects on milk yield, composition of diet and nutrient supply for pastoral milk production systems (Dillon *et al.*, 1995; Garcia *et al.*, 1998; Auldist *et al.*, 1997 and 1998; Garcia und Holmes, 1999; Häusler *et al.*, 2009). In typical pasture-based seasonal milk production regions, the majority of dairy cows calve in late winter-early spring. In mountainous regions the grazing period is quite short (5-8 months) and housing costs are high. The cows are bred for high daily milk yields and are larger and heavier on average than in pasture-based seasonal milk production regions. Under mountainous conditions a shift of the calving season to the beginning of the winter time may have positive effects on nutrient supply, milk yield and physiological parameters.

Animals, materials and methods

The experiment was performed at the organic dairy farm of the AREC Raumberg-Gumpenstein (680 m altitude, 7°C average temperature, 1014 mm precipitation year^{-1}; latitude: 47° 31/ 03/ / N; longitude: 14° 04‘26“E). A total of 33 dairy cows (13 Brown Swiss, 20 Holstein Friesian; lactation number 2.7) were assigned to three calving date groups in 2008 and 2009. The mean calving dates were 17 November (group 1), 25 December (group 2) and 20 February (group 3). During winter period all cows were housed and fed *ad libitum* with forage (grass silage, hay). Concentrate was distributed according to lactation period and milk yield, varying from 0 to 7 kg DM cow^{-1} day^{-1}. At the beginning of the grazing period grass silage and concentrate amount were continuously reduced. Grass silage feeding was completed at the beginning of the day and night grazing period (30 April). Hay was offered restrictedly (1.5 kg DM cow^{-1} day^{-1}) and concentrate was only fed to cows exceeding 28 kg daily milk yields (28-30 kg daily milk yield: 1 kg concentrate; > 30 kg daily milk yield: 2 kg concentrate cow^{-1} day^{-1}). At the end of lactation and during the dry period, cows in the cowshed got 4 kg hay and grass silage *ad libitum*. All cows were on the same pasture for 202 or 203 days (12 April-1 Nov. 2008; 15 April-3 Nov. 2009) with 177 day and night grazing days. The permanent grassland area was continuously grazed at a sward height between 4-6 cm (Ø 4.7 cm - Filip`s Folding Plate Pasture Meter). During the stable period, forage intake was recorded by 5-day recording periods each week using Calan gates. During the grazing season, at the end of lactation and in the dry period, feed intake was calculated according to the energy requirements (GfE, 2001). Nutrient and energy content of grass silage, hay and concentrate were analysed from samples pooled over six weeks (Dlg, 1997). Grazed pasture nutrient content was measured on simulated grazing plots which were cut when sward reached an average height of 8.5 cm (Starz *et al.*, 2011) and the energy content was calculated according to GfE (1998). Individual milk production was recorded twice daily and the milk ingredients were analysed three times a week. Cows were weighed weekly and the body condition was scored every second week. At the beginning of the grazing season blood samples were taken after morning milking every two weeks. Data were analysed using the MIXED procedure of the statistical program package SAS 9.2 with the fixed effects ‚calving group', ‚breed', ‚lactation number', ‚year', ‚lactation week' and ‚pregnancy group' and the continuous covariate ‚ECM-milk yield at the beginning of the lactation' (ddfm = kr; repeated statement cow within year; type compound symmetry). Statistical differences were considered to be significant when $P < 0.05$ and tended to be significant when $0.05 < P < 0.10$.

Results and discussion

According to the results of Steinwidder *et al.* (2010) and Pötsch *et al.* (2010) grazed pasture samples showed a high net energy (6.4 ± 0.33 MJ NEL kg^{-1} DM) and CP content (22 % ± 3 kg^{-1} DM). The energy contents of hay and grass silage (5.4 and 5.8 MJ NEL kg^{-1} DM resp.) and the CP contents (15% and 12% resp.) were markedly lower than that of pasture herbage. Calving at the beginning of the vegetation period significantly depressed lactation length and milk fat yield and tended in a decreased energy-corrected-milk (ECM) yield (Table 1). Contrary to group 3, the lactation curves in groups 1 and 2 showed a second peak at the beginning of the grazing season. Similar results on the lactation curves have been reported in New Zealand for autumn- and spring-calved cows by Auldist *et al.* (1997) and Garcia *et al.* (1998). From group 1 to 3 the amount of concentrate fed per cow decreased from 669 to 373 kg DM and the grazed pasture proportion increased from 43 to 50% of total feeding ration per year. The calving date had no effects on frequency of veterinary treatments and reproductive performance. The average pregnancy rate and calving interval was 85% and 365 days respectively. Nevertheless 14% of the pregnant cows had a calving interval > 415 days which indicates repeated fertility problems of these cows. At the beginning of the grazing season live weight and body condition losses, as well as the blood contents of beta-hydroxy-butyric acid, free fatty acids and aspartate transaminase were highest in group 3. In terms of management, it has to be taken into account that in group 1 all cows were bred in the winter feeding period and in group 3 during the grazing season. In group 2 the end of the grazing season fitted best with the cows' drying-off period. The milk sales revenues (milk yield and contents, premiums for winter milk) and the pasture area requirements decreased and the feeding costs increased from group 1 to 3.

Table 1. Effects of calving date on milk yield and composition of the diet

	Group				
	1	2	3	s_e	*P*-value
Lactation length (days)	299 [a]	297 [a]	284 [b]	9	0.019
ECM (kg cow^{-1})	6.300	5.974	5.449	305	0.068
Milk (kg cow^{-1})	6.360	6.135	5.727	703	0.258
Fat (kg cow^{-1})	261 [a]	245 [ab]	217 [b]	28	0.026
Protein (kg cow^{-1})	200	189	178	19	0.149
Fat (g kg^{-1} milk)	410	400	379	29	0.091
Protein (g kg^{-1} milk)	315	308	311	17	0.612
Live weight (kg)	595	550	571	39	0.069
Hay (kg DM cow^{-1} $year^{-1}$)	1.075 [a]	981 [b]	957 [b]	32	<0.001
Grass silage (kg DM cow^{-1} $year^{-1}$)	1.830	1.780	1.668	209	0.359
Grazed pasture (kg DM cow^{-1} $year^{-1}$)	2.670 [b]	2.856 [ab]	3.046 [a]	249	0.032
Concentrate (kg DM cow^{-1} $year^{-1}$)	669 [a]	541 [ab]	373 [b]	146	0.004

Conclusions

The season of the calving period markedly influenced the results of the pasture-based seasonal milk production in mountainous region. Delaying calving date from middle of November to the end of February (group 1-3) significantly depressed lactation length and milk fat yield and tended to decrease energy-corrected-milk yield cow^{-1} y^{-1}. The amount of concentrate fed cow^{-1} y^{-1} decreased and the grazed pasture proportion of total feeding ration increased from group 1 to 3. At the beginning of the grazing season live weight loss and the contents of βHBA, FFA and AST in blood samples were highest for cows in group 3.

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Profitability of organic dairy farming considering different degrees of grazing (5-year evaluation)

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Abstract

The study analyses during a 5-year period the economic situation of 50 organic dairy farms in Northern Germany with different degrees of grazing. Same-sized farms in the majority (72%) had above-average profitability if more than 60% of the energy supply from May to October came from grazing, although these farms produced 1054 kg less milk per cow. Therefore farms which can rely on high levels of pasture grass feeding should make use of this feeding system to improve profitability.

Keywords: profitability, organic dairy farming, pasture, grazing

Introduction

Dairy cows on organic farms are usually kept outdoors for grazing during the grazing period. However, the range of grazing time varies from farm to farm. In cases where there is limited availability of pasture near the milking parlour, daily grazing is limited to a restricted time per day. On farms with sufficient pasture area available near the milking parlour, grazing is allowed for most of 24 hours per day. In order to prevent grassland utilization by grazing from declining, the economic advantages of grazing have to be assessed. So far, only a few economic evaluations of stock grazing have been presented, and these do not include those from organic farms.
The following hypothesis was investigated: predominant grazing of dairy cows can be profitable even if milk yield is lower than in non-grazing systems.

Materials and methods

The following evaluation is based on four years of data obtained from 50 organic farms in Northern Germany. The calculations have been made on the basis of the farms' book-keeping data and individual farm consultations, followed up uniformly by farm branch evaluations. The production costs of the dairy farms have been evaluated according to the rules of the German Agricultural Society (DLG, 2004). This means that not only cash costs are considered but also opportunity costs for own production factors (land, labour, capital) are included.

Evaluated parameters

Data include milk production (milk yield, feeding), labour and machinery costs, profitability and loss account, capital structure. The evaluation recalculates the amount of produced milk, expressed as Energy Corrected Milk (ECM), so differences in fat- and protein contents are taken into account. The amount of concentrate fed to the dairy cows is expressed in standardized concentrate feed (E III). This term is used in the German feed advisory services. Monetary values are expressed in Euro Cent (ct).

Results and discussion

In order to estimate the milk price at which organic farms can cover production costs, a trend line of the long-term milk price has been established (Figure 1). Farms with a milk price below the trend line have less production costs than the average dairy farms of comparable herd size.

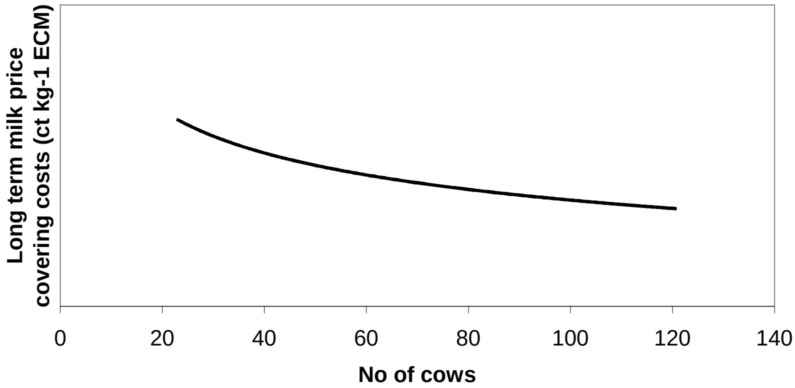

Figure 1. Correlation between the number of cows and the milk price, which covers production costs (The trend line is a mathematical derivation of the results of all farms evaluated).

The comparison of farms with different degrees of pasture shows the following: 72% of the evaluated farms with more than 60% energy supply obtained from pastures were more profitable, although they fed less than the average concentrate rates (in comparison to farms with less than 40% pasture feeding: 1180 kg instead of 1980 kg concentrates cow^{-1} and year).Cows that were predominantly fed by grazing yielded 1054 kg ECM cow^{-1} and year less milk than those with little grazing (Table 1; more details in Table 2). In the case of less grazing, only 42 to 45% of the farms were more profitable than the average. The main economic advantage of pasture is that it only costs about half as much as the same energy supplied from grass silages, and is therefore the cheapest feeding stuff; in this study the data are: 12.8 versus 26.6 ct 10^{-1} MJ NEL (Dairy Cost Calculation NRW 2008/2009, unpublished).
Results of the comparison of farms in the USA and the Netherlands with and without grazing have obtained similar results regarding profitability (Pflimlin, 2008; Evers *et al.*, 2008; Holshof *et al.* 2010). These investigations compared farms with comparable herd sizes.

Table 1. Degree of pasture and rate of successful farms 2005-2009

		Degree of pasture (1)		
		< 40%	40-60%	> 60%
		rate of more than average profitable farms (2)		
		42%	45%	72%
		Mean values, 5 years evaluation		
Milk yield	(kg ECM cow^{-1})	7467	6960	6431
Amount of concentrate (3)	(kg cow^{-1} E III)	1980	1510	1180
Amount of concentrate (3)	(kg kg^{-1} ECM)	0.265	0.217	0.184
Number of farms		16	18	16

(1) Degree of pasture grass within the total ration, May to October
(2) More than average successful farms are producing milk cheaper, when farms with equal numbers of cows are compared
(3) Included: high energy feeds (for example sugar beet pulp)

Table 2. Evaluation according to degree of grazing 2005-2009

		Degree of pasture[1]		
		< 40%	40-60%	> 60%
Dairy cows	(No.)	81	58	59
Milk yield	(kg ECM cow^{-1})	7467	6960	6413
Milk price	(ct kg^{-1} ECM)	40.3	39.9	39.5
Total output	(ct kg^{-1} ECM)	49.2	50.5	49.5
Concentrate	(ct kg^{-1} ECM)	7.8	7.0	6.0
Total feed costs	(ct kg^{-1} ECM)	24.1	25.3	23.5
Veterinary, medicine, insemination, semen	(ct kg^{-1} ECM)	1.9	1.8	1.5
Total direct costs	(ct kg^{-1} ECM)	29.2	30.4	28.1
Output exclusive direct costs	(ct kg^{-1} ECM)	20.0	20.1	21.4
Family labour input	(ct kg^{-1} ECM)	6.4	9.2	8.3
Machinery maintenance	(ct kg^{-1} ECM)	1.1	1.3	1.1
Machinery and building depreciation	(ct kg^{-1} ECM)	1.2	1.2	0.9
Total labour costs	(ct kg^{-1} ECM)	12.7	15.3	13.8
Total quota costs	(ct kg^{-1} ECM)	2.9	2.5	2.5
Total building costs	(ct kg^{-1} ECM)	3.8	4.1	3.7
Total production costs	(ct kg^{-1} ECM)	50.2	54.2	50.5
Calculated result of the dairy enterprise[2]	(ct kg^{-1} ECM)	-1.1	-3.7	-1.1
Percentage of farms, more than average successful (below the trend of the long term milk price)[3]				
Average of 5 years		42%	45%	72%
2008/2009		33%	50%	60%

[1] Proportion of pasture grass feeding of the total ration, May to October
[2] Calculated result of the dairy enterprise: difference between total monetary output and total production costs
[3] More than average successful farms with comparable number of cows are producing milk with lower costs

Outlook

Further experiments should compare farms on a broader data-basis. They should investigate the effective feeding costs with special regard to high and low amounts of pasture.

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Low input management of *Agrostis capillaris+Festuca rubra* grasslands in Romania

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Abstract

The most important factors that contribute to reductions in productivity of permanent grasslands in Romania are unfavourable climatic conditions and bad management. Within the present strategy of using organic fertilizers on permanent grasslands, there are economic and ecological concerns mainly aimed at saving resources, environment protection and, of less importance, increasing yields. This paper presents the influence of organic fertilizers, applied each year or every 2-3 years, at rates of 10-30 Mg ha^{-1}, on *Agrostis capillaris+Festuca rubra* grassland on the herbage yield and number of species in the canopy structure.

Keywords: manure, fertilization, grasslands, yield, low-input

Introduction

Meadow degradation is determined by changes in plant-living conditions and in the structure of vegetation. Over a long period of time no elementary management measures were applied to permanent meadows in Romania, and it was assumed that they could provide efficient yields without technological inputs even if grazing began early in spring and continued to late autumn. Organic fertilization has a special significance for permanent meadows if the soils show some unfavourable chemical characteristics (Carlen *et al.*, 1998). The investigations carried out until now have demonstrated that there are positive effects of reasonably applied amounts of manure on grasslands (Jeangros *et al.*, 2003; Samuil C. *et al.*, 2008; Tonn and Briemle, 2010). In this paper, we present the results obtained in a trial set up in the Pojorata - Suceava County, in the North-Eastern Carpatians of Romania, on *Agrostis capillaris+Festuca rubra* grassland.

Materials and methods

The trial was set up in 2006 on *Agrostis capillaris+Festuca rubra* grassland; altitude of 707 m; slope of 20%. Climatic conditions were characterized by mean temperatures of 6.3°C and total rainfall 675 mm. The experiment was a randomised complete block design with three replicates and plot size of 3 m×5 m. We used cattle manure (chemical composition 0.5% N, 0.3% P_2O_5 and 0.7% K_2O) to provide seven fertilization variants in addition to an unfertilized control (Table 1). In each year we obtained two cuts and the harvesting was done at ear emergence of the dominant grasses. Proportions of grasses, legumes and forbs were determined by the gravimetrical method. Canopy structure was determined in the last year of the study, 2010. To establish nutrient relations we calculated the quantity of N obtained from grassland and the N-use efficiency of organic fertilizers, based on the direct relation between them and the yield amount. Data were analysed using ANOVA and differences between averages were shown by the LSD test.

Table 1. Fertilization variants applied to *Agrostis capillaris* and *Festuca rubra* grassland

Fertilization variants	Manure applied ($Mg\ ha^{-1}$) first year	second year	third year
V_1-control	0	0	0
V_2	10	10	10
V_3	20	0	20
V_4	30	0	0
V_5	20	10	0
V_6	20	0	10
V_7	20	10	10
V_8	10	20	10

Results and discussion

In 2006, yields were between 3.0 $Mg\ ha^{-1}$ DM for the control and 4.2 $Mg\ ha^{-1}$ DM for the variant receiving 30 $Mg\ ha^{-1}$ manure fertilization applied every 3 years (Table 2). In 2007, the yields were higher than in 2006, ranging between 4.3 $Mg\ ha^{-1}$ for the control and 5.5 $Mg\ ha^{-1}$ under fertilization with 30 $Mg\ ha^{-1}$ manure applied every 3 years. In 2008, the yields were between 3.4 $Mg\ ha^{-1}$ and 5.3 $Mg\ ha^{-1}$; in 2009 between 2.1 $Mg\ ha^{-1}$ and 3.4 $Mg\ ha^{-1}$ and in 2010 between 2.2 $Mg\ ha^{-1}$ and 3.6 $Mg\ ha^{-1}$. The mean yields during 2006-2010 were influenced by type and level of organic fertilization, being between 3.0 $Mg\ ha^{-1}$ (control) and 4.2 $Mg\ ha^{-1}$ (treatment V_8). The *Agrostis capillaris*+*Festuca rubra* grassland contained a maximum of 45 species (unfertilized control) with 12 grasses, 8 legumes and 25 species from other botanical families (Table 3).

Table 2. Influence of organic fertilization on DM yield ($Mg\ ha^{-1}$)

Fertilization variants	2006	2007	2008	2009	2010	Average
V_1	3.0	4.3	3.4	2.1	2.2	3.0
V_2	3.5	5.1	4.4	2.6	2.4	3.6*
V_3	3.9	4.9	4.3	2.4	3.3	3.8**
V_4	4.2	5.5	3.9	2.5	2.6	3.7**
V_5	3.9	4.9	4.1	2.4	3.1	3.7**
V_6	3.8	5.3	4.5	2.5	3.5	3.9**
V_7	4.0	4.8	5.2	3.2	3.5	4.1***
V_8	3.6	5.1	5.3	3.4	3.6	4.2***

LSD 5%: 0.4 $Mg\ ha^{-1}$; LSD 1%: 0.7 $Mg\ ha^{-1}$; LSD 0.1%: 1.1 $Mg\ ha^{-1}$

Table 3. Influence of the organic fertilization on the composition of the canopy structure (% of coverage, number of plant species)

Functional groups/variants	V_1	V_2	V_3	V_4	V_5	V_6	V_7	V_8
Grasses	35	46	40	30	35	35	39	41
Legumes	12	18	14	30	33	33	33	30
Forbs	53	36	46	40	32	32	28	29
Number of species	45	40	40	39	37	39	40	39

Fertilization contributed to changes in botanical composition, with the proportion of grasses increasing from 35% in the unfertilized control to 46% for treatment V_2 (to the detriment of other species). The proportion of legumes was between 12% in the unfertilized control and 33% for V_5, V_6 and V_7. For the control variant, the composition of the canopy structure was: *Agrostis capillaris* (15%), *Festuca rubra* (7%), *Anthoxanthum odoratum* (2%), *Arrhenatherum* *elatius* (2%), *Briza media* (2%), *Cynosurus cristatus* (2%), *Trifolium pratense* (3%), *Trifolium repens* (2%), *Taraxacum officinale* (9%), *Achillea millefolium* (6%), *Alchemilla vulgaris* (3%), *Filipendula vulgaris* (4%), *Plantago lanceolata* (4%) and others species. The total number of species decreased to 5 to 8 species in the fertilized variants. The amount of N extracted from soil as measured in the grassland yield, and the N-use efficiency of the fertilizers, were influenced by rates and combinations of fertilizers (Table 4). The highest N-use efficiencies were 32 and 40% (treatments V_3 and V_4) and the lowest coefficient of 12% was obtained for treatment V_8.

Table 4. Nitrogen exported (taken up as part of grass yield) and nitrogen-use efficiency for different fertilization treatments

Fertilization variants	Applied N kg ha^{-1}	Exported nitrogen in grass yield		Nitrogen-use efficiency (%)
		Total kg ha^{-1}	Difference to the control kg ha^{-1}	
V_1	0	39	-	-
V_2	50	48	9	18
V_3	50	55	16	32
V_4	50	59	20	40
V_5	125	57	18	14
V_6	116	55	16	14
V_7	141	59	20	14
V_8	116	53	14	12

Conclusions

Herbage yields were influenced by type and level of organic fertilization. The management of permanent grasslands, in terms of usage, intensity of fertilization and control, greatly influences the DM production, species composition and the dominance of species in the canopy. The nitrogen uptake by grassland and the N-use efficiency of fertilizers were influenced by the rates of spread manure. The highest coefficient of using nitrogen was obtained for treatments V_3 and V_4. In practice we recommend the variants V_3 and V_4, where the yields and the structure of canopy were comparable to variants V_7 and V_8 and the N-use efficiency values were highest.

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Towards an efficient energetic conversion of landscape conservation material

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Abstract

Converting unutilised biomass into energy is an important factor for achieving the European aims of limiting CO_2 discharge and increasing the amount of bioenergy used. A source of this biomass is green garden waste and landscape conservation material which does not compete with scarce agricultural areas. The University of Kassel developed a process to produce solid fuel from such biomass with improved combustion characteristics through hydrothermal conditioning and mechanical dehydration, the integrated generation of solid fuel and biogas from biomass (IFBB). In the present study the feasibility of this system for green cut waste material was evaluated. The results showed that the procedure is able to produce high quality solid fuel and biogas from green garden waste. Elements detrimental for combustion were reduced. The ash softening temperature and lower heating value of the material were improved from 1053°C to 1245°C and from 12.26 to 16.45 MJ kg^{-1}, respectively. Methane yields of the press fluid were 254-359 L_N CH_4 kg^{-1}VS.

Keywords: bioenergy, green cut waste, landscape conservation, fuel quality

Introduction

Reduction of greenhouse gas emissions as a measure to tackle fight global climate change is one of the major aims of the European Union, which therefore has enacted the European Biomass Action plan (Anonymous, 2009). Germany has the goal to produce as much as 20% of its total primary energy consumption from renewable energy sources by the year 2020. To reach this aim in a sustainable way it was proposed to increase the use of waste products for production of bioenergy (Zah *et al*., 2007). It is recommended to use the energy embedded in biological waste fractions that are nowadays often used as compost. The University of Kassel has developed a system for the energetic use of heterogeneous and senescent plant material, the IFBB (Integrated generation of solid fuel and biogas from biomass) system (Wachendorf *et al*., 2009) in which the biomass is subjected to hydrothermal conditioning and subsequently processed using a screw press, which results in a press fluid for biogas production and a press cake for direct combustion as solid fuel. Drying of the press cake with the waste heat from the biogas combustion is a key aspect of this procedure. The IFBB technique produces a storable solid fuel with improved combustion qualities and an easily digestible press fluid, which guarantees high methane yields in short retention times. The aim of this study is to test the eligibility of the IFBB process for green cut materials.

Material and methods

The green cut material was sorted into two fractions by hand, the shrub fraction (S100; mainly small branches with leaves) and the herbaceous fraction (S0; mainly grass cut from lawns). Soil and large wood parts were sorted and taken out. All samples were chopped and the shrub fraction was milled with a hammer mill (B. Maier Zerkleinerungstechnik Ltd., Bielefeld, Germany). Samples of S0 and S100 material were taken at two dates (26.08 and 31.10) in the year 2008 and additional mixtures were produced with 33% (S33), 50% (S50) and 67% (S67) of shrub fraction. Afterwards the material was ensiled for three months in polyethylene barrels. After ensiling, the material was mashed with hot water at 40° and pressed through a screw press (Type Av, Anhydro Ltd., Kassel, Germany). The conical screw had a pitch of 1:6. The rotational speed was 6 revolutions min^{-1}; the sieve of the press was 1.5 mm in diameter. Samples of raw material (RM) before and after conditioning, press fluid (PF) and press cake (PC) were analysed for dry matter (DM) content after 48 h drying at 105°C. Crude ash was determined through burning in a muffle type oven at 550°C. Concentrations of potassium (K), magnesium (Mg), calcium (Ca), chlorine (Cl) and sulphur (S) and phosphorous (P) in RM and PC were determined by X-ray fluorescence-analysis. The concentration of carbon (C), hydrogen (H), oxygen (O) and nitrogen (N) were determined by using an elemental analyser (EA 1106, Carlo Erba Ltd., Rodano, Italy). The mass flows (MF) of each specific component into the PF were calculated according to Richter *et al.* (2010). Digestion experiments were carried out with the press fluid in a batch process described by Zerr (2006) according to the German Standard (VDI 4630, 2004) with two replicates to investigate methane yields. Lower heating value (LHV) of the PC was calculated using the formula of Boie (Hartmann, 2009). Ash softening temperature (AST) was calculated for RM and PC on the basis of the concentrations of Ca, Mg and K (% of DM) according to the formula of Hartmann (2009).

Results and discussion

Mass flows of DM varied between 0.11 and 0.20 (Table1). MF of DM was high in herbaceous material and decreased with an increasing contribution of shrub material. For Cl and K, high MF could be observed, while for Mg, P, S and Ca mass flows were intermediate. Only for N the MF into PF were lower than for DM, resulting in an undesirable increase of N in the PC.

Table 1. The relative mass flows (%) of nutrients into press fluid for a hydrothermal conditioning treatment at 40°C (S0, S33, S50, S67, S100 = 0, 33, 50, 67, 100 vol% of shrub material).

	S0	S33	S50	S67	S100
DM	20.06	20.26	16.78	14.29	11.73
K	81.41	83.22	84.01	83.01	47.51
Mg	58.12	58.28	57.89	53.72	71.88
Ca	35.47	43.18	42.39	46.28	28.12
Cl	99.36	99.20	99.95	98.49	99.39
S	55.33	60.15	59.03	62.84	45.19
P	63.73	66.07	61.85	56.96	47.24
N	4.09	25.79	12.30	15.56	5.99

For Mg, Ca, S, P, Cl and K the mass flows were similar to studies of Bühle *et al.* (2011) who investigated the use of this process for rye and maize whole crop silage and Wachendorf *et al.* (2009) for semi-natural grasslands. Only the MF of N was remarkably lower, which can be explained by the higher maturity of the investigated plant material in this study. In mature plant material a higher proportion of N is incorporated in structurally insoluble proteins and therefore cannot be reduced through hydrothermal conditioning.

Methane yields from anaerobic digestion of press fluids

For pure herbaceous (S0) material the average methane yield was 359 L_N CH_4 kg^{-1} VS (volatile solids), for S100 it was 254 L_N CH_4 kg^{-1} VS. Methane yield decreased with increasing shrub content. The readily digestible herbaceous fractions produced methane yields which were comparable to results for PF from semi natural grasslands (396-415 L_N CH_4 kg^{-1} VS) as observed by Richter *et al.* (2009).

Quality of solid fuel

For all mineral elements, except N, hydrothermal conditioning led to a reduction of mineral concentration in the press cake. Concerning Mg the reductions were between 30% and 46% and the concentrations in the PC were between 1.53 and 2.25 g kg^{-1} DM. For K, which is responsible for corrosion problems and ash slagging in combustion, the reductions ranged from 64% to 79% and the concentrations in the PC were between 2.68 and 5.13 g kg^{-1} DM. Less reductions occurred for Ca (3 to 29%) and the concentrations in the PC ranged between 8.44 and 11.17 g kg^{-1} DM, which has a positive effect, as calcium leads to a higher ash softening temperature. Maximum reduction was achieved for Cl. Reduction rates were 97% or above. Cl concentration in the PC was between 0.001 and 0.051 g kg^{-1} DM. S was reduced between 26% and 51% and concentrations in the press cake were between 0.54 (S100) and 1.48 g kg^{-1} DM (S0). N concentrations in PC were between 6.77 g kg^{-1} DM (S100) and 14.45 g kg^{-1} DM (S0). Reductions rates for P were found to be 31% to 62% and the content of P was low in the S100 material with 0.89 g kg^{-1} DM and somewhat higher in PC of S0 (2.04 g kg^{-1} DM). For all fractions the PC showed a higher AST than the RM, mainly caused through the reduction of K and Mg. The S0 material showed an AST of 1053°C before conditioning. For the processed S0 material the AST was 1245°C. The AST of the shrub fraction was 1244°C for RM and 1287°C for PC. There was an increase in the lower heating value (LHV) for the PC compared to the RM, being pronounced for S0 and S100. The LHV for S0 rose from 12.26 MJ kg^{-1} DM to 16.45 MJ kg^{-1} DM and reacted similarly to hydrothermal conditioning for the mixtures and for S100.

Conclusions

The results showed that it is possible to produce a high-quality storable solid fuel from heterogeneous green waste material through the IFBB process. The hydrothermal conditioning effectively lowered the content of undesirable minerals in the solid fuel, especially for Cl and K. The process provided a solid fuel with a higher AST and heating value. The produced PF is a highly and fast digestible material for anaerobic digestion.

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Seasonal changes in grazing behavior of sheep and goats in communal Mediterranean rangelands of northern Greece

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Abstract

Rangeland use depends to a great extent on grazing animal movements which are largely affected by the shepherd himself, but are also related to the grazing season as well as the type of livestock species. In this paper, the feeding time of sheep and goats allocated to four forage groups (woody species, grasses, forbs and cereal stubble) within representative flocks were recorded in different seasons of the year. Sheep and goats spent more time ($P \leq 0.05$) feeding on grasses during spring (56.4%) and winter (45.4%) than summer (28.5%) whereas they spent more time ($P \leq 0.05$) feeding on forbs during summer (51.5%) compared to spring and winter. During the summer period, when cereal stubble fields were used for grazing, sheep and goats devoted 23.5% and 9.9% respectively of their feeding time to stubble.

Keywords: animal movement, small ruminants, animal preferences, diet selection

Introduction

The breeding system of sheep and goats in northern Greece is mainly based on traditional grazing of communal rangelands which provide herbage to animals only for 6-7 months of the year (Yiakoulaki *et al*., 2003). Temporary pastures with winter cereals during early spring, and cereal stubble fields after harvesting during summer, are widespread practices of farmers in order to fill the feed gaps throughout the year. Sheep and goat flocks following specific grazing circuits from sheds to rangelands and agricultural fields come across an extremely heterogeneous environment which motivates their feeding behaviour. An understanding of grazing animals behaviour in such a complex environment is essential for optimizing the management of sheep and goat flocks and at the same time preserving the landscape as best as possible. In this paper, the seasonal change of sheep and goat grazing behaviour in communal Mediterranean rangelands was examined. Such information is important for determining the seasonal impact of sheep and goats grazing on rangelands and adapting the grazing management accordingly.

Material and methods

The research was conducted in Lagadas County, located northeast of the city of Thessaloniki, northern Greece, during spring and summer of 2007 and winter of 2008. The study area has a total surface of 7871 ha. Mean annual precipitation is 556 mm and mean air minimum temperature 3°C indicating a semiarid mediterranean climate. Topography varies, with the flat areas occupied by arable lands and the hills and mountains covered by natural vegetation. The latter is dominated by evergreen shrublands mainly composed of kermes oak (*Quercus coccifera* L.) interspersed by openings with herbaceous species. Animals were guided by shepherds to grazing areas during the main part of the day while at night they were sheltered in sheds. The role of shepherds is to prevent damage to the privately-owned arable crops when grazing in adjacent rangelands, and also to ensure that the animals return to the shed at night.

The feeding time (the time that animals spent grazing and browsing) of four representative sheep and goats flocks (two flocks from each animal species) was recorded in different seasons of the year. Both species are raised for milk and meat. A focal sampling technique (Altman, 1974) was applied to six adult female animals (three sheep and goats of each flock) that were marked with large numbers on their sides for identification. The animals were followed continuously by three observers for two consecutive days in each studied period. The length of time devoted to feeding on the component forage groups of rangelands, i.e. woody species (shrubs and shrubby trees), grasses and forbs (broadleaved species including legumes), and agricultural fields (cereal stubble only in summer period) was recorded. It was assumed that the time spent at each forage group reflects its proportion in the diet. In addition, forage cover of the grazing areas in each season was measured with the line and point method (Cook and Stubbendieck, 1986). More specifically, two transects of 25 meters each were used in plots 30×30 m in size and observations (plant species, litter and bare soil) were recorded every 0.5 m. Normality tests were applied on the data and an arcsine transformation was used when needed. Subsequently, they were subjected to analysis of variance by applying a nested factorial design. When significant, means were compared with the Duncan Range Test ($P \leq 0.05$). Since cereal stubble was grazed only in summer, the time devoted to this forage group was excluded from the seasonal analysis and processed seperately with a nested design (Hicks, 1973).

Results and discussion

Forage cover of woody and herbaceous species of rangelands is presented in Table 1.Woody species were the predominant forage group, whilst grasses and forbs contributed evenly in all seasons. Cereal stubble fields were dominated by stubble (34.8%) followed by grasses (30.1%), forbs (14.4%) and woody species (3.1%).

Table 1. Mean forage cover (%) of rangelands during the whole year

Season	Woody species	Grasses	Forbs	Litter[1]	Bare soil	Total
Spring	36.3	21.9	25.6	6.0	10.2	100
Summer	47.9	22.5	21.6	4.4	3.6	100
Winter	43.9	11.3	6.6	18.9	19.3	100

[1] Leaves and shoots on the ground.

The length of time devoted to feeding on the component vegetation groups of rangelands during the three seasons irrespectively of the animal species is shown on Table 2. In general, sheep and goats spent most of their feeding time on herbaceous species.

Table 2. Feeding time (min) and percentage (%) of time spent on different forage groups irrespectively of the animal species

Season	Feeding time (min)	Woody species	Grasses	Forbs
Spring	177.3	27.5b	56.4a	16.1b
Summer	178.4	20.0c	28.5b	51.5a
Winter	150.8	43.7a	45.4a	10.9b

Means of forage groups within the same column followed by a common letter were not significantly different ($P \leq 0.05$).

Specifically, they spent more time ($P \leq 0.05$) on grasses during spring and winter than summer, whereas they spent more time ($P \leq 0.05$) on forbs during summer compared to spring and winter.

Taking into account the kind of animal (Table 3) goats were found to spend more time ($P \leq 0.05$) grazing on woody species than sheep, while sheep spent more time on grasses and forbs compared to goats. In the summer period, when cereal stubble was used for grazing, sheep were found to spend more feeding time on stubble compared to goats but no significant differences ($P \leq 0.05$) were found.

Table 3. Percentage (%) of time devoted to feeding by sheep and goats on different forage groups during the whole year (irrespectively of the season) and during summer

	Whole year				Only in summer				
Animal species	Feeding (min)	Woody species	Grasses	Forbs	Feeding (min)	Woody species	Grass	Forbs	Cereal stubble
Goat	176.0	60.6a1	23.6a	15.8a	239.0	35.8a	17.6	36.7	9.9
Sheep	161.7	0.2b	63.3b	36.5b	185.6	0,2b	30.4	45.9	23.5

1 Different letters in the same column reflects significant difference ($P \leq 0.05$).

Different results in grazing behavior of sheep and goats have been reported by Yiakoulaki *et al*. (2005, 2009) working in the same area but in different environments (different combination of resources) suggesting that animals adapt their grazing behaviour to the particular environments they feed.

Conclusions

In general, sheep prefer herbaceous species and goats woody species, but both animal species adapt their grazing behaviour to the forage groups available at each season. During summer, both animal species modify their diet selection by including cereal stubble as well.

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Use of green manure for organic seed production of perennial forage grasses

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Abstract

The main objective of the current study was to evaluate the effects of six legume species (*Trifolium pratense*, *Medicago sativa*, *Trifolium repens*, *Galega orientalis*, *Medicago lupulina*, *Trifolium resupinatum*) ploughed down as green manure, on the seed yield of timothy (*Phleum pratense*) and meadow fescue (*Festuca pratensis*). Legumes were undersown into barley. In the first year of production legumes were chopped and ploughed down for green manure in June. The sown timothy and meadow fescue were used for organic seed for three years. Although *T. resupinatum* grew well in the year of sowing it completely disappeared after winter. Based on 3-year mean production data, the highest timothy and meadow fescue seed yield was obtained after ploughing down a mixture of three legumes (*T. pratense* + *M. sativa* + *T. repens*). Seed yield increased by 27.8-33.1%. Ploughed-down pure legumes (except *G. orientalis*) gave a lower but significant increase in seed yield. Having ploughed down legumes, the positive effect on organic seed was more substantial in the second and third years of production.

Keywords: *Phleum pratense*, *Festuca pratensis*, green manure legumes, organic seed.

Introduction

Timothy is suitable for mixtures with red clover and meadow fescue, and therefore very suitable for organic farming (Arlauskiene and Maiksteniene, 2004). According to Regulation EEC 2092/ 91 (ORGANIC) seed and vegetative plant material for organic farming should be organic. There is a shortage of organically grown seed of perennial grasses. In Lithuania, the experience, and research, of growing such seed is scarce. In Norway, comprehensive studies have been done on timothy, white clover, red clover and alsike clover (Aamild, 2002). In Denmark, as in Norway, growing of grass seed together with legumes has been tried (Deleuran and Boelt, 2000). Slurry and liquid manure are frequently used for fertilization of grass seed crops. If manure is unavailable on an organic farm, grasses can be supplied with nitrogen by ploughing down green manure or legume intercropping. The aim of this study was to identify suitability of legume species for green manuring for growing meadow fescue and timothy for seed on an organic farm.

Methods and materials

Field experiments were set up in central Lithuania (55°23‘N, 23°51‘E) on a medium-textured *Endocalcari-Endohypogleyic Cambisol* with a thickness of the plough layer of 25 cm, pH 7.0 - 7.1. Six legume species were tested for green manuring and undersown in spring barley (*Hordeum distichum*). Legumes were not sown in the plots of the control treatment. A full seed rate of legumes, which is recommended in Lithuania for herbage growing for forage with a cover crop, was sown: red clover cv. Vyliai (*Trifolium pratense*) 12 kg ha^{-1}; lucerne cv. Birute (*Medicago sativa*) 12 kg ha^{-1}; white clover cv. Atoliai (*Trifolium repens*) 8 kg ha^{-1}; fodder galega cv. Gale (*Galega orientalis*) 30 kg ha^{-1}; black medic cv. Arka (*Medicago lupulina*) 8 kg ha^{-1}; Persian clover (*Trifolium resupinatum*) 8 kg ha^{-1}. The legume mixture (red, white clover and lucerne) 10.6 kg ha^{-1} comprised equal proportions of seed of each species. In the sowing year, having harvested barley at grain milk-wax maturity stage for whole-crop silage, legumes were grown until late autumn. The next year, in the second 10-day period of June, we estimated the DM yield of the above-ground part of legumes and root biomass. For root biomass determination two 25×25×25 cm soil cores with roots were dug from each experimental plot. The soil cores were transferred on to a meshed sieve (2 mm) and soil was washed from roots by running water. Roots were dried at 60ºC, then dried and ground. In the laboratory, the dry roots were analysed for N by Kjeldhal method, for P by a spectro-photometrical method using 'Cary 50', for K and Ca by a flame photometry method. In the third 10-day period of June, legumes were chopped and ploughed down. The soil was prepared for grass sowing. Timothy and meadow fescue were sown in July within narrow row spacings (12 cm) without a cover crop (a common production system in Lithuania). The recorded plot area was 13×2.2 m. A randomized block design with 4 replications was used for each experiment. Data were processed by ANOVA. To evaluate the significance of the differences between means, LSD test with 5% significance level was used.

Results and discussion

In the first year of production legumes sown for green manure produced different above-ground biomass. The highest DM yield of 6320 kg ha^{-1} was accumulated in the above-ground mass of lucerne, while red clover accumulated 5130 kg ha^{-1} and the mixture of legumes 4800 kg ha^{-1}. Due to slower growth and development in the first year of production, the above-ground mass of fodder galega and white clover was the lowest. Persian clover grew well in the year of sowing; however, it completely disappeared after winter. Depending on the legume species (except Persian clover) before ploughing in, the content of nitrogen accumulated in the above-ground part and in roots was 165-272 kg ha^{-1}, phosphorus 10-23 kg ha^{-1}, and potassium 75-165 kg ha^{-1}. When estimating according to individual elements, lucerne was found to have accumulated the highest contents of them. As a result, the chopped above-ground part and roots present in the plough layer had the highest DM biomass, nitrogen, phosphorus, potassium and calcium when lucerne, red clover and mixture of these legumes with white clover had been grown.
In the first production year, the seed yield of meadow fescue increased significantly after pure stands of Persian clover, red clover, lucerne and the mixture (red clover, lucerne, white clover) had been ploughed down as green manure (Table 1). In the second year of use, the yield of meadow fescue was no longer significantly increased by green manure of Persian clover and fodder galega, and in the third year by Persian clover. In the second and third years after ploughing in, the regrown lucerne and fodder galega started to compete with meadow fescue. The data indicates that none of the legumes gave a significant increase in timothy seed yield in the first year of production. In the second year of production the seed yield of timothy declined considerably. When grass seed is grown in an organic farming system without mineral fertilization, the seed yield is usually reduced in the second year of production. The positive effect of preceding legumes showed on timothy seed yield. Significantly more seed was obtained when legume mixture or pure red clover, lucerne and black medic had been ploughed down. In the third year of production timothy seed yield was significantly increased by all legumes, except by fodder galega. The effect of legumes was greater in the second and third years. This can be explained by the fact that legume stems, and especially roots, contributed to timothy yield increase by mineralising slowly released nutrients. Moreover, legumes, especially clover, fodder galega and lucerne re-grew and by growing together partly supplied timothy with nitrogen.

Table 1. Seed yield of meadow fescue and timothy (kg ha^{-1}) as affected by green manure legumes

	Seed yield kg ha^{-1}							
	1st year of use		2nd year of use		3rd year of use		total	
Green manure legumes	fescue	timothy	fescue	timothy	fescue	timothy	fescue	timothy
Trifolium pratense	762	553	522	325	323	131	1607	989
Medicago sativa	734	503	519	319	337	151	1590	973
Trifolium repens	713	469	526	314	247	163	1486	946
T. pratensis + M. sativa + T. repens	736	531	530	387	362	193	1628	1111
Galega orientalis	593	457	372	296	270	104	1236	857
Medicago lupulina	667	493	475	339	341	143	1483	975
T. resupinatum	744	519	419	305	250	122	1413	946
Without legumes	654	507	355	267	214	95	1223	869
LSD_{05}	61.3	73.4	70.7	47.5	37.7	26.1	90.7	91.2

Research on the effects of legumes on seed grasses is scarce and controversial. In Norway, *Trifolium subterraneum* increased timothy yield by 20% (Solberg *et al*., 2007). In Denmark, perennial ryegrass seed yield was found to have been significantly increased by black medic, Persian clover and bird's foot trefoil (*Lotus corniculatus*); however, no positive effects were found for white, red and alsike clover (Boelt *et al*., 2002). Our results suggest that during the three years of production the highest timothy and meadow fescue seed yield increases (of 27.8-33.1%) were obtained having ploughed in mixture of lucerne, red clover and white clover.

Conclusions

In an organic farming system, if liquid manure is not available seed crops of grasses should be fertilized with green manure of legumes. Legumes ploughed down as green manure slowly mineralized and enriched the soil with major nutrients. Preceding legumes in the organic farming system gave a greater seed yield increase for meadow fescue than for timothy. Over the three years of production, the highest significant timothy and meadow fescue seed yield increase was obtained having ploughed down a mixture of lucerne, red clover and white clover as green manure. The positive effect of preceding legumes on the seed yield of grasses was more substantial in the second and third years of production.

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Regional differences in the intensity of the utilisation of organic soils in Germany

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Abstract

Only a small fraction of the German utilized agricultural area (UAA) is located on organic soils. Nevertheless, the drainage of these areas allowing their agricultural utilisation causes roughly 40% of the greenhouse gas emissions (GHG) associated with German agriculture. The abandonment of organic soils is an effective policy to reduce national GHG emissions. However, the question remains whether it is a relatively efficient on the national scale and whether it is effective on the global scale? A contribution to answer these questions is the knowledge of the current use of organic soils in order to calculate abatement costs and second-order effects due to indirect land use change. We analyse the intensity of land use on organic soils using the data of the farm structure survey.
In Germany, the organic soils are predominantly used for forage cropping. Marked differences between various parts of Germany are apparent with regard to the dynamics and intensity of land use. The highest intensities can be found in the north-west and south, whereas the intensity is markedly lower in the rest.

Keywords: Land use, organic soils, greenhouse gas emissions

Introduction

Undrained peatland accumulates plant remains in waterlogged conditions over thousands of years. If these areas are drained the peatland turns from being a net sink of Greenhouse gases (GHG) into a net emitter. Emissions from peatland account for 40% of Germany's agricultural GHG emissions (UBA, 2010). In most cases GHG emissions from the cultivation of peatland can only be markedly reduced if the water table is altered, implying an abandonment of agriculture or at least a significant reduction of the land use intensity (Höper, 2007).
The abandonment of the cultivation of peatland is an effective policy to reduce national GHG emissions; however, the questions remain whether it is a relatively efficient measure from the national perspective, and whether it is effective on a global scale. For both questions it is pivotal to know what is actually produced on peatland, either to calculate the abatement costs on a national level or to assess the indirect land use effects induced by reallocation of production (cf., e.g. Searchinger *et al*., 2008).
To optimise the effectiveness of this mitigation strategy we analyse the distribution of the intensity of peatland use at national level, as it is advisable to abandon production first in areas where the benefits of agricultural production are the smallest (given a comparable mitigation effect per ha).

Material and methods

We use three different data sources to describe the agricultural use of German peatland. Peatland is delimited according to the Geological Map of Germany (BGR, 2003). We derive the location and distribution of grassland and arable land from the Digital Landscape Model (BKG, 2008). Supplementary information on agricultural land use, such as stocking levels or crop rotations, was taken from the farm structural survey (FDZ, 2010). This analysis is based on the entire German farm population for the years 1999, 2003 and 2007. To account for regional difference in German agriculture, we divide our sample into four study areas reflecting regions, which differ in their contribution to the area of agriculturally used peatland and farm structure. The areas studied are selected on the basis of the German Länder. Especially the north-western (NW) and north-eastern (NE) Länder are characterised by high shares of utilised agricultural area (UAA) on peatland. While only 38% of the German UAA is located in these areas, more than 85% of the agricultural used peatland can be found in these two regions. The other two areas are the Länder located in the south (SO) and in the centre (CE).

Results

Peatland covers large contiguous areas in the north and east of Germany (Figure 1). In the South, peatland can mainly be found south of the river Danube. Roughly 8,600 km² of the UAA (~4.9% of Germany's UAA) is located on peatland. Whilst 10.9% of the Germany's grassland is located on peatland, the respective figure is 2.1% for arable land.

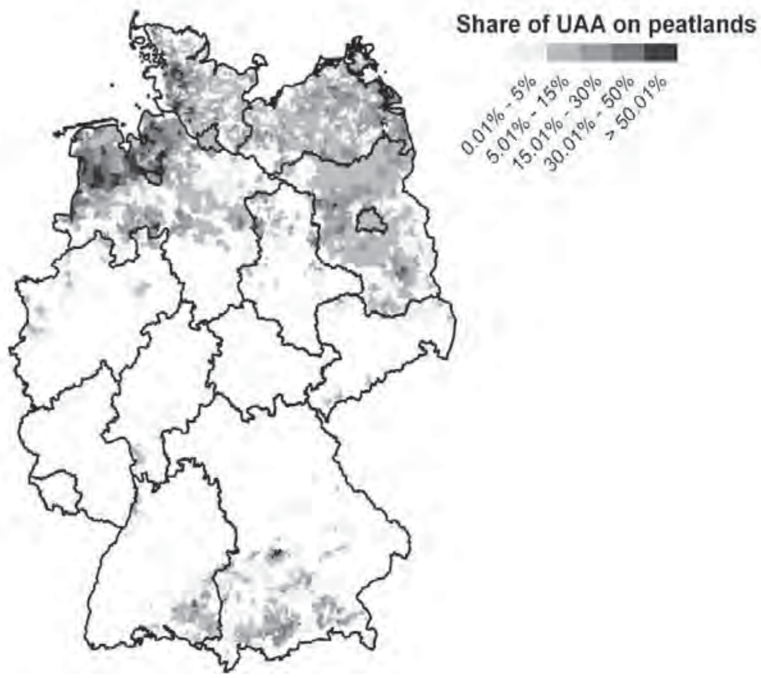

Figure 1. Distribution of the utilised agricultural area (UAA) on peatland in Germany.
Source: Own presentation based on BGR (2003) and BKG (2008).

In 2007, on average, a third of the UAA on peatland was used as arable land (Table 1). The NW differs in several aspects from the remaining areas. Firstly, the share of arable forage cropping (mainly maize) on arable land is at the expense of cash cropping, twice as high as in the other areas. Secondly, in NW, the share of arable land on UAA rose by 5% between 1999 and 2007, while it remained constant in the other areas. This is mainly due to a reduction in the area of grassland on peatland by nearly 50,000 ha.
Despite the fact that the share of main forage area on the UAA is comparable, the relevance of livestock husbandry differs substantially between the regions. For instance the average stocking density in NW is three times higher compared to NE (Table 2). Also the composition of the stock varies markedly. This is reflected by both the share of dairy cows on the grazing

livestock herd and the standard gross margin. While dairy cows account for half of the grazing livestock herd in SO, they account for only a third in NE.

Table 1. Agricultural utilisation of peatland in 2007

	AL on UAA	GL on UAA	MFA on UAA	AFC on AL	CC on AL
NW	34%	66%	79%	38%	62%
SO	28%	72%	78%	22%	78%
NE	30%	70%	76%	20%	80%
CE	36%	64%	71%	20%	80%
Germany	32%	68%	78%	30%	70%

Source: Own calculation based on BGR (2003), BKG (2008) and FDZ (2010)
AL = Arable land, GL = grassland, MFA = main forage area, AFC = arable forage crops, CC = cash crops

Table 2. Average stocking density and Standard gross margin on peatland in 2007

	LU per ha UAA	GLU per ha MFA	Dairy cows per GLU	€ SGM per ha UAA
NW	1.4	1.6	40%	1,870
SO	1.0	1.5	50%	1,580
NE	0.4	0.9	34%	790
CE	0.8	1.2	39%	1,450

Source: Own calculation based on BGR (2003), BKG (2008) and FDZ (2010)
LU = Livestock units, GLU = grazing livestock unit, MFA = main forage area, SGM = standard gross margin

Conclusions

German peatland is predominantly used for forage cropping. We can observe marked differences in the land use intensity between regions. The intensity is fairly low in NE where a significant share of the land is used by suckler cows. In SO and NW, the utilisation intensity is much higher and dairy farming is prevalent. In NW, pig and poultry fattening farms put additional pressure on the utilisation of peatland. These farms need the peatland areas less for the provision of fodder and more for the disposal of manure.

From an economic point of view the abandonment of the agricultural used peatland in NE is a very rewarding GHG mitigation option for two reasons. Firstly, compared to the other areas the short term opportunity costs are lower. Secondly, due to prevalent agricultural structure dominated by large farms, it is easier to get access to large contingent and hydrologically self-contained areas.

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Analysis of grassland conversion into arable land in Northwest Germany

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Abstract

The development of permanent grassland area and conversion into arable land are analysed at a spatially disaggregated level. Further, actors of land use change are identified, and the effect of regulations implemented to limit larger losses of grassland area, such as cross compliance, is investigated. The analysis is based on land parcel data of four German regions for the years 2005 and 2007. Considerable losses of grassland through conversion into arable land occurred at a rate of -1.3% per year. Grassland conversion is most prominent on intensively managed dairy farms and farms involved in biogas production. Also, farm structural change leads to higher conversion rates when grassland is rented to other farms. Grassland conversion could be observed even within environmentally sensitive areas, such as drinking water protection areas, flood plains, valuable grassland habitats and peatland. Obviously, the cross compliance rules have been an incentive for a rapid conversion of grassland before restrictions at the farm level are implemented. Recommendations are to make cross compliance rules more stringent on environmentally sensitive land, and to strengthen legal standards of nature and water protection.

Keywords: land use change, conservation, cross compliance

Introduction

Between 1990 and 2006, the grassland area in Germany decreased at an annual rate of -0.8%, while arable land decreased at a rate of -0.05% per year. These net figures at national level mask the fact that there have been regions where the grassland area increased, especially in hilly and mountainous areas of western Germany. Such aspects complicate the interpretation of net statistics of land use and call for more detailed analysis of gross land use changes (Gobin *et al*., 2006, Pointereau *et al*., 2008). In order to detect gross land-use change between arable and grassland, we analyse spatially referenced parcel data, and additional maps on soil, slope and protected areas. The analysis shall allow for insights into the types of farms involved in grassland conversion, and the characterisation of affected sites. For example, the effects of land-use rules within protected areas are analysed.

Materials and methods

The analyses were based on spatially disaggregated parcel data of the Integrated Administration and Control System (IACS) of four German Länder (Mecklenburg-Western Pomerania, Lower Saxony, Northrhine-Westfalia, Rhineland-Palatinate). The parcels were analysed in a Geographic Information System in order to detect land-use change and grassland losses between 2005 and 2007 (Osterburg *et al*., 2009). The data originate from farmers applications for support payments and thus cover almost the whole utilised agricultural area of the respective Länder, in total about 6.2 million hectares of agricultural land. Further, protected areas according to nature and water-related legislation, soil and slope information are included in spatial analysis. For statistical test between farm types, the Kruskall-Wallis- and the Wilcoxon rank sum test was used.

Results

Losses of grassland through conversion into arable land occurred at a rate of 1.3% per year on average, in parallel to conversions of arable land into grassland at a rate of 0.5%. Grassland conversions could be observed even within environmentally sensitive areas, such as drinking water protection areas, flood plains, peatland, valuable grassland habitats and on slopes. Conversion of arable land into grassland takes place on land less suitable for arable land use, e.g. on slopes. Often, field grass is maintained over more than 5 years, thus satisfying the definition of permanent grassland.

As part of cross compliance rules according to Reg. (EC) No. 796/2004, EU member states have to ensure the maintenance of the ratio of land under ‘permanent pasture’ in relation to the total agricultural area. Cross compliance is the attachment of environmental conditions to agricultural support policies. The term pasture is used synonymously with grassland in the respective EU legislation. Conversion of arable land to grassland increases the grassland ratio, as does the conversion of arable land to settlements and infrastructure. Thus, in many regions the relevant threshold level of a 5% drop of the grassland ratio is not reached so that grassland loss on land suitable for arable farming continues.

In three German Länder, the grassland ratio had dropped by more than 5% by 2009; another Land followed in 2010. Obviously, the cross compliance rules were an incentive for a rapid conversion of grassland before restrictions at the farm level were implemented. Also, the rules allow for further spatial segregation of grassland use, as long as there are no parcel-specific restrictions. After implementing farm-specific restrictions, grassland conversion has slowed down in the respective Länder. However, further grassland losses can occur due to exemptions from cross compliance rules. Further, farmers quitting their business can convert grassland and rent it as arable land to other farms. Cross compliance sanctions are only applicable to farms applying for support. Therefore, farm-specific rules turn out to be less restrictive compared to parcel-specific requirements to maintain permanent grassland.

Since 2011, specific grassland protection rules are applied in Germany as part of ‘good agricultural and environmental conditions’ (GAEC). This standard was rated as compulsory for member states as a result of the ‘Health Check’ of the EU agricultural policy (Reg. (EC) No. 73/2009). In Germany this site-specific protection status is applied to valuable habitats, nature conservation sites and designated flood plains, which are already protected through legal standards.

For one of the Länder (Lower Saxony), an analysis of farms involved in grassland conversion shows that dairy farms (especially those with high livestock density per hectare) and farms involved in biogas production are the most important actors (Osterburg, 2010) (see Table 1). For these figures, grassland conversion between 2005 and 2007 was analysed at the parcel level, and attributed to the farms using the respective land in 2007. The area of Lower Saxony comprises 2.6 million hectares of agricultural land and about 0.7 million hectares of grassland. Intensive dairy farms and farms producing biogas crops like green maize account for about 43% of total grassland, but almost 65% of total grassland conversion.

Grassland losses are linked to farm structural change. Farms renting additional land are often more interested in arable land, e.g. those specialised in arable crops. In Lower Saxony, farms increasing their farm area by more than 2.5% show elevated grassland conversion rates of

7.5% on average, compared to all other farms with an average grassland loss of 3% (Wilcoxon rank sum test, changes between 2005 and 2007).

Table 1. Grassland conversion into arable land in Lower Saxony between 2005 and 2007, in different farm types. Source: Osterburg (2010).

	number of of farms	share of total grassland	share of total grassland loss	grassland loss in %*	
without crops for biogas production					
Farms without livestock	5 371	3.5%	2.7%	2.7%	a
… with non-grazing livestock	3 418	1.6%	2.5%	5.3%	b
… with grazing livestock, no dairy	15 718	25.9%	11.3%	1.5%	c
… with dairy (extensive)	4 553	26.2%	19.1%	2.5%	d
… with dairy (intensive)	7 371	32.5%	40.2%	4.3%	e
with crops for biogas production					
Farms without livestock	591	0.5%	1.8%	12.5%	f
… with non-grazing livestock	766	0.4%	1.6%	12.8%	f
… with grazing livestock, no dairy	1 145	2.1%	4.5%	7.7%	g
… with dairy (extensive)	725	3.9%	8.3%	7.4%	h
… with dairy (intensive)	901	3.4%	7.9%	7.9%	h
total	40 559	100.0%	100.0%	3.5%	

* Same letters indicate that the difference in the respective distribution is not significant ($P > 0.05$, Wilcoxon rank sum test).

** Dairy extensive: < 1.8 livestock units (LU) per hectare main forage area (MFA), Dairy intensive: > 1.8 LU/ha MFA.

Conclusions

Maintenance of valuable grassland is an objective of environmental policy. Thus, it can be recommended to make cross compliance rules more stringent on ecologically sensitive land, and to provide parcel-specific protection. Also, legal standards of nature and water protection could be strengthened. Standards to maintain the grassland area at farm level are not effective. Due to farm structural change, farmers would be able to rent additional grassland from farmers abandoning the business. This would allow them to convert parts of their grassland. On the other hand, given the higher economic value of arable land, grassland conservation should not be an area-wide imperative.

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Vegetation change of mountainous hay meadows to intensified management regime in organic farming

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Abstract

The whole vegetation assemblage of 60 relevés (4 m²) in a block design was examined at two mountainous hay meadow stands over a two-year period. All sites were situated at a certified organic farm, managed according to the guidelines of organic farming since 1995. According to the traditional management, acreages are mowed two times per year followed by grazing and solid manure fertilisation in autumn. The effect of management intensity (two, three, four cuts per year and adapted fertilisation) was tested for coverage of most frequent species: *Trisetum flavescens*, *Dactylis glomerata*, *Poa pratensis*, *Poa trivialis*, *Festuca pratensis*, *Lolium perenne*, *Trifolium repens*, *Taraxacum officinale* agg., *Carum carvi* and *Achillea millefolium*. Our main interest was to detect how fast cover changes of different species occur. During the investigation period of two years, almost all taxa showed a significant alteration when mown more than 2 times a year. Stolon- and rosette-forming plants profited from increased management whereas tall tuft grasses lost coverage.

Keywords: hay meadow, management intensity, meadow species, cover percentage

Introduction

Managed, semi-natural grassland accounts for about half of the agricultural area in Austria, but still remains the cornerstone of dairy farming. In 2009 almost 25% of permanent grassland was managed organically, especially in the mountainous regions. At the same time, organic farms enlarged their average field areas to a greater extent than conventional farms (BMLFUW, 2009). According to the concept of a closed substance cycle the majority of nutrients necessary for milk and beef production should be obtained from the farm's own forage. Thus, in order to increase forage quality, farmers often increase their cutting frequencies and rate of organic fertilising (Karrer *et al*., 2010). This process strongly alters species assemblages on former traditionally managed permanent grassland stands. Depending on growth form and susceptibility to nutrients, plant species react by increasing or decreasing coverage. However, the rates of change in cover of traditionally managed non-sown mountainous hay meadows remain unclear and are tested in an on-farm field experiment. In this paper trends of two years of the investigation are discussed.

Materials and methods

The pilot farm is located in the Upper Styrian Pöls valley on the crystalline bedrock of the ‚Niedere Tauern'. Cattle breeding is carried out, based on hay meadows and pastures. After a vegetation survey in 2008, the two most homogenous meadows were selected at 920 and 980 m, resp., both facing 230° SW and characterised by an average inclination of 25%. Soil type is cambisol dominated by sandy loam, at a pH of 5.3 to 5.8. Annual mean temperature at the farm ranges from 4 to 6°C and annual precipitation from 1000 to 1100 mm. The grassland refers to the association *Cardaminopsido halleri-Trisetetum flavescentis*, typical for mountainous hay meadows cut two times a year (Bohner *et al*., 2000). No sowing of cultivars was performed within 15 years before the experiment. The meadows were cut two times a year and fertilized by manure 15 years before the experiment. At the two selected meadow fields we established 30 plots (4 m²) arranged in an incomplete block design, meaning that three out of all six treatments are aligned in one column, where we applied different cutting frequencies and different types of organic fertilisation (Table 1). At each cutting level we used two different types of organic fertiliser resulting in six treatments, all with five pseudo replicates per field. Before each mowing we recorded cover percentage of each species based on Schechtner (1958). Statistical analysis was implemented with proc MIXED of SAS 9.2 ($P < 0.05$) for species specific mean cover percentages (average of all measures per single species and year) of the whole growing season 2010. The result of the cutting impact was displayed as LS-means (LSMEANS). Test of pairwise differences were arranged with Tukey-Kramer and significant differences between LS-means are shown with different lower-case letters (Table 2).

Table 1. Treatments and mowing dates 2009 and 2010

Management options			Mowing date			
Treatment	Cut/year	Fertiliser	1	2	3	4
1	2	Manure	June 1-8	Aug. 17-20		-
2	2	Slurry	June 1-8	Aug. 17-20		-
3	3	Manure	May 16-23	July 18-21	Sept. 13-29	-
4	3	Slurry	May 16-23	July 18-21	Sept. 13-29	-
5	4	Manure	May 9-12	June 27-30	Aug. 1-5	Sept. 13-29
6	4	Slurry	May 9-12	June 27-30	Aug. 1-5	Sept. 13-29

Results and discussion

Changes in annual average cover percentage of the most frequent species in 2010, as well as differences in cutting frequency levels are shown in Table 2. The tuft grasses *Trisetum flavescens*, *Dactylis glomerata*, *Lolium perenne* and *Festuca pratensis* reproduce by a number of shoots that remain connected to the parent plant after mowing. *T. flavescens* and *F. pratensis* declined in treatments cut three or four times, in contrast to *L. perenne,* which is smaller in habit and more susceptible to intensive management. This observation corresponds to inverse effects documented by Briemle (1994), i.e. a decrease of *L. perenne* but an increase of *T. flavescens* after three years of extensification. So far, management has had no impact on cover percentage of *D. glomerata*, which can be explained by its life span, which for tussock grasses was determined to be six to eight years (Schmitt, 1995). *Carum carvi* shows increasing cover values with increasing management intensity. This taxon is known to fill gaps quickly in intensively managed meadows by seedling establishment (e.g. Dierschke and Briemle, 2008). *Poa pratensis*, a valuable grass with subterranean shoots, significantly lost cover with ascending cutting frequency. This is surprising, as cultivars of this species are used in seed mixtures for intensively managed meadows and pastures (e.g. Starz *et al*., 2010). Obviously, regional ecotypes in extensively used hay meadows are not susceptible to intensification. *Poa trivialis* is a grass forming numerous aboveground down-bending shoots after the first mowing. It increased in treatments with three and four cuts a year through capturing free gaps. *Trifolium repens* also increased its coverage expanding by above-ground runners. These two species profit most from a four-cut management, also shown in the adjoining ‚Enns valley‘ (Karrer *et al*. 2010).

Table 2. Analysis of variance and pairwise differences of coverage (averages over field 1 and 2) for dominant grassland species in 2010 influenced by varying management intensity.

Parameter	Cutting frequency			
	2	3	4	
	LSMEAN	LSMEAN	LSMEAN	*P*
Trisetum flavescens	32 [a]	15 [b]	15 [b]	**<0.0001**
Dactylis glomerata	8 [a]	9 [a]	10 [a]	0.1767
Lolium perenne	4 [b]	8 [a]	9 [a]	**<0.0001**
Festuca pratensis	4 [a]	4 [ab]	3 [b]	**0.0197**
Taraxacum officinale agg.	9 [a]	9 [ab]	7 [b]	**0.031**
Carum carvi	4 [c]	5 [b]	8 [a]	**<0.0001**
Poa pratensis	18 [a]	16 [a]	13 [b]	**<0.0001**
Poa trivialis	12 [b]	16 [a]	18 [a]	**<0.0001**
Trifolium repens	22 [b]	21 [b]	30 [a]	**<0.0001**
Achillea millefolium	18 [a]	10 [b]	3 [c]	**<0.0001**

Conclusion

After two years we recorded significant changes in coverage of the most frequent meadow species due to management intensification. Short-lived rosette herbs reproducing predominantly by seeds, and plants with aboveground creeping stems, benefit most from increasing cutting intensity. On the other hand, tall tussock grasses lost cover abundance and left open space. Valuable forage crops decreased in cover with higher management intensity except for *Lolium perenne* and *Trifolium repens*. Our results are in accordance with observations of several farmers, that meadows became patchy after an increase in mowing frequency on traditional mountainous hay meadow stands without seeding of suitable species and cultivars.

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Forage feeding value of continuous grazed sward on organic permanent grassland

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Abstract

Continuous grazing provides low-cost forage with a high feeding value for milk and beef production and is a suitable pasture system in organic farming. To assess the forage feeding value of continuously grazed sward, a 3-field trial was carried out under harsh east Alpine conditions (680 m altitude, 7°C average temperature, 1000 mm annual precipitation). Forage contents of net energy (6.3-7.0 MJ NEL kg^{-1} DM) and crude protein (202-236 g kg^{-1} DM) varied on a high level during the vegetation period. Moreover, amounts of crude fibre (176-243 g kg^{-1} DM) and neutral detergent fibre (373-475 g kg^{-1} DM) were within the recommended range for ruminates. In conclusion, continuous grazing as a possible organic grassland use under harsh climate conditions can be recommended.

Keywords: organic farming, grazing, crude nutrients, structural carbohydrates

Introduction

Grazing, as the most animal-friendly means of husbandry, is regulated in organic farming and has still a very high priority in Alpine regions of Austria. Organic farms in Austria are very small-scale, in contrast to farms in European favourable areas. Austrian organic farms have an average size of 19 ha with 10 cows per farm (BMLFUW, 2009). Therefore, continuous grazing represents an interesting pasture system for these small-scale grassland farms, if smooth and gently sloped areas are available. Previous investigations (Münger, 2003) attested to high forage feeding value of continuously grazed swards. To assess this for the East Alpine area, a three-year (2007-2009) field trial was carried out at the organic grassland and dairy farm of the Agricultural Research and Education Centre (AREC) Raumberg-Gumpenstein. The hypothesis of this investigation was that the harsh climate of the Eastern Alps influences the forage feeding value of continuously grazed swards and decreases the nutrient content in contrast to favourable grassland regions.

Materials and methods

The trial was carried out on an organically managed, continuously grazed area (latitude 47° 31‘03“N, longitude: 14°04‘26“E, 680 m altitude, 7°C average temperature, 1014 mm precipitation per year) as a randomized block design with three replicates. To sample the continuously grazed variants (4 different reseeding mixtures) a part of the plots was fenced out from grazing. Seven times per year the fenced area of the plots was harvested with a motor mower (cutting level 5 cm). The sampling date started in the first week of May and ended in the last week of October (7th sampling date). Between the sampling dates, a period of 4-6 weeks elapsed, depending on sward height (target height 15 cm, measured with a ruler). The sample cutting area on the continuous grazing variant was changed between two harvest times. One part of the continuous grazing variant was grazed 50% of the time by dairy cows. A detailed description of the biomass yield as well as the botanical composition is presented in Starz *et al*. (2010). After harvest, a part of the sward sample was dried at 50°C, for further content analyses. In the laboratory of AREC Raumberg-Gumpenstein, the crude nutrients (crude ash CA, crude protein CP, ether extract EE and crude fibre CF) were determined via Proximate Analysis. Furthermore, contents of structural carbohydrates (neutral detergent fibre NDF, acid detergent fibre ADF and acid detergent lignin ADL) were also assessed. Regarding the MJ net energy lactation (NEL) and MJ metabolic energy (ME), the calculation was based on a regression equation considering crude nutrients (GfE, 1998).

Data were checked for adherence to the normal distribution and homoscedasticity using analysis of variance via visual testing of the fit diagnostics in SAS 9.2. Statistical analysis was implemented with PROC mixed of SAS 9.2 with a *P*-value below 0.05 (n = 252). The main factors were replication, variant, sampling date (7 times per year) and year. Beside these factors, the sward height (differing on a small scale) at the sampling date was used as covariate in the model. The results of this analysis were displayed as LS-means (LSMEANS), standard error (SEM) and residual standard error (se). Test of pairwise differences were arranged with Tukey-Kramer and significant differences between LS-means are shown with different lower-case letters.

Results and discussion

In Table 1 the results from continuously grazed swards, contents in dry matter (DM) and organic matter (OM), under organic and East Alpine conditions are listed. The table shows the chronological sequence, from each sampling date with the forage feeding value during the vegetation period (2007-2009). Crude protein content decreased significantly, at a high level, from first (202 g kg^{-1} DM) to the second (175 g kg^{-1} in DM) sampling date but increased by the end of the vegetation period (228 g kg^{-1} DM). This observation is in accordance with results from Norway (Johansen,

Table 1. Crude nutrients, structural carbohydrates and energy contents of continuously grazed swards at the 7 sampling dates in the vegetation period.

Para-meter	Unit	1 *LSMEAN*	1 *SEM*	2 *LSMEAN*	2 *SEM*	3 *LSMEAN*	3 *SEM*	4 *LSMEAN*	4 *SEM*	5 *LSMEAN*	5 *SEM*	6 *LSMEAN*	6 *SEM*	7 *LSMEAN*	7 *SEM*	*P*-value	s_e
CA	g kg^{-1} DM	93^{a}	2.2	88^{a}	2.4	109^{bc}	2.2	110^{bc}	2.2	104^{b}	2.4	114^{c}	2.2	122^{d}	2.7	<0,0001	10.4
CP	g kg^{-1} DM	202^{b}	1.9	175^{a}	2.2	224^{c}	2.0	203^{b}	1.9	218^{c}	2.2	236^{d}	1.9	228^{cd}	2.5	<0,0001	11.5
CP	g kg^{-1} OM	223^{b}	2.2	192^{a}	2.5	251^{cd}	2.2	228^{b}	2.2	243^{c}	2.5	266^{e}	2.2	260^{e}	2.9	<0,0001	13.1
EE	g kg^{-1} DM	31^{e}	0.3	26^{a}	0.3	28^{c}	0.3	30^{d}	0.3	28^{bc}	0.3	27^{ab}	0.3	26^{ab}	0.4	<0,0001	1.5
EE	g kg^{-1} OM	34^{c}	0.3	29^{a}	0.4	31^{b}	0.4	33^{c}	0.3	31^{b}	0.4	30^{ab}	0.3	30^{ab}	0.4	<0,0001	1.7
CF	g kg^{-1} DM	194^{b}	2.5	243^{f}	2.8	223de	2.6	231^{e}	2.5	218^{d}	2.9	206^{c}	2.6	176^{a}	3.2	<0,0001	12.4
CF	g kg^{-1} OM	213^{b}	2.8	266^{f}	3.1	251de	2.9	259^{ef}	2.8	243^{cd}	3.1	233^{c}	2.8	200^{a}	3.5	<0,0001	13.6
NDF	g kg^{-1} DM	381^{a}	6.5	475^{c}	6.9	431^{ab}	6.5	439^{a}	6.5	423^{bc}	6.9	409^{bc}	6.5	373^{a}	7.3	<0,0001	22.6
NDF	g kg^{-1} OM	420^{a}	7.5	521^{e}	7.9	483^{cd}	7.5	493^{d}	7.5	473^{bc}	7.9	462^{b}	7.5	424^{a}	8.4	<0,0001	24.8
ADF	g kg^{-1} DM	222^{a}	2.4	282^{c}	2.6	268^{c}	2.4	282^{ab}	2.3	266^{c}	2.7	242^{c}	2.4	215^{bc}	3.0	<0,0001	12.0
ADF	g kg^{-1} OM	245^{a}	2.8	309^{cd}	3.1	301^{cd}	2.8	317^{ab}	2.8	297^{bc}	3.1	273^{d}	2.8	245^{cd}	3.4	<0,0001	13.3
ADL	g kg^{-1} DM	26^{a}	0.7	35^{cd}	0.7	36^{c}	0.7	33^{ab}	0.7	36^{bc}	0.7	31^{d}	0.7	27^{cd}	0.8	<0,0001	3.1
ADL	g kg^{-1} OM	29^{a}	0.7	38^{bc}	0.8	40^{c}	0.8	37^{b}	0.7	40^{c}	0.8	35^{b}	0.7	31^{a}	0.9	<0,0001	3.4
ME	MJ kg^{-1} DM	11.48^{e}	0.04	10.71^{d}	0.04	10.52^{bc}	0.04	10.41^{ab}	0.04	10.63^{cd}	0.04	10.72^{d}	0.04	10.46^{a}	0.05	<0,0001	0.19
ME	MJ kg^{-1} OM	12.65^{d}	0.04	11.74^{ab}	0.04	11.81^{ab}	0.04	11.69^{a}	0.04	11.87^{b}	0.04	12.11^{c}	0.04	11.91^{b}	0.05	<0,0001	0.20
CP ME^{-1}	g MJ^{-1}	17.6^{b}	0.2	16.3^{a}	0.2	21.3^{e}	0.2	19.5^{c}	0.2	20.5^{d}	0.2	22.0^{f}	0.2	21.8^{ef}	0.2	<0,0001	0.9
NEL	MJ kg^{-1} DM	7.03^{d}	0.03	6.45^{bc}	0.04	6.34^{ab}	0.03	6.25^{a}	0.03	6.39^{bc}	0.04	6.50^{c}	0.03	6.47^{c}	0.04	<0,0001	0.14
NEL	MJ kg^{-1} OM	7.75^{c}	0.03	7.07^{a}	0.04	7.11^{a}	0.03	7.02^{a}	0.03	7.14^{a}	0.04	7.34^{b}	0.03	7.37^{b}	0.04	<0,0001	0.16
CP NEL^{-1}	g MJ^{-1}	28.7^{b}	0.3	27.0^{a}	0.3	35.4^{e}	0.3	32.5^{c}	0.3	34.1^{d}	0.3	36.3^{e}	0.3	35.3^{de}	0.3	<0,0001	1.5

PEQ: protein energy quotient

2010) and Switzerland (Münger, 2003). Variability in crude protein contents (see Figure 1) of grazed swards were also found in investigations in north-east Germany (Braun, 2006) and may be caused by weather conditions. Similar to crude protein, the energy content decreased at the beginning (7.0 MJ NEL kg^{-1} DM), and stabilised at 6.5 MJ NEL kg^{-1} DM towards the end of the vegetation period (Figure 1). The generally high energy content underlines the high forage feeding value with continuous grazing. Similar NEL contents of 7.1 kg^{-1} DM (Schori, 2009) for rotational grazed swards were measured in a West Alpine area under organic conditions. Beside CP and NEL, the structural carbohydrates play an important role for fulfilment of fibre requirements of ruminants, which is a main focus for organic feed. NRC (2001) characterise the minimum NDF content for high performance dairy cows between 250 and 330 g kg^{-1} DM in the whole ration. This recommended range for ruminates was fulfilled at every sampling date and demonstrates the suitability of this type of fodder for seasonal pasture-based systems. In such systems grazed grass present the bulk of the daily ration and fibre supply is important for rumination. Regarding the content of NDF concentrate feeding is limited in pasture-based systems.

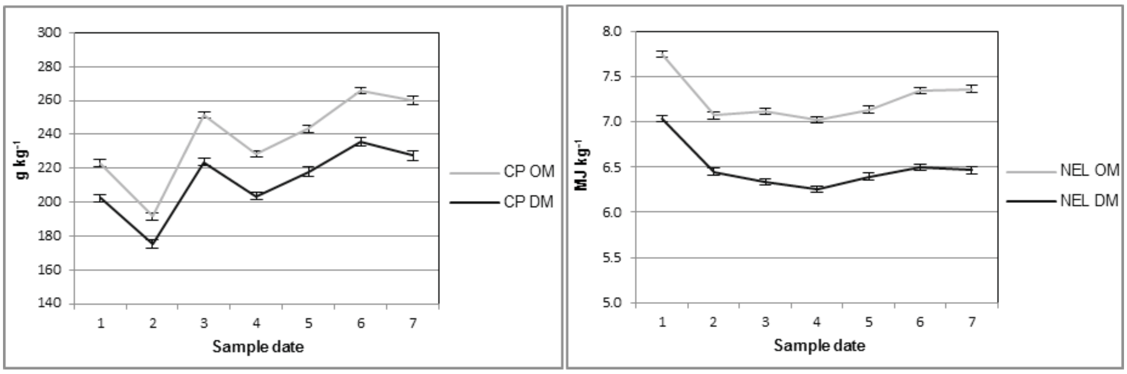

Figure 1. Chronological sequence of crude protein (left) and net energy lactation (right) and displayed standard error bar.

Conclusion

Continuous grazing provides fodder with high forage feeding value. The high contents, especially of energy and crude protein, are also reachable under the harsh climatic conditions of the Eastern Alps and with organic farming. In this case, continuous grazing in disadvantaged regions keeps up with favourable European grassland regions and could be a suitable system for small-scale organic grassland farms in Austria.

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Growth and quality dynamics of semi-natural grassland in river flood plains

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Abstract

The conservation and reintroduction of semi-natural grassland in flood plains of rivers is a crucial step towards soil and water protection, when the risk of flooding, as a consequence of climate change, increases. In a two-year field experiment, three grassland swards (a standard mixture, a diversity mixture and a pure *Phalaris arundinacea* sward) were cultivated with two fertilizer treatments on a flood plain of the River Werra in Northern Hesse, Germany. Dry matter (DM) yield and organic composition of biomass were determined fortnightly during two growth periods (first cut in July, second cut in October) in 2009 and 2010. Results showed a significant influence of sward type, fertilizer (only in the first growth period) and sampling date on the growth and quality parameters. Highest annual DM yields were obtained in the standard mixture (14.7 t ha^{-1} a^{-1}), followed by the diversity mixture and the *Phalaris arundinacea* sward (8.4 and 7.6 t ha^{-1} a^{-1}, respectively). Whilst crude protein decreased and fibre fractions (NDF, ADF) increased continuously with increasing sward maturity in the first growth period, changes of these parameters in the second period were less pronounced.

Keywords: climate change, flood plains, semi-natural grassland, sward development

Introduction

As an effect of climate change, an increase of extreme weather phenomena, such as torrential rain, is predicted, which might lead to higher risks of flooding along watercourses. Site-adapted and extensively managed grasslands are a suggested way of land use to ensure important soil and water protection functions in flood plains (Van Der Ploeg *et al*., 1999). If the grasslands are to be managed according to agri-environmental schemes, certain standards, such as a delayed first cut or a limit to fertilization, have to be fulfilled. However, beside the environmental value, the quality of the biomass of these grasslands is an important factor and determines whether it can be utilised with an economic benefit or not. Within the trans-disciplinary research project 'KLIMZUG-Northern Hesse', adaptation strategies of agricultural management to climate change are evaluated. The objective of this study was to assess formation of biomass quantity and quality of three grassland swards, located in a flood plain, under two fertilizer regimes during two growth periods.

Materials and method

In August 2008 a field experiment with the two factors sward type (standard mixture, diversity mixture and Phalaris arundinacea sward; Table 1) and fertilizer (0 kg N ha^{-1} and 100 kg N ha^{-1} as chicken manure) was established as randomised block design with four replications and a plot size of 60 m². The site was located in the flood plain of the River Werra in Witzenhausen (52°21' N, 9°52' E, altitude 137 m a.s.l., mean annual rainfall during the experiment 863 mm, mean daily temperature during the experiment 9.0°C) on a loamy sand. Fertilization was carried out at one date in March in the year 2009 and 2010, respectively. Biomass sampling in both years started on 06 May and was repeated fortnightly at five dates until the first cut on 01 July. After a recovering period, biomass sampling started again on 27 July and was repeated fortnightly at six dates until the final harvest date on 06 October. Sampling dates varied no more than two days between the two years and presented dates are mean values. Dry matter (DM) yields were assessed by sampling an area of 0.25 m². Concentrations of DM, crude protein (CP), ether extract (EE), neutral detergent fibre (NDF) and acid detergent fibre (ADF) were analysed according to standard methods and the use of near infrared spectroscopy (NIRS). Mean values were calculated for the two experimental years. Analysis of variance (ANOVA) was performed for each growing period separately by using the procedure MIXED in SAS (SAS Institute, 1996) with sward type (ST), fertilizer treatment (FT), sampling date (SD) and the interactions ST × FT, ST × SD and FT × SD as fixed effects and SD as repeated factor with each plot as investigated subject.

Table 1. Characteristics of experimental swards

Sward type	Number and group of species	Dominant species
Standard mixture	5 grasses	*Festuca pratensis, Phleum pratense, Poapratensis, Alopecurus pratensis, Agrostis stolonivera*
	2 legumes	*Trifolium hybridum, Trifolium repens*
Diversity mixture	11 grasses	*Alopecurus pratensis, Festuca nigrescens, Poa pratensis, Cynosurus cristatus, Trisetum flavescens*
	24 herbs	*Silene dioica, Centaurea jacea, Plantago lanceolata, Crepis biennis, Achillea millefolium*
	1 legume	*Lotus pedunculatus*
Phalaris arundinacea sward	1 grass	*Phalaris arundinacea*

Results and discussion

The three swards differed significantly in all parameters in both growth periods (Table 2). The influence of fertilizer treatment was only significant for DM yield and ADF in the first growth period and for NDF in both periods. The influence of sampling date was highly significant for all parameters in both growth periods. The interactions show that, swards react differently to fertilizer application regarding DM concentration, CP and NDF in the first growth period as

Table 2. ANOVA of DM yield and concentrations of DM, CP, EE, NDF and ADF as function of sward type (ST), fertilizer treatment (FT), sampling date (SD) and their interactions.

Source of variation	DM yield *F*	DM yield *P*	DM conc. *F*	DM conc. *P*	CP conc. *F*	CP conc. *P*	EE conc. *F*	EE conc. *P*	NDF conc. *F*	NDF conc. *P*	ADF conc. *F*	ADF conc. *P*
1st period												
ST	106	<0.001	4.7	0.023	18	<0.001	261	<0.001	5.1	0.017	258	<0.001
FT	24	<0.001	2.4	0.139	3.8	0.069	3.1	0.094	51	<0.001	16	0.001
SD	282	<0.001	158	<0.001	213	<0.001	180	<0.001	222	<0.001	463	<0.001
ST × FT	<1	0.984	22	<0.001	4.1	0.035	2.0	0.160	7.4	0.004	3.0	0.076
ST × SD	13	<0.001	2.5	0.017	4.3	0.003	6.0	<0.001	3.1	0.004	1.6	0.141
FT × SD	3.1	0.020	3.2	0.017	1.4	0.240	1.4	0.259	<1	0.986	1.3	0.283
2nd period												
ST	41	<0.001	73	<0.001	112	<0.001	96	<0.001	33	<0.001	266	<0.001
FT	<1	0.852	<1	0.893	2.2	0.157	2.8	0.110	17	0.001	1.9	0.186
SD	136	<0.001	49	<0.001	46	<0.001	41	<0.001	8.7	<0.001	54	<0.001
ST × FT	3.7	0.046	10	0.001	8.2	0.003	2.0	0.159	12	0.001	2.3	0.125
ST × SD	8.2	<0.001	12	<0.001	8.7	<0.001	9.1	<0.001	6.5	<0.001	6.3	<0.001
FT × SD	<1	0.735	<1	0.698	<1	0.667	<1	0.684	<1	0.538	1.6	0.176

well as DM yield, DM concentration, CP and NDF in the second growth period. The interaction between sward type and sampling date was significant for all parameters except for ADF in the first growth period. A changing fertilizer effect at different sampling dates was only observed for DM yield and DM concentration in the first period.

Figure 1 shows the dynamics of the analysed parameters for the treatments without fertilizer, which were chosen as an example, as management under most agri-environmental schemes does not allow any fertilization. DM yields increased strongly until the harvest date in the first period and to a lower extent with a levelling-off in the second period. The annual DM yields were 14.7 t ha^{-1} (standard mixture) 8.4 t ha^{-1} (diversity mixture) and 7.6 t ha^{-1} (*Phalaris arundinacea* sward). DM concentration increased in the first period in all swards and in the second period only in the diversity mixture and the *Phalaris arundinacea* sward. In the first period CP decreased from 150-187 to 66-89 g kg^{-1} DM, while NDF increased from 375-403 to 533-550 g kg^{-1} DM. In the second period, CP decreased only in the *Phalaris arundinacea* sward, whereas NDF did not change at all. Patterns of EE were comparable to those of CP and changes of ADF were comparable to those of NDF.

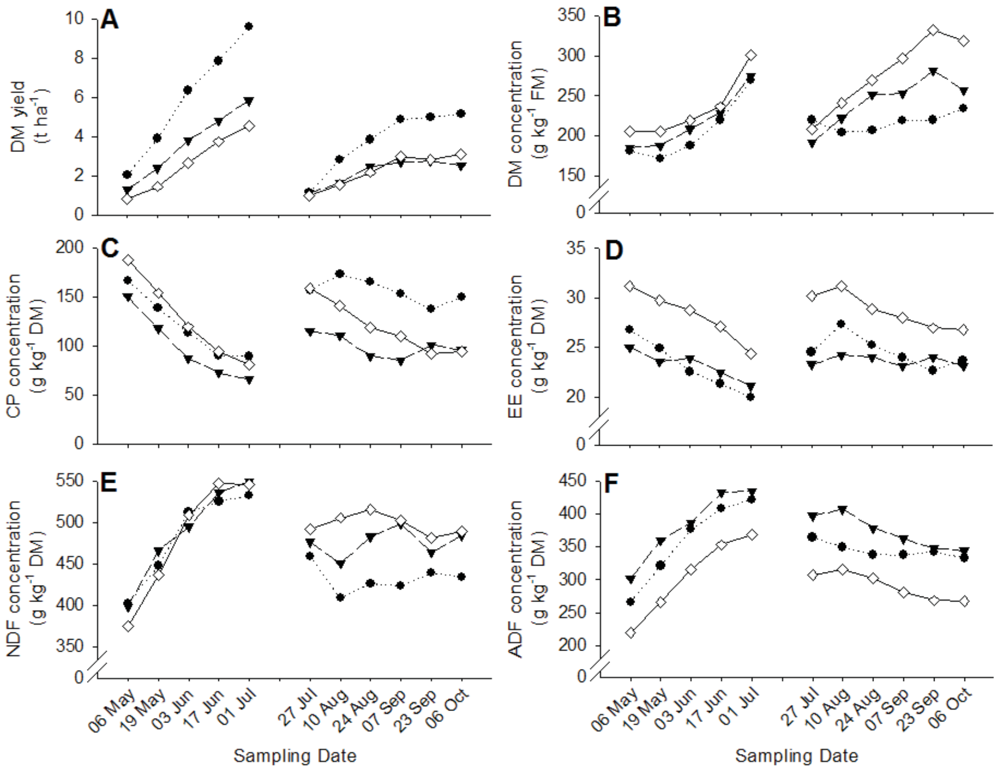

Figure 1. Dynamics of (A) DM yield and of concentration of (B) DM, (C) CP, (D) EE, (E) NDF and (F) ADF of three different grassland swards (···•···, standard mixture; ––▼––, diversity mixture; –◇–, *Phalaris arundinacea* sward) without fertilization in two growth periods as mean values of 2009 and 2010.

Conclusions

All grassland swards obtained high annual yields considering the extensive management and showed typical growth and quality dynamics. Choice of sward for reintroducing grassland to river flood plains will depend on whether priority is given to biodiversity, yield or quality.

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Energy prodcution from the biomass of semi-natural grassland in river flood plains

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Abstract

Bioenergy production is a possible option for the utilization of semi-natural grasslands, which contribute to soil and water protection in flood plains of rivers, when the risk of flooding, as an effect of climate change, might increase. In a two-year field experiment, three grassland swards (a standard mixture for wet grasslands, a diversity mixture and a pure *Phalaris arundinacea* sward) were cultivated with two fertilizer treatments (0 kg N ha^{-1} and 100 kg N ha^{-1} as chicken manure) on a flood plain of the Rriver Werra in Northern Hesse, Germany. Dynamics of chemical composition was determined fortnightly during two growth periods (first cut in July, second cut in October) in 2009 and 2010. Two bioenergy conversion scenarios (combustion and anaerobic digestion) were evaluated and compared based on the chemical composition of the biomass. The results suggest declining anaerobic degradability (i.e. methane production) and improving combustion properties (i.e. mineral composition) of the biomass with increasing sward maturity. Net energy yields were higher for combustion compared to anaerobic whole-crop digestion.

Keywords: climate change, flood plains, semi-natural grassland, biogas, combustion

Introduction

Adaptation strategies of agricultural management to climate change were evaluated within the trans-disciplinary research project 'KLIMZUG-Northern Hesse'. One of these strategies is the conservation or reintroduction of semi-natural grassland in flood plains of rivers in order to improve soil and water protection. However, the use of biomass of these grasslands in livestock production is decreasing, but the utilization for energy purposes might be a promising approach. The objective of this study was to assess the dynamics of chemical composition of grassland biomass with regard to bioenergy production of three grassland swards, located in a flood plain, under two fertilizer regimes during two growth periods.

Materials and methods

In August 2008 a field experiment with the two factors sward type (standard mixture, diversity mixture and pure *Phalaris arundinacea* sward) and fertilizer (0 kg N ha^{-1} and 100 kg N ha^{-1} as chicken manure) was established in a as randomised block design with four replications and a plot size of 60 m^2. Biomass sampling was carried out fortnightly in two growth periods with five dates in the first period and six dates in the second period. Description of the site, the swards, fertilization and biomass sampling is given elsewhere (Richter *et al*., 2011b). Concentrations of the organic fractions crude protein, crude fibre, ether extract and nitrogen-free extracts as well as concentrations of ash and the elements C, H, N, K and Cl were analysed according to standard methods and the use of near infrared spectroscopy (NIRS). Specific methane yields were calculated based on the organic fractions according to VDI 4630 (2004) and higher heating value (HHV) was calculated according to Friedl *et al*. (2005). Net energy yields for the two conversion systems whole-crop digestion and combustion of hay were calculated in an energy balance with methane yields and HHV as energy outputs and with energy input data according to Richter *et al*. (2011a).

Analysis of variance (ANOVA) were performed for each growing period separately by using the procedure MIXED in SAS (SAS Institute, 1996) with sward type (ST), fertilizer treatment (FT), sampling date (SD) and the interactions ST×FT, ST×SD and FT×SD as fixed effects and SD as repeated factor with each plot as investigated subject.

Results and discussion

For all investigated parameters, differences between sward types and differences between sampling dates were significant in both growth periods (Table 1). The influence of fertilizer treatment was only significant for ash concentration in the first growth period. However, swards reacted differently to fertilizer application regarding N in both periods and K in the second period. The interaction between sward type and sampling date was significant for all parameters except for CH_4 yield in the first growth period, which was also the only parameter with a significant interaction between fertilizer treatment and sampling date.

Table 1. ANOVA of concentrations of ash, N, K, Cl and CH4 yield and HHV as function of sward type (ST), fertilizer treatment (FT), sampling date (SD) and their two-way interactions.

Source of variation	Ash conc.		N conc.		K conc.		Cl conc.		CH_4 yield		HHV	
	F	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*
1st period												
ST	147	<0.001	18	<0.001	<1	0.513	14	<0.001	29	<0.001	42	<0.001
FT	5.9	0.026	3.8	0.069	1.1	0.306	5.5	0.310	1.8	0.194	<1	0.987
SD	57	<0.001	213	<0.001	161	<0.001	11	<0.001	218	<0.001	24	<0.001
ST × FT	<1	0.479	4.1	0.035	2.9	0.081	2.1	0.149	2.1	0.149	2.7	0.095
ST × SD	6.0	<0.001	4.3	<0.001	4.0	<0.001	2.5	0.018	1.6	0.133	2.9	0.007
FT × SD	<1	0.541	1.4	0.240	1.2	0.307	1.8	0.143	6.1	<0.001	1.2	0.310
2nd period												
ST	135	<0.001	112	<0.001	73	<0.001	72	<0.001	35	<0.001	152	<0.001
FT	1.8	0.193	2.2	0.157	<1	0.585	<1	0.569	2.2	0.157	<1	0.873
SD	10	<0.001	46	<0.001	178	<0.001	42	<0.001	24	<0.001	17	<0.001
ST × FT	<1	0.498	8.2	0.003	6.7	0.007	<1	0.636	3.1	0.072	1.5	0.253
ST × SD	3.1	0.002	8.7	<0.001	13	<0.001	5.8	<0.001	6.5	<0.001	4.9	<0.001
FT × SD	<1	0.466	<1	0.667	<1	0.636	<1	0.479	1.1	0.371	<1	0.502

As management under most agri-environmental schemes does not allow any fertilization, Figure 1 shows the dynamics of the analysed parameters for the treatments without fertilizer. Concentrations of ash, N and K as well as methane yields declined during the first period and reached values of 86-119 g kg^{-1} DM, 11-14 g kg^{-1} DM, 21-24 g kg^{-1} DM and 263-303 L_N kg^{-1} VS, respectively, on the harvest date. There was no change of Cl concentration and HHV during the first period. In the second period, ash concentration only declined for the standard mixture, whereas N concentration, Cl concentration and HHV only declined in the *Phalaris arundinacea* sward. Potassium concentration declined in all swards and CH_4 yield did not change during the second period.

The net energy yields of both conversion systems were increasing during both growth periods mainly due to an increase in DM yield (Richter *et al*., 2011b);, however, the change was greater for combustion compared to whole-crop digestion (Figure 1G and 1H). Annual net energy yields were between 8.6 (diversity mixture) and 15.0 (standard mixture) MWh ha^{-1}

for whole-crop digestion and between 22.8 (*Phalaris arundinacea* sward) and 46.5 (standard mixture) MWh ha^{-1} for combustion. However, the latter figures have to be interpreted with caution, since the concentrations of ash, N, K and Cl at the harvest dates were still too high to consider the biomass as a solid fuel in commercial combustion plants (Richter *et al.*, 2011a).

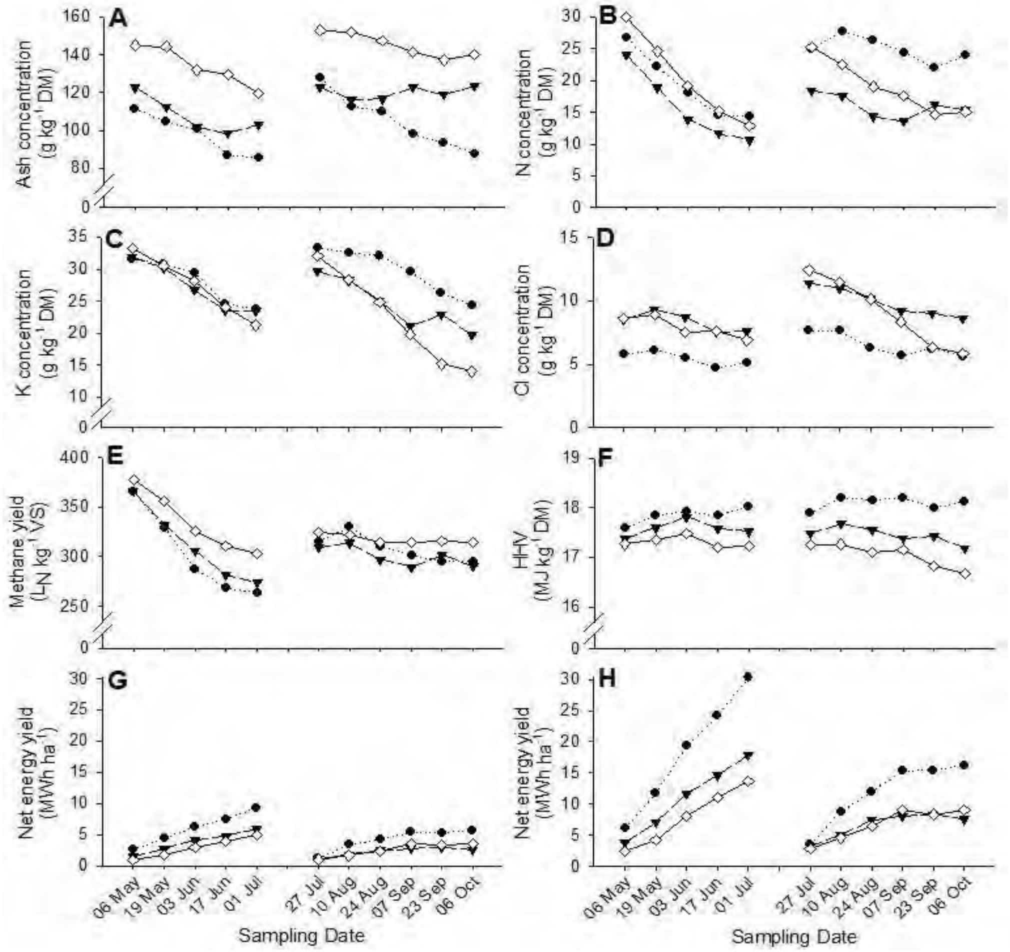

Figure 1. Concentrations of (A) ash, (B) N, (C) K and (D) Cl and (E) methane yield, (F) higher heating value and net energy yield of (G) whole-crop digestion and (H) combustion of hay of three grassland swards (···•···, standard mixture; —▼—, diversity mixture; –◇–, *Phalaris arundinacea*) in two growth periods as mean values of two years (2009 and 2010).

Conclusions

Considering all quality aspects of energy production (low ash and element concentration, high net energy yield), the standard mixture performed best. Combustion of grassland biomass obtained higher net energy yields than anaerobic digestion, with highest values at the harvest dates, when also combustion quality was also highest. Thus, a delayed cut would be suggested.

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Energy balance of bioenergy cropping systems under the environmental conditions of Schleswig-Holstein

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Abstract

A 2-year field trial was conducted at two sites in northern Germany to perform an energy balance for bioenergy cropping systems. An analysis of fossil energy input and energy efficiency was carried out to quantify the impact of cropping system (maize monoculture, maize-wheat rotation, permanent grassland), nitrogen (N) level, and N type. Considering the whole production chain including conversion to biogas, maize monoculture had a higher net energy yield than the other systems investigated. Energy input was dominated by energy demand for conversion to biogas, while the impact of N-fertiliser type was less pronounced.

Keywords: energy balance, biogas, maize, permanent grassland

Introduction

Biogas production in Germany is largely based on maize and shows an increasing trend towards large biogas plants. The latter results in longer transport routes for fermentation substrates and biogas residues and may therefore have negative effects on the climate due to increased greenhouse gas emissions (GHG). In addition, energy crop production is often characterised by a high use of fossil energies. Although various studies on life cycle assessment (LCA) of biogas production are available, many are based on literature data, especially with regard to balances of energy and GHG emissions. Furthermore, data for northern Germany are generally limited. The aim of this paper was to generate an energy balance for biogas production systems in northern Germany as part of a LCA based on a 2-year field trial incorporating the whole chain of plant cultivation, harvesting, transport and conversion to biogas.

Materials and methods

Within the framework of the Biogas-Expert project of Kiel University, a field trial was conducted at two experimental sites in northern Germany. The aim of the joint project Biogas-Expert is to contribute to a sustainable optimization of biogas production by comprehensive experimental trials and systems modeling. Three cropping systems (maize monoculture, maize-whole crop wheat-Italian ryegrass, permanent grassland) were investigated at two experimental stations, Hohenschulen (HS) (annual rainfall 750 mm, average daily temperature 8.3°C, soil type sandy loam) and Karkendamm (KD) (annual rainfall 844 mm, average daily temperature 8.3°C, soil type sandy sand). N-fertiliser was applied at four levels (0, 120, 240, 360 kg ha^{-1} on wheat and maize; 0, 160, 320, 480 kg ha^{-1} on grassland) and differed in treatments: calcium ammonium nitrate (CAN) and biogas residue from co-fermentation was applied at KD and HS, with cattle slurry additionally applied at KD and pig slurry at HS. The energy balance calculation was based on the process analysis method by Hülsbergen *et al*. (2001), where energy input only takes into account the direct and indirect input of fossil fuels. Diesel fuel use was calculated by multiple regression equations considering field size (20 ha), soil type, working distance field-biogas plant (8 km) and fertilisation technique. The underlying data were taken from the KTBL databases (KTBL, 2010). The upstream processes for machinery were calculated according to Gaillard (1997), based on KTBL (2010) and Scholz and Kaulfuß (1995). Conversion data for indirect input were assumed as follows: diesel, 42 MJ l^{-1} (Gaillard *et al*., 1997); mineral N fertilizer as CAN, 39.7 MJ kg^{-1} (Patyk and Reinhardt, 1997); herbicides, 288 MJ kg^{-1} (Green, 1987) slurry, 11.6 MJ m^{3-1} (Häussermann and Döhler, 2010) and biogas residue, derived from slurry 11.6 MJ m^{3-1}. For conversion a combined heat and power plant (500 kWh), with electric efficiency of 40% and thermal efficiency of 41.5% was assumed. The energy output calculations ($output_{el}$, $output_{th}$, nutrients) are based on the methane production potentials of maize, whole crop wheat, and grass investigated in an earlier subproject of the Biogas Expert framework converted to MJ ha^{-1} by using a methane heating value of 35.9 MJ m^{3-1}(KTBL, 2006) and N-, P- and K-uptake of the investigated cropping systems. A covariance analysis of the relationship of N input to total energy input (GJ ha^{-1}) and energy output (GJ $ha+^{-1}$) was performed by means of SAS Proc GLM assuming a quadratic function, where N input was considered as covariable.

Results and discussion

The comparison between the maize-monoculture (FF1) and the maize-wheat rotation (FF2) at HS as well as between FF1 and permanent grassland (FF4) at KD showed a noticeable higher energy output for FF1 than for FF2 and FF4, which was mainly caused by the higher dry matter yield (Figure 1a, 1b). Considering the energy input, FF2 and FF4 showed slightly lower values than FF1. This, however, could not overcompensate the higher energy output, resulting in higher net energy yield of FF1 at HS (difference: 32 GJ ha^{-1}) and at KD (difference: 50 GJ ha^{-1}), which is in agreement with Gerin *et al*. (2008). The higher energy input rates for FF1 were caused by heat and electricity demand for conversion to biogas, which were assumed to be 20% of the generated electricity for heat and 7.5% for electricity. Nevertheless the input/output ratio ranging between 1.9 and 2.7 for all investigated cropping systems was clearly positive as was also reported by Eder *et al*. (2009).

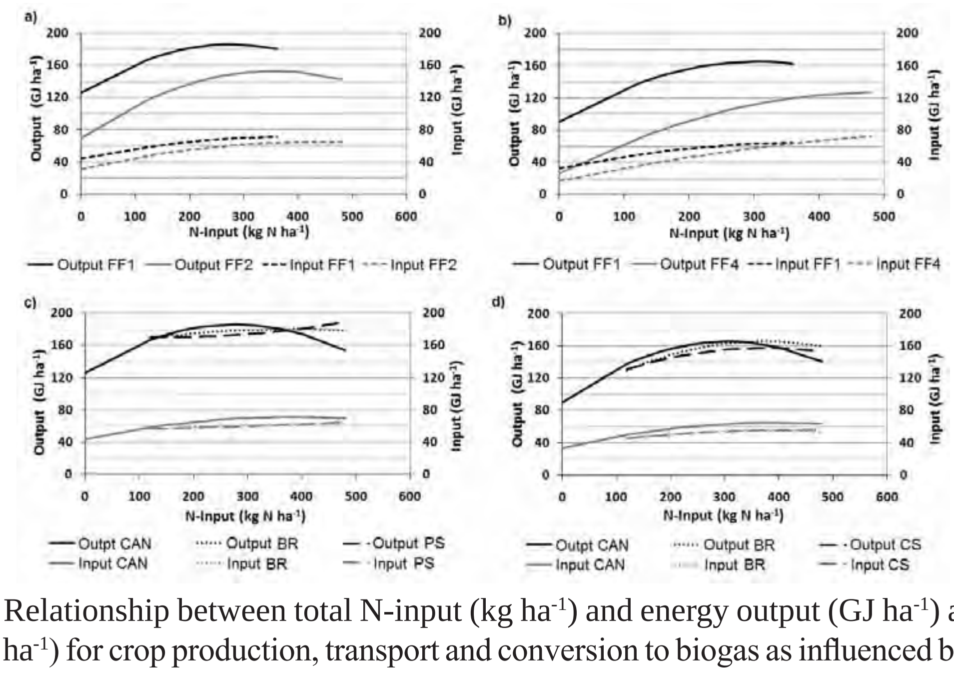

Figure 1. Relationship between total N-input (kg ha^{-1}) and energy output (GJ ha^{-1}) and energy input (GJ ha^{-1}) for crop production, transport and conversion to biogas as influenced by cropping system (1a, 1b) and N fertilizer type (1c, 1d). FF1 = maize-monoculture, FF2 = maize-wheat rotation, FF4 = permanent grassland, CAN=calcium ammonium nitrate, BR = biogas residue, PS = pig slurry, CS = cattle slurry.

The comparison of fertiliser types showed less pronounced differences in energy input as well as energy output (Figure 1c, 1d). Higher input values induced by the high indirect energy input for fertilizer production have been expected, especially for CAN fertilized cropping systems. Figure 2 provides an example for all components included in the energy input for the N-treatments providing the highest net energy yield of FF1 at both HS (240 kg N ha^{-1}) and KD (280 kg N ha^{-1}). When considering only crop production, CAN use induced an input 6-8 GJ ha^{-1} higher compared to biogas residue. This impact of N-type, however fades into the background when including the conversion to biogas due to the high energy input for the conversion process.

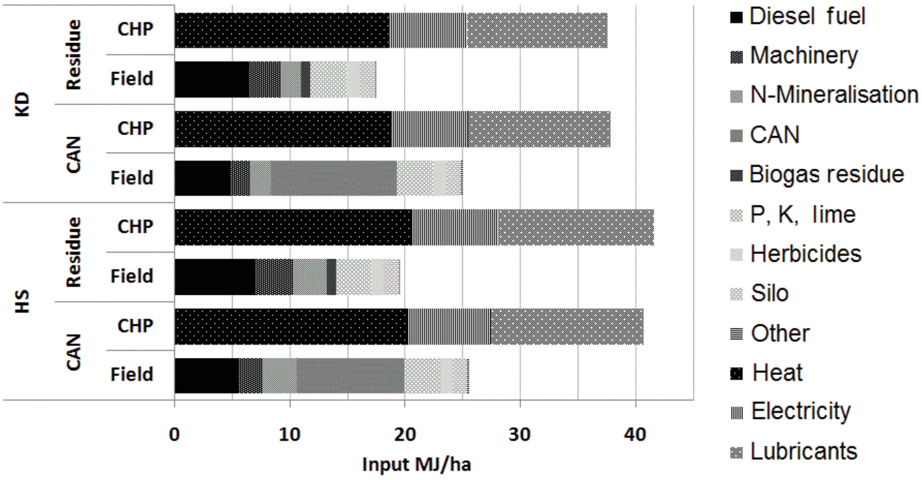

Figure 2. Components of energy input for FF1 crop production (field) and conversion (CHP) using CAN-fertiliser and biogas residue at Hohenschulen (HS) and Karkendamm (KD).

Conclusions

Net energy yield clearly differed between the investigated cropping systems. Contrary to the expectations, maize-monoculture achieved highest net energy yields. N-fertilizer type had an impact with respect to the energy balance of crop production, but was of minor importance when considering the whole production chain. A CO_2 balance will be performed in the next step to allow conclusions about the GHG-reduction potential.

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Intake of forage by sheep and goats grazed on wooded rangelands of deciduous oak and beech trees in northern Greece

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Abstract

Wooded rangelands of deciduous oak and beech trees in Greece are mainly grazed by domestic animals but they also fulfil multiple objectives and functions. Vegetation in such environments is characterized as highly heterogeneous in terms of species richness, structure and size, as well as in nutrient content and time spent in the ruminant digestive tract. In this paper, the intake of sheep and goats grazing on wooded rangelands dominated by deciduous oak and beech trees was investigated in northern Greece. It was determined by using the bite-count method during the spring and autumn grazing periods. Intake of sheep was higher than that of goats for both grazing periods as a result of higher ($P \leq 0.05$) grazing time and bite frequency.

Keywords: small ruminants, bite count method, silvopastoral systems

Introduction

Wooded rangelands of deciduous oak and beech trees occupy a significant part of the total area of forests in Greece. These areas are mainly utilized by domestic and wild animals, but they also provide multiple functions and products such as timber, fuelwood, charcoal, mushrooms, recreation etc. Vegetation of this environment is characterized as highly heterogeneous and variable, as it is consists of deciduous trees and shrubs, evergreen shrubs, grasses, legumes and forbs. Sheep and goats grazing in such environments select their bites from highly contrasted plant species and plant parts differing in structure and size, digestibility and time spent in the ruminant digestive tract. These factors influence the two central components of the instantaneous intake rate (g min^{-1}), bite frequency (bite min^{-1}) and bite weight (g bite^{-1}) (Spalinger and Hobbs, 1992) with the latter being more important in the control of total daily intake (Hodgson, 1985). Such information for the heterogenous environment of Mediterranean wooded rangelands is relatively limited (Dumont *et al*., 1995; Kababya *et al*., 1998; Agreil and Meuret, 2004). In this paper the intake of sheep and goats grazing in a mixed flock on wooded rangelands of deciduous oak and beech trees in northern Greece was studied. Such knowledge is important for integrating grazing into management of these areas as well as for determining the environmental impact on animal production systems.

Materials and methods

The study was conducted at the Municipal Department of Ossa in Lagadas county of Thessaloniki, northern Greece in the spring and autumn of 2002. The climate is semi-arid Mediterranean with cold winters and a long hot and dry summer period of at least four months. Soils, mainly derived from metamorphic rocks (Fockel and Mollat, 1979), are shallow and acid (pH 5.2-6.4), poor in nitrogen, phosphorus and organic matter, and have a sandy-loam texture. Oaks (*Quercus pubescens* Willd., and *Quercus fraineto* Ten.) and beech (*Fagus moesiaca* K. Maly) were the dominant tree species in the study area resulting in an overstory crown density of less than 30%. The understory vegetation comprised both shrubby and herbaceous species. *Quercus coccifera* L., *Carpinus orientalis* L., *Pyrus amygdaliformis* Vill. and *Rosa canina* L. were the main shrub species, while *Dichanthium ischaenum* L., *Chrysopogon gryllus* L. Trin., *Thymus sibthorpii* Benth., *Dactylis glomerata* L. and *Poa bulbosa* L. were the dominant herbaceous species.

A mixed flock of 50 goats and 70 sheep, both of which were comprised of local breeds, was used for the experiment. By using a GPS, the area used by this flock during a grazing day was found to be about 45 ha. In this particular area, five randomly selected plots, 30×30 m each in size, were used to measure ground cover by using the loop method (Cook and Stubbendieck, 1986). Only understory vegetation (up to 1.50 m) was recorded and categorized into grasses, forbs and woody species. Four 2 year-old female animals (two sheep and two goats) were marked with large visible numbers and were directly observed for four consecutive days by two well-trained observers. Each experimental animal was observed for a 30-min period from a certain distance in order not to affect its behaviour. Bite frequency (bites min^{-1}) and the time spent grazing (min day^{-1}) were recorded. Simulated bite samples of the selected grasses, forbs and woody species were hand clipped in order to estimate the bite weight (g DM $bite^{-1}$). Daily dry matter intake (g day^{-1}) was determined as the product of bite frequency, bite weight and grazing time. A total of 32 individual observation periods of 30 min were obtained. On any grazing day, the animals were allowed to get settled for 30 min before observations were initiated. Supplementary feed was not given to the animals during the experimental period. Water and salt were available *ad libitum*. All measurements were subjected to an analysis of variance (Steel and Torrie, 1980). The LSD test was used for detecting mean differences ($P \leq 0.05$).

Results and Discussion

Herbaceous vegetation covered most of the soil surface (grasses contributed 51.5% and forbs 15.3%) whilst woody species represented a small percentage of vegetation available to the animals (5%). Bare ground and rocks were 4% and 0.5%, respectively, whilst litter which included past year's vegetation growth as well as fallen oak or beech leaves was 23.2%.

Intake of sheep was higher than that of goats but significant differences ($P \leq 0.05$) were found only for the spring grazing period (Table 1). Bite frequency and grazing time of sheep were greater ($P \leq 0.05$) compared to goats for both grazing seasons while bite weight of sheep was smaller than that of goats. However, no significant differences were found. It seems that sheep compensate for small particle size by increasing bite frequency. Our results are consistent with findings reported by, e.g., Allden and Whittaker (1970) and Arnold and Dudzinski (1978).

Table 1. Intake (DMI), bite frequency (BF), bite weight (BW) and grazing time (GT) of sheep and goats in wooded rangelands of deciduous oak and beech trees in spring and autumn.

	Spring		Autumn	
	Sheep	Goats	Sheep	Goats
DMI (g day^{-1})	1226.4a	920.2b	694.5a	520.6a
BF (bites min^{-1})	68.33a	42.69b	72.80a	30.34b
BW (g DM $bite^{-1}$)	0.18a	0.28a	0.10a	0.19a
GT (min day^{-1})	99.7a	79.8b	95.4a	90.3b

[a, b] indicate significant differences ($P \leq 0.05$) in the same row between sheep and goats for each season.

The bite weight of sheep on woody species was very small (Table 2) and the range was extremely narrow (from 0.05 to 0.09 g DM $bite^{-1}$). Similarly, a narrow range of bite weights (from 0.08 to 0.15 g DM $bite^{-1}$) has also been reported by Agreil *et al.* (2006) for sheep grazing on broom shrub lands. In contrast, bite weight of goats was higher ($P \leq 0.05$) for the woody species compared with forbs. This may have resulted from the higher DM content in woody species, but also from the possibility of prehension of them from different angles (Landau *et al*., 2000).

Table 2. Bite frequency (BF) and bite weight (BW) of grasses, forbs and woody species selected by sheep and goats.

	Spring			Autumn		
	Grasses	Forbs	Woody	Grasses	Forbs	Woody
Sheep						
BF (bites min^{-1})	68.68a	73.88a	52.57a	65.84a	85.76a	61.43a
BW (g DM $bite^{-1}$)	0.25a	0.24a	0.05b	0.06ba	0.16a	0.09b
Goats						
BF (bites min^{-1})	56.60b	35.42ca	38.62a	33.85a	30.29a	26.90a
BW (g DM $bite^{-1}$)	0.28ab	0.23b	0.32a	0.16a	0.20a	0.21a

[a, b] indicate significant differences ($P \leq 0.05$) in the same row for each season.

Conclusions

Although intake is mainly affected by bite weight, the higher grazing time and bite frequency of sheep resulted in higher intake values compared with goats.

Acknowledgements

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Conservation strategies of *Vavilovia formosa* (syn. *Pisum formosum*), a high-mountainous pea relative, in Armenia

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Abstract

High-mountainous pea (*Vavilovia formosa* (Stev.) Fed) has a distribution ranging from Turkey, over Armenia, Georgia, Lebanon, Syria and Azerbaijan to Iraq and Iran, limited to the mountainous areas of at least 1500 m a.s.l. Its main potential genomic, genetic, taxonomic and agronomic importance is that it could be the closest to the lost common ancestor of the whole tribe *Fabeae*. Developing a long-term strategy of its *in situ* conservation, especially in the regions where it grows abundantly such at Mount Ughtasar and Geghama Mountains, is needed. The greatest threats to the survival of *V. formosa* are both wild and nomadic domestic animals that graze it, probably being attracted by a leaf dry-matter crude protein content of more than 220 g kg^{-1}. On poorer soils, it is mice that may prevent the regeneration and multiplication of *V. formosa* by collecting its shattered seeds, with an average crude protein content of 350 g kg^{-1}. So far, the only successful example of an *ex situ* conservation of *V. formosa* is within the *Flora and Vegetation of Armenia* plot of the Yerevan Botanic Garden.

Keywords: Armenia, chemical composition, crop wild relatives, *ex situ* conservation, *in situ* management, *Vavilovia formosa*.

Introduction

The species known today as *Vavilovia formosa* (Stev.) Fed. was named for the first time by Steven in 1812 as *Orobus formosus* Stev. Later, it was classified as a species of its closest relatives within the tribe *Fabeae*, namely *Lathyrus* L., *Pisum* L. and *Vicia* L., and was known mostly as *Pisum formosum* (Stev.) Alef. Finally, it was granted the status of a separate, monospecific genus *Vavilovia* Fed. (Mikić *et al*., 2009).

V. formosa is a relict and endangered plant found in rocky areas at altitudes from 1500 m up to 3500 m, with Central and Eastern Caucasus as its mainland and a distribution in Armenia, Azerbaijan, Georgia, Iran, Iraq, Lebanon, Russia, Syria and Turkey (Kenicer *et al*., 2009). This perennial and herbaceous species has long roots, strong rhizomes, creeping stems, leaves with one pair of leaflets and a characteristic mucro-like rachis tip (Figure 1a), pink flowers (Figure 1b) and linearly oblong pods (Figure 1c) with round, smooth and dark-coloured seeds (Figure 1d).

This brief review is aimed at presenting the recent achievements and milestones of the current research on *Vavilovia formosa*.

***In situ* research**

An informal international interest group on *V. formosa* research was developed during 2008 attempting to revive the interest in this species (Mikić *et al*., 2010). The first scheduled action was to carry out first expeditions in search for *V. formosa* after the last one by a joint Soviet-British team twenty years earlier and few minor botanical reports from Turkey.

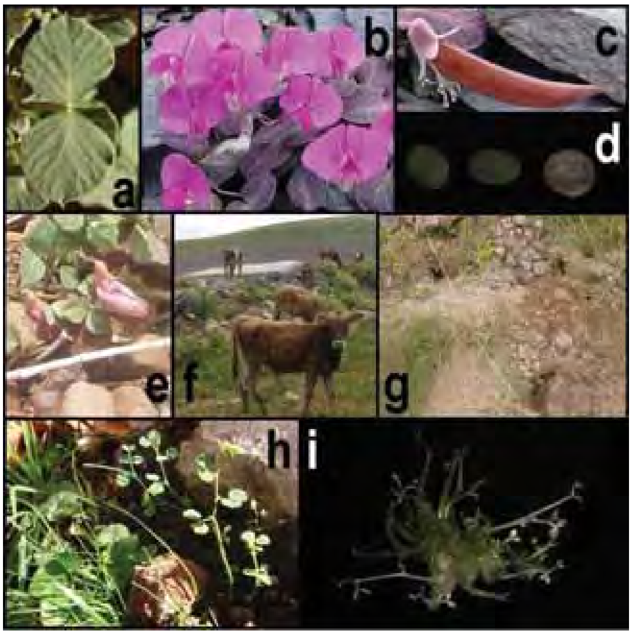

Figure 1. (upper row) Details of *V. formosa* morphology: leaf (a), flower (b), pod (c) and seeds (d). (middle row) Three main forms of threats to the *V. formosa* survival: early frosts (e), cattle (f) and mice (g). (lower row) *Ex situ* (h) and *in vitro* (i) plants of *V. formosa*

During the summer 2009, three expeditions in total were conducted at two locations in Armenia (Sarukhanyan *et al*., 2009), targeted on the basis of the previous preliminary visits (Akopian and Gabrielyan, 2008). The Mount Ughtasar in southern Armenia was visited on July 17 and August 27, while the Geghama Mountains in the central region of the country were visited on August 20. The first expedition to Ughtasar resulted in the discovery of a *V. formosa* population in full bloom of 7.5 hectares in size, with plant parts sampled for herbarium and chemical analysis and whole plants collected for *ex situ* conservation. The expedition to the Geghama Mountains located more populations, with one completely destroyed by grazing domestic and wild animals, especially cattle and sheep (Figure 1f). The Mount Ughtasar was visited when the first frost had begun, destroying most of the flowers (Figure 1e). A small number of seeds was collected for further chemical analysis and *in vitro* propagation. The seeds that had already shattered were unable to recover since they had obviously been gathered by a numerous population of mice (Figure 1g).

Ex situ conservation

So far, several attempts have been made towards the *ex situ* conservation of *V. formosa*, most notably in the USSR (Makasheva *et al*., 1973) and UK (Cooper and Cadger, 1990), with a limited success. Today, the only place where the ex situ conservation of *V. formosa* is carried out is within the plot *Flora and Vegetation of Armenia* in the Botanical Garden in Yerevan (Akopian *et al*., 2010), where the specimens collected in the Ughtasar and Geghama Mountains were planted in its alpine hill with artificial scree. At the moment, the plants are in vegetative stage, with no fully-developed flowers so far (Figure 1h).

From the very few mature seeds collected in the Ughtasar Mountain, a successful *in vitro* culture of *V. formosa* was developed with still slow rooting (Figure 1i). In case of flowering, various *interspecies* hybridisation will be done between *V. formosa* and pea (*Pisum sativum* L.), common vetch (*Vicia sativa* L.) or grass pea (*Lathyrus sativus* L.), thus checking the reports on its possibility (Golubev, 1990).

The average crude protein content in *V. formosa* leaf dry matter was 220.69 g kg^{-1}. The content of neutral and acid detergent fiber (NDF and ADF) was 452.7 g kg^{-1} and 344.6 g kg^{-1} in stem and 364.0 g kg^{-1} and 246.7 g kg^{-1} in leaf dry matter. The crude protein content in seed dry matter of *V. formosa* was 357.81 g kg^{-1}. Due to a limited number of the available *V. formosa* seeds, it was not possible to determine its content of anti-nutritional factors.

V. formosa shall surely remain in the very focus of the multidisciplinary research on legumes, especially since its potential, demonstrated agronomic use and its importance in the evolution and molecular taxonomy of legumes and its tribe *Fabeae* (Smýkal *et al*., 2010).

Conclusions

Recent years witness a wide revival of both interest in and research on *Vavilovia formosa*, justifying rare achievements done decades ago and opening novel horizons for multidisciplinary approaches. Future efforts aimed at *in situ* preservation of this relict and endangered species are essential for any *ex situ* research, with particular reference to molecular taxonomy and breeding.

Acknowledgements

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Bio-agronomic evaluation of fifteen accessions within Psoralea complex

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Abstract

Recent research indicates that *Psoralea* complex has potential as a pasture legume for Mediterranean disadvantaged areas. It is a perennial legume widely distributed in the Mediterranean Basin. A germplasm collection was conducted in Sardinia and then a preliminary bio-agronomic evaluation started during 2009-2010. Morphological traits of the plants, stems, leaves, flowers, and tolerance to cold and drought were observed. Data on summer biomass production, forage quality and intensity of 'oil' smell were collected. Results showed significant differences between the accessions for most of the traits considered. The accession 'Albo-H Tol Frio' (var. *albomarginata*) was associated with high summer forage production and tolerance to frost. Growing this plant may provide alternative sources of natural fodder protein, reducing the costs for supplements, fertilizers and soil tillage.

Keywords: perennial legumes, *Psoralea bituminosa*, *P. morisiana*, germplasm, forage quality.

Introduction

Perennial forage legumes adapted to dry and marginal Mediterranean environments will assume increasing importance under future climate change predictions of lower and more erratic patterns of rainfall. They will enhance the stability of the feed base for livestock, create options for rehabilitation of degraded or eroded lands, increase biodiversity and may provide new medicinal benefits. Recent research indicates that *Psoralea* complex has potential as a forage legume for Mediterranean disadvantaged areas (Ventura *et al.*, 2009). *Psoralea bituminosa* C.H. Stirton (syn. *Bituminaria bituminosa* L.) is a perennial legume widely distributed in the Mediterranean Basin, and it grows and remains green all-year-round even during summer and autumn, and is assumed to be tolerant of heavy grazing (Sternberg *et al*., 2006). A large diversity exists in the Canary Islands with 3 varieties: var. *albomarginata* (coastal semiarid areas), var. *crassiuscula* (high elevation subhumid areas) and var. *bituminosa* (wider adaptation), while *P. morisiana* Pignatti and Metlesics is an endemic, present in Sardinia. To explore the potential of Sardinian germplasm a collection was carried out. This paper presents some preliminary results about its bio-agronomic characterization.

Materials and methods

A germplasm collection for *P. bituminosa* and *P. morisiana* during summer 2009 was conducted in Sardinia. For each site of the seed collection a complete set of data (climate, soil, topography, companion species, grazing pressure, etc.) were reported. A preliminary bio-agronomic evaluation on 8 accessions (5 belonging to *P. morisiana* and 3 to *P. bituminosa*) was carried out in the season 2009-2010. Also 3 accessions of var. *bituminosa*, 2 of var. *albomarginata* and var. *crassiuscola*, respectively, from Canary Islands were included as test in the field evaluation, for a total of 15 accessions. An experimental field at the Centre for the Conservation and Valorization of Plant Biodiversity (North Sardinia, 40°35'N 8°22'E) was established. The climate is typical of the central Mediterranean basin with long-term average annual rainfall of 540 mm and a strong summer drought from June to September. Scarified seeds of each accession were germinated in jiffy pots in October 2009 and the seedlings grown in a greenhouse, and then planted in the field in mid February. The soil is calcareous alluvial, with a pH (water) of 6.9. A randomized experimental design with 12 spaced plants per plot and 3 replicates was used. Quantitative and qualitative morphological traits of the plants, stems, leaves and flowers were collected. Tolerance to cold and drought as percentage of surviving plants were observed. Data on summer dry matter (DM) production per plant and forage quality as chemical composition were determined on subsamples dried at 60°C. Neutral detergent fibre (NDF), acid detergent fibre (ADF), acid detergent lignin (ADL) and ash were determined according the method of Goering and Van Soest (1976) while crude protein was done according to the Kjeldahl method (Martillotti *et al*., 1987). Also the intensity of 'oil' smell was evaluated using an empirical scale (0 = absent; 1 = weak; 2 = medium; 3 = strong) as average of two summer dates (6 and 28 July 2010).

Results and discussion

The two species were found in the range 0-1000 m a.s.l. Total annual rainfall ranged from 450 to 900 mm, mean of minimum temperature of coldest month from 2.1 to 6.1°C, and mean of maximum temperature of warmest month from 27.4 to 30.4°C as. Plants were mostly collected on rocky areas that were heavily grazed, often on slopes with neutral or alkaline sandy shallow soil. The results of field evaluation have shown differences between the accessions for most of the traits considered. Some morphological plant traits grouped for the three botanical varieties of *P. bituminosa* and *P. morisiana* are reported in Table 1.

Table 1. Averages and ranges of some morphological plant traits.

		height (cm)		diameter (cm)		no. stems/plant	
species/botanical var.	no. acc.	avg	range	avg	range	avg	range
P. bituminosa crassiuscola	2	53.4	45-61	74.7	72-77	11	10-11
P. bituminosa albomarginata	2	30.6	28-33	46.8	47-47	13	8-17
P. bituminosa bituminosa	6	58.1	28-100	80.8	38-104	8	5-9
P. morisiana	5	42.3	28-56	45.6	38-51	8	6-13

The accession 'Albo-H Tol Frio' (var. *albomarginata*) was associated with high summer forage production (Figure 1) and tolerance to frost and drought (98%). Calnegre (var. *bituminosa*) despite its significantly higher dry matter production showed low tolerance to cold with only 25% of plants surviving.

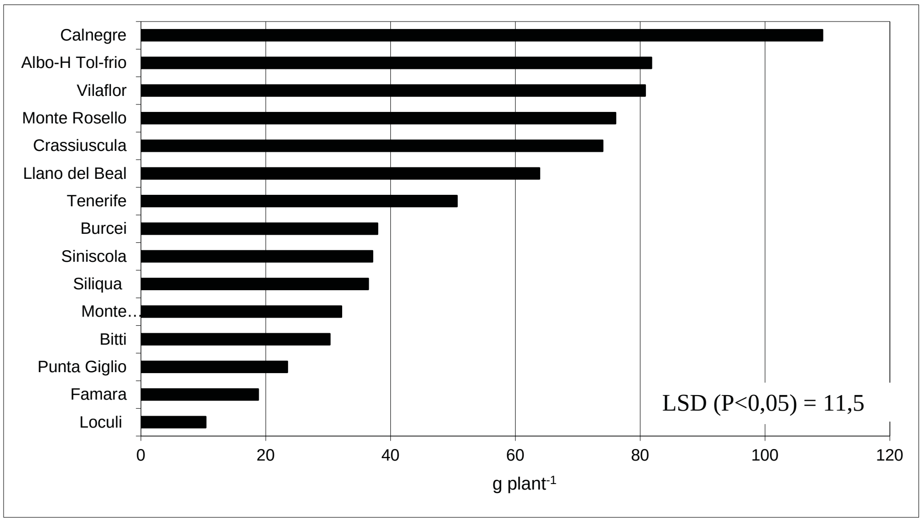

Figure 1. Dry matter production at the end of summer 2010 for the 15 accessions.

The variation in forage quality among accessions is reported in Table 2. Differently from Pecetti *et al*. (2009) significant differences ($P \leq 0.05$) were observed for crude protein, fibre and lignin. Generally *P. morisiana* accessions showed lower NDF, ADF and ADL content than *P. bituminosa* accessions.

Table 2. Variation in forage quality in germplasm of *P. bituminosa* and *P. morisiana*.

Accessions species/botanical variety	accession	CP (%)	NDF (%)	ADF (%)	ADL (%)	Ash (%)
P. bituminosa crassiuscula	Crassiuscula	10.5[ab]	46.9[bc]	26.6[bcd]	7.7[bcd]	8.6[bc]
P. bituminosa crassiuscula	Vilaflor	10.7[a]	53.9[ab]	30.5[b]	7.4[cd]	7.4[d]
P. bituminosa albomarginata	Famara	10.2[ab]	42.4[c]	25.6[cd]	6.9[def]	9.6[a]
P. bituminosa albomarginata	Albo-H Tol-frio	10.6[ab]	46.4[c]	29.7[bc]	7.1[de]	9.1[ab]
P. bituminosa bituminosa	Calnegre	8.8[cde]	45.7[c]	27.8[bcd]	6.6[def]	7.8[cd]
P. bituminosa bituminosa	Tenerife	10.4[ab]	43.6[c]	24.7[d]	6.1[ef]	9.6[ab]
P. bituminosa bituminosa	Llano del Beal	7.7[e]	59.7[a]	39.4[a]	8.8[ab]	5.6[e]
P. bituminosa bituminosa	Monte Rosello	8.4[de]	55.3[a]	37.7[a]	7.7[bcd]	5.8[e]
P. bituminosa bituminosa	Loculi	8.8[cde]	55.7[a]	37.2[a]	9.5[a]	6.1[e]
P. bituminosa bituminosa	Siniscola	8.8[cde]	54.1[a]	36.6[a]	8.7[abc]	6.2[e]
P. morisiana	Siliqua	10.6[ab]	40.6[c]	21.4[d]	6.3[ef]	6.9[de]
P. morisiana	Burcei	9.4[bcd]	44.3[c]	23.9[d]	6.7[def]	8.3[bc]
P. morisiana	Monte Gonareddu	8.1[de]	44.1[c]	48.2[a]	5.7[f]	6.3[e]
P. morisiana	Bitti	9.4[bcd]	35.6[cd]	19.6[de]	4.9[fg]	6.2[e]
P. morisiana	Punta Giglio	9.7[abc]	41.7[c]	23.7[d]	5.7[f]	6.4[e]

Accessions values followed by different letters are significantly different at $P \leq 0.05$ according to analysis of variance and Duncan's multiple range test.

'Oil' smell was absent in all accessions of *P. morisiana* and in the 'Famara' accession of var. *albomarginata*. The other evaluated accessions did not differ significantly in smell intensity, although some trends were evident among var. *bituminosa* accessions that ranged from 0.5 ('Loculi') to 1.9 ('Monte Rosello' and 'Siniscola'). Hand-rubbing of the plants had little effect in eliciting a stronger smell.

Conclusion

These preliminary results are very encouraging in view of the valorization of *Psoralea* as a perennial forage legume for marginal rainfed areas. Growing *Psoralea* in permanent dense stands may provide alternative sources of natural fodder protein, reducing the costs at farm level for supplements, fertilizers and soil tillage.

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Perennial ryegrass for biogas production: How do cutting frequency and cultivar maturity influence methane yield?

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Abstract

Biogas production has expanded substantially in Germany, including marginal regions for maize cultivation. A 2-year field trial was conducted in the marsh-region of northern Germany to analyse the impact of cutting frequency (3- *vs.* 4-cut system), N-fertilisation (optimal *vs.* oversupply treatments) and maturity group (mid-early *vs.* late) on the dry matter and methane yield of perennial ryegrass. Our hypothesis, that a reduction of cutting frequency could increase economic competitiveness, was confirmed. Due to its higher DM yield, the 3-cut system overcompensated the higher specific methane yield of the 4-cut system, resulting in significantly higher annual methane hectare-yield.

Keywords: Anaerobic digestion, methane, *Lolium perenne*, competitiveness, cutting regime, heading date

Introduction

After the introduction of high subsidies in 2004, the production of methane from anaerobic digestion of slurry and/or biomass to generate electricity/heat has greatly expanded in Germany. Silage maize is the dominant substrate supplier due to its high methane yield potential. But because of its cold and wet soils, the marsh region of northern Germany is a marginal site for maize cultivation. Here, forage grasses such as *Lolium perenne* may outcompete maize with respect to yield and yield stability. If it was possible to reduce the production costs, e.g. by reducing the number of cuts, the competitiveness of forage grasses could be increased. The objective of the current study therefore was to investigate the effect of cutting frequency, N-fertilisation, and maturity group on yielding performance and quality of grassland grown in a coastal marsh region of northern Germany.

Material and methods

The study was based on a 2-year field trial (2009-2010), conducted as a randomised complete block design with 4 replicates on a heavy clay soil (40% clay, gleyic Fluvisol (calcaric), pH 7.0) close to the west coast of Schleswig-Holstein. Two *Lolium perenne* cultivars differing in heading date (Trend, 4n, mid-early; Twymax, 4n, late) were grown in a 3- and 4-cut system. Mineral N fertiliser was applied as calcium ammonium nitrate at levels of 360 (optimal) and 480 kg N ha^{-1} (oversupply). Specific methane yield (l_N kg_{OM}^{-1}) of the optimally fertilised treatments (360 kg N ha^{-1}) was quantified by a Batch Test, where samples (chopped to 2 cm of length, unensiled, oven dried, 3 lab replicates) were anaerobically fermented for at least 30 days at 38°C. Unfortunately, specific methane yield so far was only available for 2009. Data were analysed statistically by SAS Proc Mix where replicate, year, cutting frequency, N-fertilisation and maturity group were included as fixed factors. Multiple comparisons were conducted by the Tukey-Kramer method or t-test and Bonferroni-Holm adjustment.

Results and discussion

Annual dry matter (DM) yield was significantly affected by an interaction between maturity group and cutting frequency (Figure 1). The mid-early cultivar Trend was characterised by a significantly lower DM yield in the 4-cut compared to the 3-cut-system. Yielding performance of late cultivar Twymax, however, was not influenced by cutting regime. A reduction of DM yield under higher cutting frequency was also found by Wilman *et al*. (1976). However, Tobi *et al*. (2011) reported a strong influence of environmental conditions on the ranking of cutting systems with respect to DM yield, while they did not detect any significant impact of maturity group on yield performance.

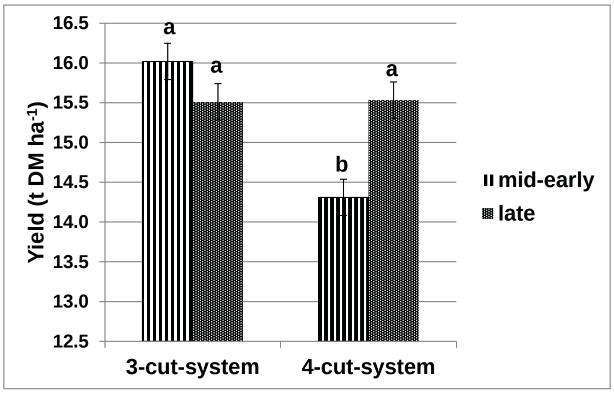

Figure 1. Annual dry matter yield (t DM ha^{-1}) averaged over two experimental years (2009-2010) as influenced by maturity group and cutting regime. Columns not sharing a common letter are significantly different.

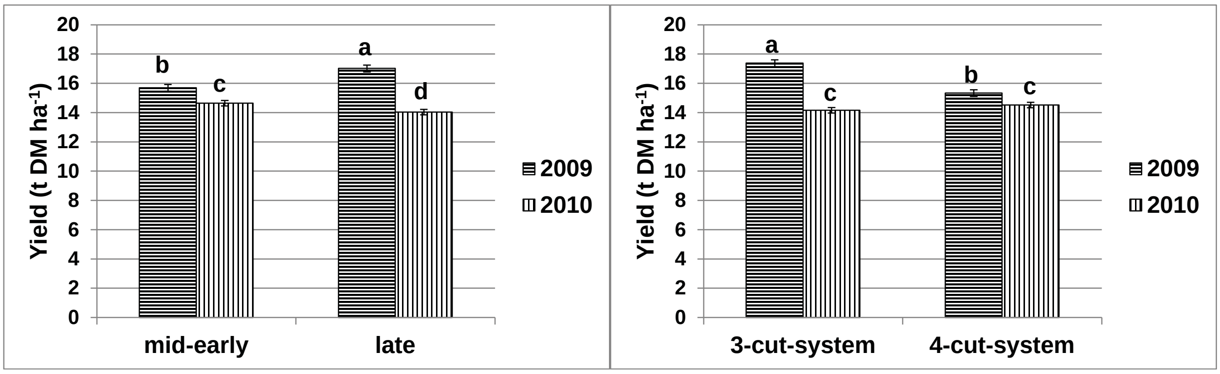

Figure 2. Dry matter yield (t DM ha^{-1}) as influenced by maturity group and year (left), and by cutting regime and year (right). Columns not sharing a common letter are significantly different.

The impact of maturity group on DM yield depended on the year (Figure 2). In 2009, mid-early Trend yielded significantly less than late Twymax, whereas this was reversed in 2010. Furthermore, the cutting regime effect differed between years. A significant influence of cutting frequency on DM yield was detected only in the first experimental year. The interactions with the year may be attributed to weather conditions, but could also be due to sward age effects. Methane hectare-yield varying between 4643 and 5159 $m^3{}_N$ ha^{-1} on an annual basis (Table 1) and between 428 and 2853 $m^3{}_N$ ha^{-1} for single cuts (data not shown) were in the upper range reported for intensively managed permanent grassland and grass leys (Amon *et al*., 2006; Wienforth *et al*., 2010). Methane hectare-yield is determined by the specific methane yield

(l_N kg_{OM}^{-1}) and dry matter yield. The annual average specific methane yield was significantly higher for the 4-cut system (384.4 l_N kg_{OM}^{-1}) than for the 3-cut system (346.5 l_N kg_{OM}^{-1}). Similar results for the impact of cutting frequency have been documented by Lemmer and Oechsner (2002). Due to the overriding importance of DM yield, however, we found significantly higher annual methane hectare yields for the 3-cut system than for the 4-cut system. Furthermore, mid-early Trend showed higher methane-hectare yield than late Twymax (Table 1). We thus could not confirm that higher management intensity will increase annual methane hectare-yield, as stated by Prochnow *et al*. (2009).

Table 1. Annual methane hectare yield (m^3_N ha^{-1}) of the first experimental year (2009), as affected by maturity group or cutting frequency.

Maturity group	Cutting frequency	Methane yield (m^3_N ha^{-1})	Standard error
Mid-early		4643.1a	95.52
Late		5159.3b	95.52
	3	5097.3a	95.52
	4	4705.0b	95.52

Conclusion

Results of the first experimental year reveal that reducing the cutting frequency from 4 to 3 cuts results in significantly higher annual methane hectare-yield, while reducing the costs per unit energy produced. A lower cutting frequency might cause a faster decline of sward density and persistence and will probably require regular reseeding. In order to be able to analyse such effects, longer term experiments are required.

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Comparison of Swiss breeds with New Zealand Holstein-Friesian in pasture-based, seasonal-calving systems

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Abstact

The objective of the study was to compare, within pasture-based seasonal calving systems, the production and reproduction performances of Swiss Holstein-Friesian (CH HF), Fleckvieh (CH FV) and Brown Swiss (CH BS) dairy cows with New Zealand Holstein-Friesian (NZ HF) dairy cows, taken as reference for such systems. NZ HF cows were paired with Swiss cows on 15 Swiss farms. Over 3 years, 259 lactations were analysed. The two Holstein-Friesian strains had the highest milk efficiency (52.1 and 50.2 kg ECM per kg liveweight$^{0.75}$ *vs.* 44.3 and 43.6 kg for CH FV and CH BS; $P < 0.05$). The CH FV cows had the best reproductive performance, with more pregnant cows within 6 weeks of breeding (81% *vs.* 66, 63 and 46% for NZ HF, CH BS and CH HF; $P < 0.10$). Although CH HF cows are efficient milk producers, their poor reproductive performance compromised their suitability for pasture-based seasonal-calving systems. Conversely, CH FV seems promising for such systems owing to good reproductive performance.

Keywords: pasture, seasonal calving, dairy breeds, milk production, reproduction

Introduction

In Switzerland, nearly 60% of agricultural land is permanent pasture and the implementation of systems and cow genetics capable of optimal utilization of the natural resources is a priority. The full-pasture, seasonal-calving milk production system was introduced in Switzerland in the early 2000s. In such systems, cows must calve each year at the same fixed period to match herd feed demand curve and the pasture growth curve. Thus, cows with high fertility are necessary in order to maintain the calving pattern and we investigated if the main Swiss breeds are adapted to those systems. The present experiment aimed to compare, within pasture-based seasonal-calving systems, the productive and reproductive performance of Swiss Holstein (CH HF), Swiss Fleckvieh (CH FV) and Swiss Brown Swiss (CH BS) cows with New Zealand Holstein-Friesian (NZ HF) cows, taken as reference owing to their high milk production efficiency and fertility.

Materials and methods

The present study was carried out on 14, 13 and 10 dairy farms in years 2007, 2008 and 2009 respectively, involving 259 lactations of 134 cows in the four breeds NZ HF (n = 131 lactations, 58 cows), CH HF (40, 24), CH FV (crosses between Simmental and Red Holstein; 43, 27), and CH BS (45, 25). Experimental cows were representative of their population of origin (based on pedigree breeding worth). On each farm, each NZ HF cow was paired with a Swiss breed cow according to calving date and age. Management policies were similar between herds (low-input, pasture-based, spring-calving system).

Milk volume and composition, as well as body condition score (BCS, 1-5 scale with 0.25 increment) were assessed monthly. The lactation body weight was averaged over three values (at 38, 124 and 281 post-partum) and used to calculate milk production efficiency (milk yield per metabolic body weight). Continuous and binomial variables were analysed by linear mixed models and mixed logistic regressions respectively, including breed as fixed effect, year, farm within year and cow as random effects (R statistical software). Multiple testing biases were accounted for.

Results

There were significant differences between breeds for all the production parameters (Table 1). The CH FV achieved a higher submission rate in the first three weeks of the breeding season than the NZ HF (86 *vs.* 53%, $P < 0.01$); CH BS and CH HF were intermediate (58 and 70%). These CH FV also had a higher 1st and 2nd service conception rate than CH HF (89 *vs.* 59%, $P < 0.05$); NZ HF and CH BS were intermediate (76 and 72%). Consequently, CH FV became pregnant earlier than other breeds (Figure 1).

Table 1. Milk production, bodyweight and body condition of New Zealand Holstein Friesian (NZ HF; n = 131 lactations), Swiss Holstein (CH HF; n = 40), Swiss Fleckvieh (CH FV; n = 43) and Swiss Brown Swiss (CH BS; n = 45) dairy cows managed in seasonal-calving pasture-based systems.

Item	n	NZ HF	CH HF	CH FV	CH BS	P_{breed}
Milk production over 270 days						
Milk yield (kg)	259	5321^{b}	5921^{c}	5291^{ab}	4927^{a}	< 0.001
ECM yield 1 (kg)	259	5531^{b}	5840^{b}	5363^{b}	4814^{a}	< 0.001
Fat content (%)	259	4.25^{c}	4.01^{ab}	4.15^{bc}	3.86^{a}	< 0.001
Protein content (%)	259	3.46^{b}	3.20^{a}	3.31^{a}	3.27^{a}	< 0.001
ECM persistency[3]	259	0.79^{b}	0.74^{a}	0.76^{ab}	0.72^{a}	< 0.001
ECM efficiency[2] (kg. $kg^{-0.75}$)	221	52.1^{b}	50.2^{b}	44.5^{a}	43.8^{a}	< 0.001
Average body weight	221	514^{a}	592^{b}	605^{b}	523^{a}	< 0.001
Body condition (1 to 5)						
BCS at calving	251	3.25^{b}	3.05^{a}	3.52^{c}	3.38^{bc}	< 0.001
BC change from calving to 30 days	249	-0.28	-0.37	-0.24	-0.24	0.129
BC change from calving to 100 days	247	-0.40	-0.50	-0.39	-0.45	0.415
Maximum BC loss in 300 days	242	-0.55	-0.65	-0.64	-0.61	0.230

[1] Energy corrected milk (4.0% fat, 3.2% protein and 4.8% lactose content)
[2] Energy corrected milk per average lactation metabolic weight, i.e. per (average lactation BW)
[0.75] Thirty-eight lactations with missing weights were excluded from the analysis
[3] Ratio of ECM yield of the days 101 to 200 to the ECM yield of the days 1 to 100
[a, b, c] values with different superscript letters are significantly different ($P < 0.05$)

The differences in production outcomes observed between NZ HF and CH HF were within the range of differences reported for Holstein-Friesian (HF) strain comparison studies in low-input pasture-based systems (Horan *et al.*, 2005; Macdonald *et al.*, 2008). With regard to the produced ECM yield per metabolic weight, the two HF strains were the most efficient milk producers (+14% in comparison with CH FV and CH BS). A lower milk efficiency was expected for the CH FV cows, which are dual-purpose cows, but not for the dairy-type CH BS cows. High milk production efficiency was not reached in the same way by the two HF strains, CH HF having lower fat and protein content than NZ HF, but also a lower milk persistency, indicating a sharper lactation curve. Part of the CH HF efficiency could be attributed to body fat mobilization. Indeed, although BCS change over the first 100 days of lactation did not significantly differ, daily weighing on one farm revealed a greater body weight loss for CH HF cows (-32 *vs.* -9 kg 30 days post-partum for CH HF *vs.* NZ HF, P<0.01) and metabolites measurements performed in 2008 revealed higher non-esterified fatty acids and β-hydroxybutyrate concentrations for the CH HF cows.

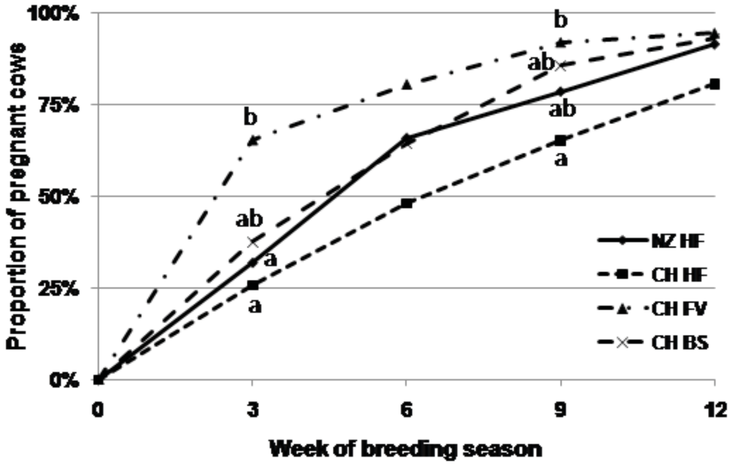

Figure 1. Proportion of pregnant cows within 3, 6, 9 and 12 weeks of the breeding season for New Zealand Holstein Friesian (NZ HF; n = 131 lactations), Swiss Holstein (CH HF; n = 40), Swiss Fleckvieh (CH FV; n = 43) and Swiss Brown Swiss (CH BS; n=45) dairy cows managed in seasonal-calving pasture-based systems.

Discussion

Only the CH FV achieved the New Zealand objectives for reproductive performance, with 65% of the cows being pregnant within three weeks of the breeding period. This excellent result could be explained by an early onset of regular ovarian activity (as suggested by progesterone profiles performed in 2008), a very good submission rate, suggesting good oestrus expression, and very good fertility. In NZ HF cows, a delayed onset of cyclicity, as suggested by progesterone profiles in 2008 (commencement of luteal activity 51 *vs.* 29 days post-partum for NZ HF *vs.* CH FV, $P < 0.01$) and by other studies (Macdonald *et al.*, 2008), could explain the poor submission rate; but thanks to good fertility they could catch up later in the breeding season. Poor submission rate and fertility explained the insufficient pregnancy rates for CH HF cows.

Conclusions

Although CH HF cows are efficient milk producers even in low-input systems, their poor reproductive performance compromised their suitability for pasture-based, seasonal-calving systems. Conversely, although CH FV cows are less milk production oriented, this breed seems promising for such systems in Switzerland owing to good reproductive performance.

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Digestate application on cocksfoot (*Dactylis glomerata* L.) swards - effects on yield, N content and C/N ratio

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Abstract

Anaerobic decomposition of biodegradable materials could contribute to the development of renewable energy. If a biogas plant is available on a farm, it is possible to secure a continuous process biomass - biogas - biomass. In this process, digestate could be used as fertilizer for alternative grassland system. The influence of digestate application on biomass production, botanical and structural composition of cocksfoot (*Dactylis glomerata* L.) was explored in an experiment carried out in Lithuania (55°24´N) on an *Apicalcari - Endohypogleyic Cambisol*, light loam during 2008-2010. Biomass yield of cocksfoot, fertilized with digestate, under the current production conditions did not differ significantly from that of swards supplied with mineral fertilizers. Our preliminary experimental evidence suggests that digestate application favours cocksfoot biomass accumulation and results in a higher C/N ratio.

Keywords: digestate, cocksfoot, biomass yield, nitrogen accumulation

Introduction

Agriculture and food industries produce high quantities of organic residues which could be used as raw materials for biogas production. Anaerobic decomposition of organic material contributes to the reduction of residues and increases the energy value of farming by producing biogas, and utilizing digestate instead of using mineral fertilizers (Salminen *et al*., 2001; Tani *et al*., 2006; Wang *et al*., 2010). Because of the different origins of raw material for biogas production, digestate contains 5.0-40 g kg^{-1} of nitrogen, ~0.7 g kg^{-1} of phosphorus and ~0.4 g kg^{-1} of potassium (Wulf *et al*., 2002; Lehtomaki *et al*., 2008). Such a chemical composition could be promising when utilizing digestate on the swards of perennial grasses.
The present study aimed to investigate the potential utilization of digestate on cocksfoot (*Dactylis glomerata* L.) swards and evaluate the impact on biomass yield and quality.

Materials and methods

Field experiments were carried out during 2008-2010 in central Lithuania (55°24´N). Cocksfoot (*Dactylis glomerata* L.) swards were grown on an *Apicalcari - Endohypogleyic Cambisol*, light loam. The biomass yield, morphological characteristics and concentration of total nitrogen (N) and total carbon (C) in the swards of the first year of use were analysed. Unfertilized swards, two levels of fertilization with mineral nitrogen fertilizers (N_{180} and N_{360}) and five levels of fertilization with digestate (N_{90}, N_{180}, N_{270}, N_{360} and N_{450}) were chosen for the research. The digestate obtained after anaerobic decomposition of pig manure and organic residues in a biogas plant was used in our experiment. The concentration of total nitrogen in digestate varied from 6.1 to 7.5 g kg^{-1}. In the first year of cocksfoot cultivation, 1/3 of mineral fertilizers and digestate were applied at cocksfoot tillering stage. In the first year of use of swards, fertilizers were applied to swards twice in spring, at the beginning of vegetation and after the first cut. Four cuts of swards were taken in 2009 and three cuts in 2010.The concentration of total N in

the digestate was measured using ISO 11261 methodology. The total N and organic carbon in cocksfoot biomass were determined using the Dumas method (DIN/ISO 13878). The weather conditions differed between years. The highest temperature and humidity was in 2010, as compared to the years 2008 and 2009 and to the long-term average.
Differences were considered significant at a probability level below 0.05 ($P < 0.05$).

Results and discussion

When choosing energy crops for biogas production, it is very important to ensure the uniformity of chemical composition of biomass. This could be achieved by management of homogenous swards. In our research, the nitrogen fertilization did not show any significant effect on the botanical composition of cocksfoot swards. Pure cocksfoot accounted for more than 95% of the swards.
In 2009, the air temperature and humidity were lower compared to the year 2010, but that year cocksfoot swards produced significantly higher biomass yield. The N fertilization exerted a significantly higher effect on all swards compared to the unfertilized treatments. On the other hand, there was no significant difference in annual biomass yield between the swards fertilized with N_{180} and N_{360} level of mineral fertilizers, and the same nitrogen ratio in the digestate (Figure 1).

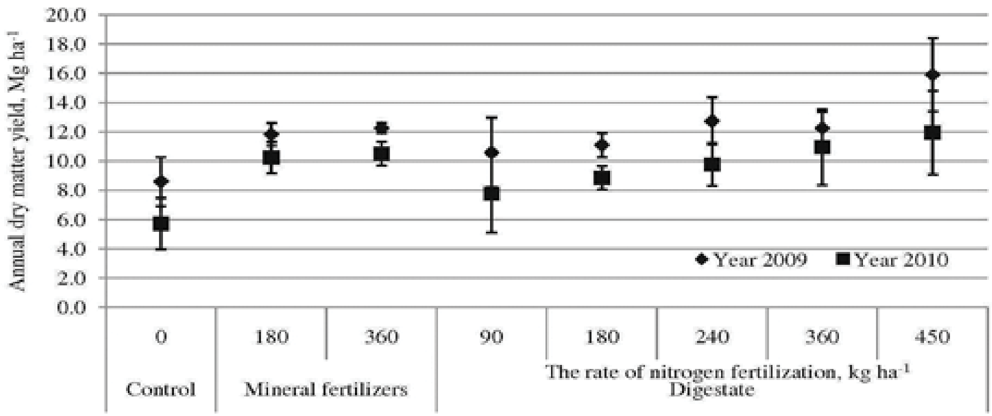
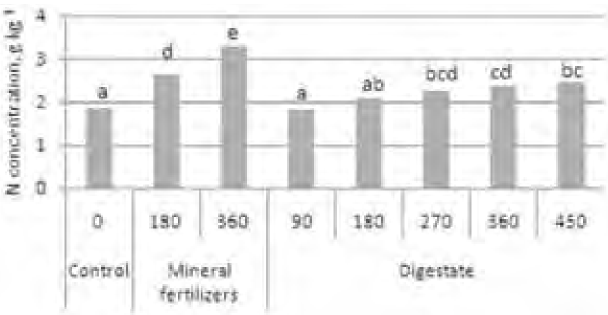
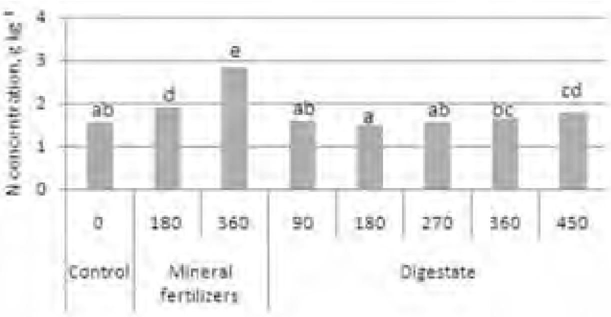


Figure 1. Annual biomass yield of cocksfoot fertilized with mineral fertilizers and digestate

The swards supplied with mineral N fertilizers exhibited a slightly better utilization ofN. Therefore the content of N and crude protein was significantly higher in the biomass of swards, fertilized with mineral fertilizers compared with organically fertilized swards (Figure 2).

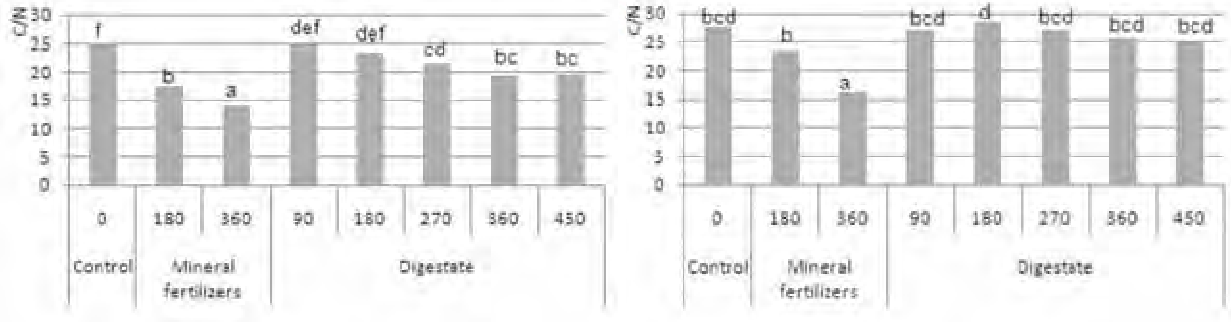




Year 2009 Year 2010

Figure 2. The concentration of nitrogen in cocksfoot biomass

During biogas production anaerobic bacteria consume carbon roughly 20-30 times faster than nitrogen, the optimum carbon to nitrogen (C/N) ratio in the biomass for anaerobic digestion is 20-30 (Dennis, 2001). In our research, the C/N ratio was the lowest in the swards fertilized with mineral fertilizers (Figure 3) and it did not reach the minimum values for optimal anaerobic process. The C/N ratio in the swards fertilized with digestate was higher than 20 and did not exceed the maximum values.



Year 2009 Year 2010

Figure 3. The variation of carbon to nitrogen ratio in coksfoot biomass in 2009 and 2010

Conclusions

Our research evidence suggests that mineral fertilizers did not give any significantly higher effect on annual biomass yield compared to the swards fertilized with the same levels of nitrogen in the digestate. The carbon to nitrogen ratio in the biomass of cocksfoot, fertilized with digestate was better suited for biogas production compared to that in the biomass of cocksfoot fertilized with mineral fertilizers.

Acknowledgements

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The impact of white clover-winter wheat bi-cropping on cereals in an organic crop rotation

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Abstract

The potential of white clover to supply winter cereals with biologically fixed N was investigated in an experiment conducted on a loamy *Cambisol*. Spring barley, white clover as pure-sown crops, and clover with barley cover crops were established in the spring of the first experimental year. In the autumn, wheat was direct drilled into differently sown and managed clover to form a bi-cropping system. In other treatments wheat was conventionally sown after ploughing in of pre-crops. In the autumn of the second year, winter rye was conventionally drilled into the plots. The N content of pre-crop residues incorporated into the soil was higher in clover treatments with the barley cover crop. The wheat grain yield was higher (5.3-6.0 t ha^{-1}) after ploughing in clover. The grain yield was significantly lower in the bi-cropping system and varied depending on the treatments (1.3-4.7 t ha^{-1}); however, the yield was high for an organic crop rotation. The highest N concentrations in wheat grain yield were observed in bi-cropping. The winter rye grain yield was higher after differently direct drilled wheat (2.7-3.5 t ha^{-1}) compared with that of conventionally drilled wheat (1.7-2.05 t ha^{-1}). N concentration in rye grain was higher after a bi-cropping system had been used.

Keywords: bi-cropping, winter wheat, white clover, N, grain yield

Introduction

Many low-input farming systems rely on biological N fixation to supply N for cereals involving a legume and growing multiple crops. In intercropping systems involving a legume and a non-legume, part of the N fixed in the root nodule of the legume may be available for the non-legume component or for subsequent crops (Elgersma *et al*., 2000; Nemeiksiene *et al*., 2010). According to previous research, cereal bi-cropping into white clover is a good alternative and might have high potential for organic farming, especially on farms where there is no source to supplement the soil N with organic manure (Thorsted *et al*., 2006; Hiltbrunner *et al*., 2007). The objectives of this study were to investigate the possibilities of reducing interspecific competition and increasing N-transfer from white clover to winter wheat by applying the drilling methods for forming a bi-cropping system.

Materials and Methods

The study was conducted at the Lithuanian Institute of Agriculture during 2007-2009 on a loamy *Cambisol*; pH ranging from 6.8 to 7.5; humus content 2.3-2.6%; P 74-79 mg kg^{-1}; K 135-140 mg kg^{-1}. The experimental design was a randomised block with 3 replicates. White clover (*Trifolium repens* L.) sown at 15.6, spring barley (*Hordeum vulgare* L.) at 4.7 million seed ha^{-1} in the spring of the first experimental year were pre-crops for winter wheat (*Triticum aestivum* L.). Spring barley (Br) and white clover (Wcl) were sown alone and clover was sown with a spring barley cover crop (Br-Wcl) (Table 1). In the autumn, winter wheat was sown conventionally (CD) after white clover ploughing-in, or direct drilled with a disk (DD) or rotary drill (DR) into living clover, forming a bi-cropping system. Winter wheat was sown at a rate of 5.0 million seed ha^{-1}. Winter rye for grain was conventionally sown (at 5.5 million seed ha^{-1}) in the autumn of 2008 and harvested in 2009. The inorganic nitrogen in DM yield was measured by the Kjeldahl method. Statistical analyses were performed using ANOVA at a significance level of $P < 0.05$.

Table 1. Experimental design

Wheat pre-crops 2007		Winter wheat sowing method 2008		Winter rye 2009
Spring barley[1)]	Br	Ploughing	CD	Conventional sowing
Spring barley+White clover[2)]	Br-Wcl	Ploughing	CD	Conventional sowing
White clover[3)]	Wcl	Ploughing	CD	Conventional sowing
White clover[4)]	Wcl	Ploughing	CD	Conventional sowing
White clover[5)]	Wcl	Bi-cropping	DD	Conventional sowing
White clover[6)]	Wcl	Bi-cropping	DR	Conventional sowing
Spring barley+White clover[7)]	Br-Wcl	Bi-cropping	DR	Conventional sowing
Spring barley+White clover[8)]	Br-Wcl	Bi-cropping	DD	Conventional sowing

Note: [1)] Br, [2) 4) 7) 8)] white clover (Wcl) biomass grown till ploughing or sowing, [3) 6)] Wcl cut twice, biomass chopped and left in a field [5)] Wcl cut twice, biomass chopped and left in a field, brushed before disk drilling.

Results and discussion

In order to estimate the mode of action of pre-crops for winter wheat we identified biologically fixed N content in the roots and stubble of pre-crops (Table 2). Spring barley sown alone exerted significantly lowest effect on N content in residues of wheat pre-crops. Different management of white clover during the period from spring to autumn in the treatments resulted in slightly different N content in ploughed-in plant residues. However, significant difference was obtained only in one treatment where clover was grown with barley cover crop (DD[7)]). White clover can accumulate very different content of N in stubbles and roots (Elgersma *et al.*, 2000; Høgh-Jensen *et al.*, 2004) and the proportion of clover adds to N supply (Kayser *et al.*, 2010).

Table 2. The influence of pre-crops on winter wheat and succeeding winter rye grain yield and N concentration in grain

Sown plants and sowing method		N content in residues of pre-crops kg ha^{-1}	Winter wheat 2008 Grain yield kg ha^{-1}	Winter wheat 2008 N in grain g kg^{-1}	Winter rye 2009 Grain yield kg ha^{-1}	Winter rye 2009 N in grain g kg^{-1}
Br	CD[1)]	48.3^{a}	3871^{f}	12.4^{a}	1670^{a}	10.6^{a}
Br-Wcl	CD[2)]	103.6^{abc}	5251^{h}	12.7^{a}	1780^{a}	10.5^{a}
Wcl	CD[3)]	79.6^{abc}	6015^{c}	14.4^{b}	1775^{a}	11.1^{a}
Wcl	CD[4)]	67.7^{abc}	6036^{c}	14.6^{bc}	1994^{a}	11.6^{ab}
Wcl	DD[5)]	57.6^{abc}	4722^{g}	13.7^{b}	2652^{b}	12.6^{b}
Wcl	DR[6)]	73.5^{abc}	2930^{e}	16.0^{d}	3346^{cde}	14.2^{cd}
Br-Wcl	DR[7)]	139.0^{c}	1676^{d}	15.5^{cd}	3462^{e}	14.8^{d}
Br-Wcl	DD[8)]	108.7^{abc}	1268^{a}	17.4^{e}	2972^{bc}	14.5^{cd}

Note: values in the same column followed by the different letter within a sowing method are significantly different ($P < 0.05$) according to Duncan's multiple range test.

Our findings indicated that organic grain yield was quite high after ploughing in white clover and conventional sowing of winter wheat. Bi-cropping resulted in lower wheat grain yields than ploughing-in and conventional sowing, especially when wheat was direct drilled with a disk (DD[8)]) and rotary (DR[7)]) drills into clover grown with barley cover crop. The bi-cropping resulted in significantly higher ($P < 0.05$) grain yield when white clover had been brushed before direct drilling wheat with a disk drill (DD[5)]) and with a rotary drill (DR[6)]) compared to wheat sown with the same drills into clover which had been grown with a cover crop. To produce large grain yields in bi-cropping there are several limitations and N uptake could be one of them. N uptake was affected by the dry period of 2008. Kayser *et al.* (2011) also suggest that N mineralization and N uptake in plants is reduced during a dry period. Bergkvist (2003) concluded that the main competitive effect of white clover on intercropped wheat is not for N, but intensive expansion of white clover canopy. The benefit of intercropping is that a higher N concentration in wheat grain could be obtained than in wheat sown as a pure crop. The highest N concentration was obtained from sowing wheat into WCl with Br cover crop with a disk drill (DD[8)]). A slightly higher ($P < 0.05$) N concentration in the wheat grain yield was determined in a bi-cropping system where wheat was sown with a rotary drill into pure WCl, or WCl with Br cover crop (DR[6)] DR[7)]). According to Thorsted *et al*. (2006), wheat N content could increase on average by 31% when clover was brushed once or more times during wheat growing period. In our study we used white clover brushing only before direct drilling of wheat and did not obtain such good results of N concentration; however, higher grain yield was obtained than in other direct-drilled treatments.

In the third experimental year, winter rye grain yield showed opposite results to those of winter wheat in the second year of the experiment. The winter rye grain yield was significantly higher ($P < 0.05$) after differently direct-drilled wheat (DD[5)], DR[6)], DR[7)], DD[8)]) compared to the yield of conventionally drilled wheat (CD[1), 2), 3),4)]). Eriksen *et al*. (2008) stated that management strategies adopted in both grassland and arable phases appear to be the primary instrument in avoiding nutrient losses in mixed crop rotations. Because we did not use any fertilizers for rye, it is likely that the incorporated clover residues affected rye grain yield and soil N was utilised with low losses. N concentration in the rye grain was also higher after the bi-cropping had been used. The ploughed-in clover residue is considered to be a good N source for following crop. The effect on rye grain yield was significant ($P < 0.05$) after bi-cropping system. Generally, this trend was considerably stronger for grain-N concentration, but not always for grain yield in bi-cropping system.

Conclusions

The grain yield of winter wheat was affected by sowing technique. Bi-cropping would be the most successful if white clover competition was restricted by brushing it before direct drilling of wheat using a disk or rotary drill. N concentration in bi-cropped wheat grain was higher than in wheat grown as a sole crop. The winter-rye grain yield and quality were significantly higher after bi-cropping compared to the conventional system.

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An economic analysis of different grassland cultivation system for preserving the Austrian landscape

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Abstract

During the last 60 years the ongoing intensification, specialization and the decrease of agricultural farms in Austria has led to cessation of farming in low-yield areas. As a result of this decreasing cultivation of farmland and reduced agricultural area, biodiversity is dwindling, and the typical Austrian landscape is changing. A detailed study to find the economically and ecologically best-use measure to protect the typical landscape was carried out by the AREC. In this investigation five different utilization systems were compared: mulching, hay fodder, silage for biogas, pasturing for beef production and pasturing for sheep production. Mulching was the most cost-effective measure costing € 128-205 per ha for all slopes. The costs for producing hay and silage increased sharply with increasing gradient on slopes (hay: € 163-560; silage: € 194-617). The pasturing of the areas with sheep or cattle was the most intensive system in terms of cost and labour time (cattle: € 715-1,376; sheep: € 900-1,125). On areas with slopes with more than 35% inclinations, none of these measures provides an income higher than the invested costs; therefore public support is necessary to prevent the present cultural landscape from being lost.

Keywords: landscape management, profitability, mulching, beef production, sheep husbandry

Introduction

A multi-functionally working farm complies with a large number of duties and functions. Beside the guarantee of the population´s food supply, and preservation of the foundations of natural living like climate, air, water and soil, the care for cultural landscape also plays an important role. Due to the fact that during the last 60 years the number of farms has decreased, extensive and low-yielding grassland areas are either not being farmed anymore or are being reforested; hence, the agriculturally utilized area declines and a change in the scenery arises. There is a broad public interest in an adequate preservation of landscape; however, in some places this is no longer achieved as a by-product of milk and meat production, and therefore it is necessary to demonstrate other options. In an interdisciplinary research project, extensive systems for grassland management for the preservation of cultural landscape were compared, and the ecological and economic advantages and disadvantages of the particular systems were analysed (Buchgraber *et al*., 2006).

Material and methods

During a period of 10 years the following utilization systems for the maintenance of the cultural landscape were investigated: (1) Mulching (annual chaffing with flail mower) with harvesting and disposal of grass; (2) Hay: mowing and preparation of hay with 86% dry matter (DM), selling ex-field for € 13 per 100 kg fresh weight; (3) Silage: mowing and preparation of pre-wilted silage with 35% DM and transport to the biogas plant 10 km away by tractor or transporter, and a selling price of € 27 per ton fresh weight); (4) Pasturing for beef production: heifers, steers and also bulls were raised; meat prices of € 2.85/€ 3.17/€ 3.11 per kg slaughter weight; (5) Pasturing for sheep husbandry; meat price for lambs of € 4.92 per kg slaughter weight. The economic analysis of the systems is based on the accruing performances, whereby the underlying data represent average values for the whole test period. For the calculation, virtual plots of 1 ha were used for all procedures, three gradients (< 35%, 35-50%, and > 50%) were taken into account. The mechanical equipment was adapted due to the gradients. Costs of mechanisation were calculated with standard values, and an own-farm mechanization system was considered. The average grazing period of the husbandry systems was about 153 days per year during the experiment. The costs of the winter feeding (hay and silage) of the animals were fully included in the calculations. Incomes as well as the costs for all systems were evaluated in terms of actual market prices. Table 1 shows the working time for all maintenance techniques. The working hours for mulching were assessed by a time study, and for the other investigated systems standard settings were implemented. A labour cost of € 10 per hour was used in the assessments. It was assumed that stables and storages were completely amortized and no costs for buildings were included. Further, supports and premiums were not included, as an objective reflection and a comparison of measures were easier due to the huge number of application possibilities.

Table 1. Working time scheme of the utilization systems (hours $year^{-1}$ ha^{-1})

Method	Gradient < 35%	35-50%	> 50%
Mulching (mowing tractor)*	1.25	1.43	5
Hay**	6.6	12.3	16.1
Silage**	7.4	10.5	14.4
Beef production**	28	28	28
Lamb production**	15.6	15.6	15.6

Source: * own records, ** default values acc. to BMLFUW (2008)

Results and discussion

A summary of the costs of all examined maintenance measures (see Table 2) shows that the maintenance by means of mulching clearly represents the most cost-effective variant. However, this could have negative ecological effects, e.g. the decrease of biodiversity, and should therefore not be seen as the main procedure for the maintenance of landscape. Both variants of cutting are more cost-efficient than the maintenance of areas by means of pasturing. The costs of pasturing are sharply higher due to the fact that the costs thereby incurred result from a full-year period whereas the mowing of grass only take place once a year, and these costs increase disproportionately with increasing steepness of the slope. With respect to the animal husbandry systems it is shown that on slopes of < 35% there are lower costs with the pasturing of cattle than with the pasturing of small ruminants. However, if the gradient increases, the cost difference between the systems will increasingly become smaller and the pasturing of sheep will become more and more interesting, from an economic view as well as from the ecological view.

Table 2 illustrates the profit margin of all systems. For the reason that the procedure of the mulching represents a chaffing of the area without harvesting, no saleable product (on the actual market) is created in this procedure. It is shown that with a preparation of hay and pre-wilted silage and its disposal from the field, where gradients are < 35% it is possible to achieve a positive profit margin after subtraction of the working costs.

Table 2. Costs and Profit Margin (PM) of all measures for maintenance in € ha^{-1} according to gradient

	Gradient					
	< 35%		35-50%		> 50%	
Method	Cost	PM	Cost	PM	Cost	PM
Mulching (mowing tractor)	128	-128	147	-147	205	-205
Hay	163	292	411	-34	560	-183
Silage	194	165	502	-202	617	-318
Heifers	760	205	1,145	-365	1,376	-596
Steers	729	169	1,091	-193	1,279	-382
Bulls	715	197	1,064	-152	1,245	-334
Lambs	900	95	1,042	-47	1,125	-130

Source: own calculations

With the increasing steepness of the area, however, the realized sales revenue does not compensate for the higher costs of the preparation, which are due to the increased demand of working-hours and equipment as well as of the lower yields per ha. The husbandry of bulls and steers is the most suitable option for pasturing up to a gradient of 35%, on the basis of the shorter finishing period and also of the higher slaughter income per kg slaughter weight. Further, the high demand for operational hours due to the relatively high working times in the cattle-stablings also shows up in the costs. Sheep pasturing is very costly and extensive in terms of income at all gradients. With increasing steepness of the area the costs only rise marginally and the pasturing with sheep becomes more and more efficient.

Conclusion

From an economic point of view, mulching represents the most reasonable measure to maintain the productivity of grassland. It may be necessary to minimize the use of mulching where this is an inappropriate measure for maintaining ecological value (see Dux *et al.*, 2009). Both of the examined animal husbandry systems represent the most cost-intensive variants. However, in these cases the preservation of the grassland is a by-product of the meat production. On gradients above 35% none of the tested measures was profitable. These negative profit margins, after the subtraction of the working costs, have to be balanced by federal support systems and premiums in order to guarantee the maintenance of the multi-functionality of the endemic agriculture (cf. Randall, 2010 and Nuppenau, 2001). Public good is therefore directly preserved by the public authorities for the public.

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Specific utilization intensity of permanent grassland used as biogas-substrate

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Abstract

The production of biogas is a trend in German agriculture and it is at least one solution for the use of permanent grassland that is no longer needed because of the decline of animal husbandry. The conditions for a successful use of grass materials for biogas are not yet clear. Dry matter production, ensilability and methane production of grassland growths with reduced utilization intensity were investigated under the new objectives. In a 5-year experiment, the LAZBW Aulendorf investigated the changes of the grassland attributes. Four different treatments (1 = 5 cuts; 2 = 2 cuts and 1 late cut; 3 = 2 cuts plus one late mulching; 4 = 3 early cuts and one late mulching) were compared in an experiment with 4 replications. Variation of botanical composition, yield potential, crude fibre contents and ensilability were observed. The potential methane production was investigated using the Hohenheimer Biogas Yield Test (Helffrich and Oechsner, 2003). The results show that the highest utilisation intensity of grasslands did not equal the highest methane yields. Therefore, reduction from 5 to 3 cuts is possible and also an economically successful strategy.

Keywords: grassland management, cutting frequency, grassland yields, forage quality, biogas production, methane yield

Introduction

In the early years of the 2000s, a dramatic decrease in the number of milking cows in Baden-Wuerttemberg could be observed, and alternative use of the residual grasslands was an important question. LAZBW Aulendorf therefore carried out an experiment entitled “two times cutting and then?” in 2003, before the biogas boom had started (Elsaesser, 2007). Due to the current compensation rates for electricity from biogas under the Renewable Energies Act (EEG), many farmers in Germany have built biogas plants. In Baden-Wuerttemberg nearly 700 biogas plants were in operation at the end of 2010. Nearly all biogas-farmers use plant biomass from the fields or from grassland, in addition to slurry and manure from livestock, as a fermentation substrate. Maize silage is most commonly used because of some well-known advantages, but grass silage also plays an important role. For the successful nutrition and feeding of dairy cows high forage quality is essential. Therefore, intensive utilisation with frequent cutting of grassland is needed. It is not yet clear if biogas plants have the same requirements, due to the much longer retention time of the substrate in the fermentation tank, or if they can digest slowly degradable organic matter as well. Accordingly, the reduction of the cutting frequency could be a possible strategy for grassland management in order to save time and costs. The question now is whether new forms of grassland management can help to solve the problems in terms of providing best forage quality on the one hand, and the use of large grassland areas at the other.

Materials and methods

The experiment was established on a permanent grassland at the experimental station LAZBW Aulendorf in South Germany (590 m a.s.l. average 1000 mm annual rainfall and 7°C mean temperature) and was conducted from 2003 to 2008. Four management treatments were compared, using 25 m² plots with 4 replications (Table 1). Botanical composition, dry matter (DM) yields, forage quality parameters (energy content, crude protein, crude fibre and methane yield) and ensilability were investigated. The potential methane yield was tested by using the 'Hohenheim Biogas Yield Test' (HBT). The investigation of the methane yield has not been completed yet, so only preliminary results can be given.

Table 1. Treatments

	Treatment	Cutting frequency	Amount and partitioning of N supply (kg ha^{-1})
V1	Control	5 times per year	250 (60/60/60/50/20)
V2	Early cut and harvest	2 early cuts (1st decade in May and 2nd decade in June and late 3rd cut in September)	120 (60/60/0/0/0)
V3	Early cut and mulching	2 early cuts (1st decade in May and 2nd decade in June and late mulching in September)	160 (80/80/0/0/0)
V4	Early cut and mulching	3 early cuts (1st decade in May and 2nd decade in June, end of July and mulching of the last regrowth in October)	120 (60/40/20/0/0)

Results and discussion

Significant differences between the treatments concerning the yields of DM and energy were observed (2004-2008). It was surprising that the nitrogen (N) yield was much higher than the N fertilisation. Three early cuts resulted in a higher N output than only two cuts with the same amount of N fertilizer. Large differences could be observed in net energy contents, with strong decreases in the 3rd and 4th cuts. Concerning the net energy yield, it seems that the reduction of cutting frequency has clear effects. Energy yields were highest with the usual management, but three cuts and additional late mulching also showed good results, saving N fertiliser and working time for harvests at the same time. Also, the ensilability of the late third cut in treatment 2 may have caused problems because of the high amount of crude fibre and less sugar. The silage contained more butyric acid but the pH was low enough.

Table 2. Mean values of DM and N yields and total net energy (same letters = n.s. $P < 0.05$)

Treatment	DM (t ha^{-1})	Energy (NEL MJ ha^{-1})	N yield (kg ha^{-1})
1	11.48^{a}	$69{,}667^{a}$	311.0^{b}
2	10.08^{b}	$58{,}440^{b}$	305.9^{b}
3	11.48^{a}	$65{,}263^{a}$	350.3^{a}
4	11.53^{a}	$67{,}849^{a}$	$321.5^{a\,b}$

Treatment 2 lead to significantly lower DM yield. Comparing treatment 1 and 2, the results of methane yield in 2008 are shown in Table 3. The results raise the question about the economic implications, which will be considered briefly. Comparing treatment 1 (5 cuts) and 2 (3 cuts) the reduced amount methane in treatment 2 was 170 m³ per hectare in 2008. Assuming an electrical efficiency of 36% this means 616 kWh electrical power. The current compensation rates for electricity from biogas under the EEG for an average biogas plant are 20 ct/kWh. This leads to 123 € less payment per hectare for the electricity in treatment 2. On the other hand, two grassland cuts per year can be saved. Variable costs per cut for mowing, raking and chopping are around 80-110 € per hectare. This reduces the costs of harvest per year by

160-220 €. Thereby, the reduced methane yield per hectare is more than compensated by cost savings. On the other hand, the higher proportion of crude fibre may lead to technical problems in the biogas plant. The amount of electrical power for running the plant may increase and the wear of the technical equipment can be higher.

Table 3. Methane yield in treatment 1 and 2 in 2008 (same letters = n.s. $P < 0.05$)

Treatment	Cut	Date	Energy (NEL MJ DM^{-1})	Crude fibre (%)	DM (t ha^{-1})	Specific Methane yield (Nl kg oTS^{-1})	Methane yield (m³ ha^{-1})
1	1	19.05.	6.13	31.33	3.95	320	1,167
	2	19.06.	6.16	26.49	2.21	310	627
	3	21.07.	6.24	23.84	1.02	314	291
	4	19.08.	6.18	23.59	2.10	302	580
	5	23.09.	6.34	21.42	0.91	324	272
	Total				10.18 a		2,937 a
2	1	19.05.	6.00	32.33	4.38	317	1279
	2	19.06.	6.10	28.03	2.52	325	746
	3	23.09.	5.20	32.72	2.78	288	741
	Total				9.67 a		2,767 a

There is no significant difference between treatments 1, 3 and 4 in DM yield. The results of the investigated samples show that there is a very high correspondence of the DM yield and the methane yield (Figure 1). Unfortunately, the investigation of the methane yield has not been completed yet, but this high correspondence leads to the assumption that there is also no significant difference in methane yield between treatments 1, 3 and 4.

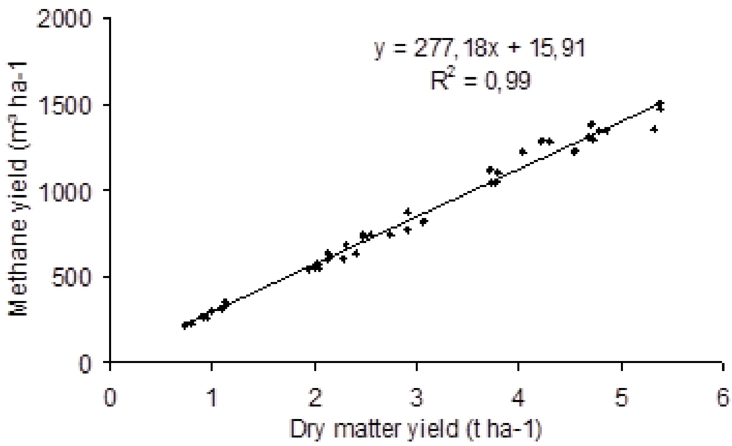

Figure 1. Correspondence of the dry matter yields (t DM ha^{-1} cut^{-1}) and the methane yields (m³ methane ha^{-1} cut^{-1}) of the investigated samples in the year 2008

Conclusions

In order to reach the best forage quality for dairy production it is necessary to cut grassland early and often. For the use of grass in biogas plants it seems to be more efficient to focus on high DM yields with few cuts. This is better linked with high methane yields per ha. Moreover, the reduction of the intensity of grassland management is preferable in terms of the economic aspects for biogas farmers. Problems may be caused by the high content of crude fibre, but this seems to be a technical problem in biogas plants and should be resolvable.

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Pasture establishment for the development of sheep farming as an alternative land use for the less favoured areas

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Abstract

North Evros is a less favoured region in north-eastern Greece where agriculture is the main activity. There are few available pastures in this region and, as a result, a lot of sheep farms are semi-extensive. The sheep graze communal rangelands, which are near the sheep barn or in fallows, and on cultivable land after harvesting. However, many intensive sheep farms have recently been established in which sheep are kept indoors and fed only harvested forage. It is well documented that grazing is a very important activity for the animals' welfare. The purpose of this paper was to study whether the alternative land use with the establishment of pastures in this region can contribute to increasing the number of sheep farms. To this end, three farming systems (intensive, semi-extensive with natural grassland grazing and semi-intensive with cultivated pastureland grazing) have been studied in order to evaluate the costs of feeding and especially the forage cost.

Keywords: dairy sheep, grazing, feed cost, production system

Introduction

The prefecture of Evros is a less favoured region located in the north-eastern part of Greece. Its total area is 424,800 hectares of which 42.3% is arable land, 32.3% is covered by forests and rangelands and 10.6% are pastures and grasslands (HSA, 2000). Agriculture and animal husbandry are important parts of the local economy. There are a total of 17,842 agricultural and animal farms in the area of which, 3,105 are animal farms, whilst 3,537 are both agricultural and animal farms. The average farm size is 8.4 hectares (HSA, 2001). An important part of livestock production is dairy sheep. There is a total of 154,000 sheep in Evros, of which 51,000 are in the northern part of the prefecture. However, pastures and natural grasslands are limited in this area and the crop production consists mainly of winter cereals (wheat, barley), maize and alfalfa.

There exist three types of sheep farming systems in the area: intensive, semi-intensive and traditional semi-extensive. In intensive systems, no grazing is applied, automated milking equipment is used and dairy sheep breeds are raised. Their diet is based on alfalfa hay and corn silage that are mainly are produced locally by the farmers. Recently, the number of intensive dairy sheep farms has been increased in the northern part of the prefecture as elsewhere in Greece. On the other hand, in the semi-intensive system, livestock feeding is based on pasture grazing and harvested forages. Generally, this system is not common in Greece. Finally, in

the traditional semi-extensive systems grazing is applied in communal natural grasslands and on stubble grazing after harvest.
Advantages and disadvantages concerning the welfare of sheep have been reported for both extensive and intensive farming systems (Fitzpatrick *et al*., 2006; Sevi *et al*., 2009). In the present study the feeding costs, and especially the costs of the forage costs, in the abovementioned farming systems were compared.

Materials and methods

An economic survey was conducted using the stratified sampling method and an appropriately designed questionnaire based on economic data for the year 2009. In particular, the livestock of the farms, the annual feeds and their cost, duration of grazing, the annual operating cost of the farm and the production of milk were recorded. The cost of communal natural grasslands was evaluated as the labour and the rental cost. Additionally, total expenditure for purchase of animal feed per farming system and per feed category, with emphasis on roughages, were calculated. Specifically for the semi-intensive system, the pastures' herbage production and utilisation were measured by 0.5×0.5 m quadrats in grazed and protected plots. In addition, with the use of the appropriate equations and tables (Zervas, 2000; NRC, 2007) the percentage of the sheep requirements in energy (NEL Mj/day) and protein (DP g/day) for each feed were estimated.
All collected data were presented per farming system and per animal unit for the purpose of comparisons and in order to estimate the efficiency of feed in meeting energy and protein needs in relation to their cost.

Results and discussion

The total expenses for feed per animal were 153.1 €, 105.7 € and 120.0 € (Table 1) for intensive, semi-intensive and semi-extensive production systems respectively. Regarding the contribution of each feed category to feed expenses, roughages had the higher percentage (Table 1) compared to concentrates and grazing. Moreover, the required feed costs for 1 kg of milk was lower for the semi-intensive system (0.4 €), whilst it was similar for the intensive and semi-extensive systems (0.6 €) (Table 1).

Table 1. Total feed costs per animal and expenses per feed type and milk produced in the three production systems

	Expenses for feed/animal	Expenses for forages/ animal		Expenses for concentrate feed/animal		Expenses for grazing/ animal		Milk production/ animal	
Production systems	€	€	%	€	%	€	%	kg	€/kg
Intensive	153.1	82.6	54.0	70.5	46.0	0.0	0.0	259.5	0.6
Semi- intensive	105.7	49.1	46.5	39.7	37.5	16.9	16.0	238.1	0.4
Semi extensive	120.0	69.9	58.3	37.7	31.4	12.4	10.3	207.0	0.6

This indicates that the semi-intensive farming system is the most economic system, followed by semi-extensive one, although the cost of grazing was higher in the semi-intensive system. This could be attributed to the fact that the available forage production from pastures in the semi-intensive farming systems was higher compared to the other systems, leading in forage autonomy (Benoit *et al*., 1997), which reduced the feeding cost.

The forages covered around half of the energy and protein requirements to the sheep in the intensive system (Table 2). The corresponding percentages were higher for semi-intensive and semi-extensive systems for both energy and protein, reaching approximately 70% (Table 2). However, the contribution of grazing in this percentage was higher in the semi-intensive system than in semi-extensive. Specifically, in the semi-intensive system the contribution of grazing in energy and protein requirements was approximately 45%, whereas the contribution of roughages and concentrates was 25% and 30% respectively.
Consequently, there is strong evidence that in a semi-intensive system, the forages covered the energy requirements by a greater amount compared with the other two systems. The same trend was observed in grazing for both energy and protein requirements (Table 2).

Table 2. Requirements of energy and protein (%) from feed types and their efficiency ratio

	Forages/animal				Grazing/animal			
	Energy		Protein		Energy		Protein	
Production systems	% total needs	Relative efficiency	% total needs	Relative efficiency	% total needs	Relative efficiency	% total needs	Relative efficiency
Intensive	50.8	0.9	57.6	1.1	-	-	-	-
Semi intensive	71.4	1.1	73.8	1.2	46.0	2.9	42.2	2.6
Semi extensive	63.7	0.9	77.7	1.1	27.0	2.6	23.1	2.2

Conclusions

Semi-intensive farming system was less expensive compared to the two other systems. The establishment of pastures could contribute to a more sustainable dairy sheep production system in the less favoured areas.

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Evaluation of fuel and biogas production on typical semi-natural grasslands in Germany, Wales and Estonia

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Abstract

Regular and delayed harvest of species-rich grasslands is a precondition of maintaining the biodiversity status, but often not cost-effective due to low nutritional value and absence of substrate-adapted conversion techniques to produce energy from the highly lignified biomass. Combustion characteristics can be improved by water mashing and subsequent dehydration of the biomass, whereas the remaining liquid is a suitable substrate for biogas production. The present study deals with an evaluation of energy production from semi-natural grasslands according to a recently suggested technique (integrated generation of solid fuel and biogas from biomass, IFBB). During mechanical dehydration, 0.80 of the dry matter was transferred into the press cake. Combustion relevant nutrients like potassium and chlorine were extracted from the parent material by 0.78 respectively 0.84. Methane yields from press fluid digestion ranged between 272 and 333 l CH_4 kg^{-1} VS (volatile solids).

Keywords: biodiversity, bioenergy, biogas, semi-natural grassland, solid fuel

Introduction

The use of biomass from low yielding and species-rich grasslands for energy recovery is considered as an option to maintain biodiversity status of endangered vegetations. Regular cut of semi-natural grasslands is crucial with regard to ensuring the current plant inventory, but often threatened by the abandonment of low-intensity agricultural practices (Ostermann, 1998). Chemical characteristics of grassland from nature conservation areas have special demands on the technique used for the conversion of this biomass into usable energy carriers. Conventional conversion technique like biogas production from digestion of silage is connected with low gas yields due to the highly senescent biomass (Richter *et al*., 2009). Combustion of hay made from this grassland biomass is also affected by technical constraints due to high proportions of minerals, nitrogen and sulphur leading to problems of ash melting, corrosion and increased emissions (Obernberger *et al*., 2006). The present study aims at the investigation of 18 European semi-natural grasslands concerning the conversion performance into solid fuel and biogas according to the procedure of the integrated generation of solid fuel and biogas from biomass (IFBB, Wachendorf *et al*., 2009). The paper shows results on nutrient flows during mechanical separation and methane yields from the derived press fluids.

Material and methods

The experimental basis are biomasses from a total of 18 typical semi-natural grassland communities in Germany, Wales and Estonia (Bühle *et al*., 2010). The biomass was chopped directly after harvest and ensiled in 60-l-polyethylene barrels. The silage was pre-treated by water mashing (silage:water ratio of 1:8) at 25°C for 30 min and subsequently mechanically dewatered by a screw press. Silage and press cake were analysed for dry matter (DM), ashes, nitrogen (N), sulphur (S), potassium (K), magnesium (Mg), calcium (Ca) and chlorine (Cl) using an elemental analyzer and X-ray fluorescence. Determination of biogas production from press fluids was performed in batch experiments, in accordance with VDI 4630 (2004) and described in Richter *et al*. (2009) with three replicates. In order to test significant differences between nutrient contens of the silage and the press cake, ANOVA was used.

Results and discussion

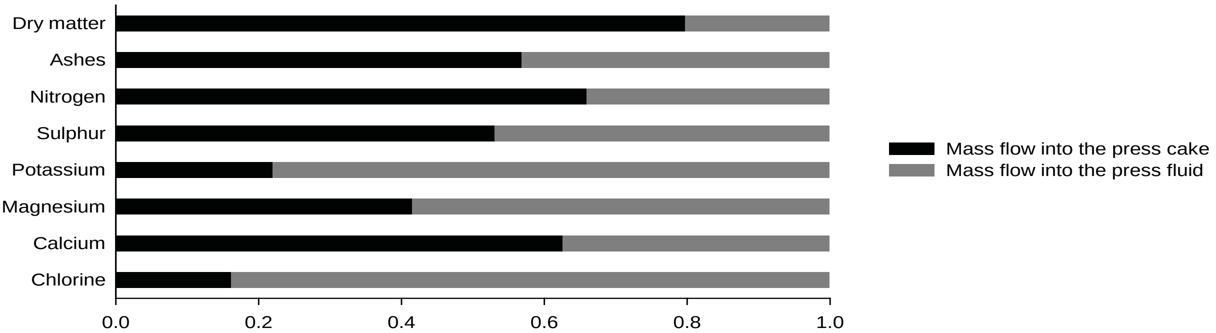

Figure 1. Mean values of mass flows of dry matter, ashes, nitrogen, sulphur, potassium, magnesium, calcium and chlorine into the press cake and the press fluid during mechanical separation of 18 semi-natural grasslands in Germany, Wales and Estonia.

During mechanical dehydration, DM was transferred into the press cake with a proportion of 0.80 (Figure 1). Mass flow of ashes into the press cake was lower (0.57) than those of DM leading to reduced ash content in the solid fraction and, thereby improved its combustion characteristics (Bühle *et al*., 2011). N and S were transferred into the press cake by 0.66 and 0.53, respectively. Highest extractions from the silage into the press fluid were obtained for K (0.78 into the press fluid) and Cl (0.84) which are characterised by a high mobility in the plant. Reduction of these nutrients in the fuel is of major importance for ash melting and corrosion behaviour. Ca and Mg mainly form complexes with organic counterions and are therefore less transferable into the liquid. Altogether, mechanical separation led to significant extractions of nutrients detrimental to thermal use from the grassland biomass and simultaneously provides a valuable liquid with high content of minerals which can be used as fertilizer after digestion. Methane yields from press fluids have been investigated for six experimental sites in Germany (Figure 2). Highest methane yields were observed for press fluids from Lowland and Mountain hay meadows ranging between 307 and 333 l CH_4 kg^{-1} VS (volatile solids). Similar yield was obtained by press fluid digestion from species-rich *Nardus* grassland (316 l CH_4 kg^{-1} VS). Comparatively low methane yields resulted from press fluids of *Molinia* meadow and Humid tall herb with 272 and 284 l CH_4 kg^{-1} VS, respectively. The variability of anaerobic digestibility indicates strong effects of the parent biomass on the biogas production. Thus, further research will focus on relations of methane yields and chemical composition of the parent material and the press fluids.

Conclusions

Water mashing and mechanical dehydration of the grassland biomass resulted in high transfer rates into the press liquid particularly in terms K and Cl, leading to improved combustion characteristics in view of corrosion and ash melting behaviour. Methane yields from press fluid digestion showed that the liquid fraction is a suitable substrate for biogas production due to its high anaerobic digestibility.

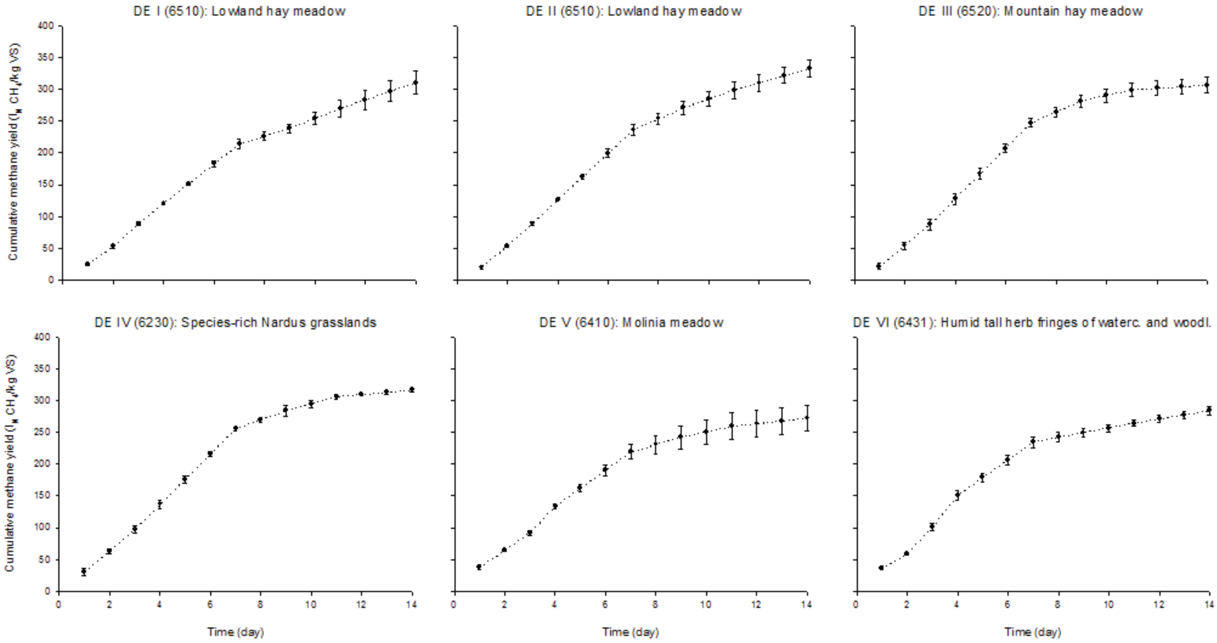

Figure 2. Mean values (with s.e. of mean) of methane yields (lN CH_4 kg^{-1} VS) of press fluids derived from six semi-natural grasslands (NATURA code and habitat type shown in Figure) in Germany (DE).

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Improving combustion performance of European grassland biomass through water mashing and subsequent dehydration

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Abstract

Thermal use of grassland biomass from protected areas can be an option to convert fibrous biomass into net energy with a high degree of efficiency. Nevertheless, high contents of combustion-relevant compounds affect the use of such biomass in conventional heating systems. Partial extraction of those nutrients from the parent material can be achieved by mashing and mechanical dehydration of the fuel.

In this study, the quality of the parent biomass and the resulting press cake after dehydration of 18 typical grassland sites in Germany, Wales and Estonia was investigated.

The results suggest that content of the ash could be reduced from 83 to 58 g kg^{-1} DM, concentration of ash melting and corrosion inducing elements like potassium and chlorine decreased from 10.6 to 2.9 g K kg^{-1} DM and from 3.8 to 0.7 g Cl kg^{-1} DM through mashing and dewatering. The calculated ash softening temperature was elevated from 1085 (silage) to 1186°C (press cake). Emission-causing elements like N and S were also slightly reduced.

Keywords: bioenergy, combustion, nature conservation, semi-natural grassland, solid fuel

Introduction

Increasing abandonment of traditionally low-input management of semi-natural grasslands in rural and disadvantaged areas makes demand on future options of alternative use. Energy recovery from the grassland biomass could be one option; however, high concentration of nutrients may affect thermal use regarding corrosion (chlorine, sulphur), ash melting (potassium) and emissions (nitrogen, sulphur) of these biofuels (Obernberger *et al*., 2006). The Integrated Generation of Solid Fuel and Biogas from Biomass (IFBB, Wachendorf *et al*., 2009) aims at the improvement of combustion characteristics of the biomass through reduction of nutrients detrimental to thermal use by water mashing and mechanical dehydration. Within the present study, 18 semi-natural grasslands in Germany, Wales and Estonia have been processed to a press cake according to the IFBB procedure and investigated concerning combustion relevant nutrients (ashes, N, S, K, Ca, Mg, Cl) of the initial biomass and the derived press cakes. Furthermore, ash melting behaviour and heating values were determined.

Material and methods

Silages (SI) and press cakes (PC) were derived from 18 semi-natural grasslands in Germany, Wales and Estonia as described by Bühle *et al*. (2010). After harvest, the biomass was chopped without wilting and ensiled in 60-l polyethylene barrels for at least 6 weeks (3 replicates per site). The silage was pre-treated by water mashing at 25°C for 30 min and subsequently mechanically dewatered by a screw press. SI and PC were analysed for C, H and N using an elemental analyzer (EA 1106, Carlo Erba Ltd., Rodano, Italy). K, Ca, Mg, S and Cl were analysed by X-ray fluorescence. The ash softening temperature (AST) was calculated based

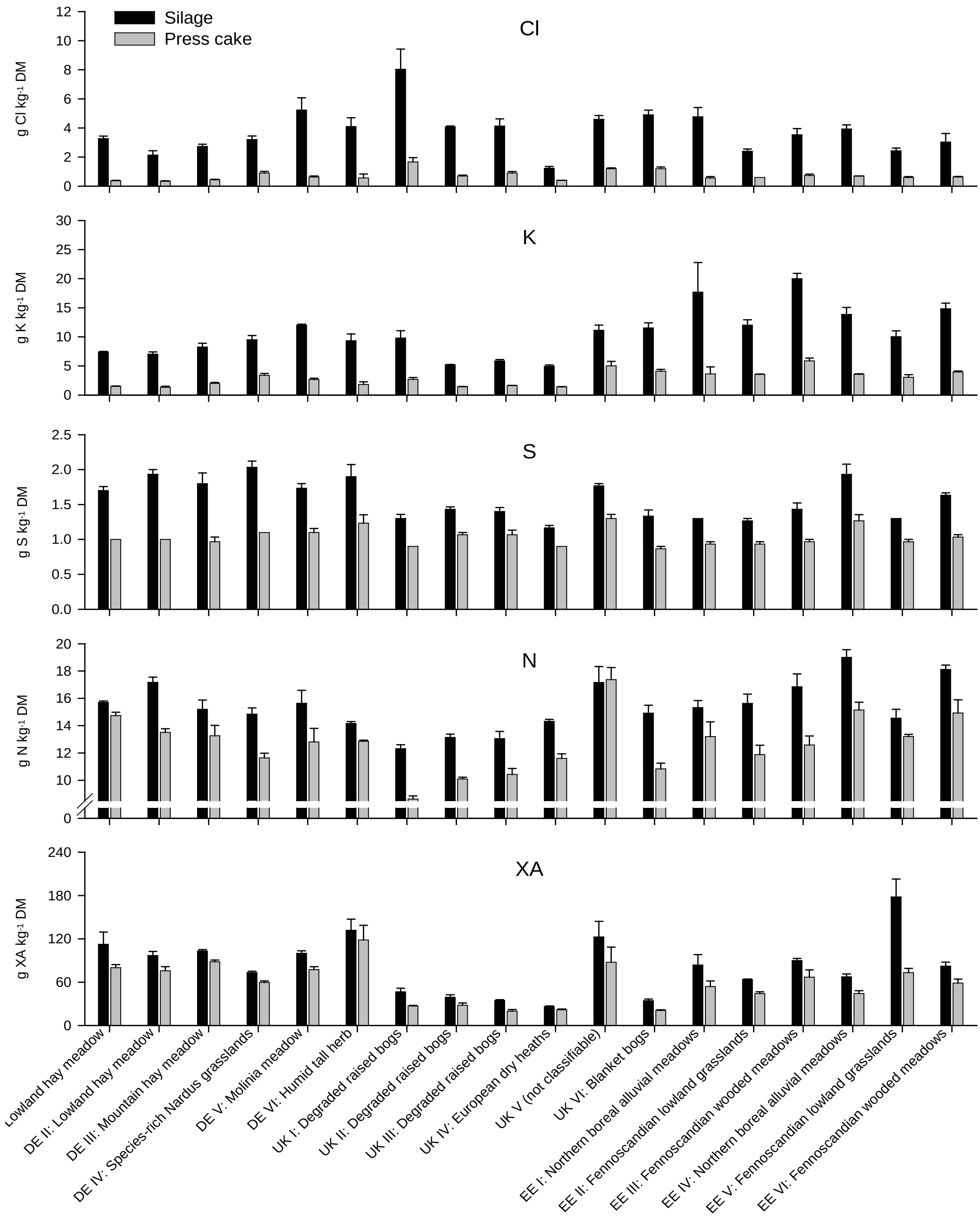

Figure 1. Mean values (with s.e. of mean) of concentrations (g kg^{-1} DM) of ashes (XA), nitrogen (N), sulphur (S), potassium (K) and chlorine (Cl) in the silage and the derived press cake of 18 semi-natural grasslands in Germany (DE I - DE VI), Wales (UK I - UK VI) and Estonia (EE I - EE VI) (n = 3).

on the concentrations of K, Ca and Mg according to Hartmann (2009). The higher heating value (HHV) of SI and PC was calculated based on the concentrations of C, H and N using the empirical equation developed by Friedl *et al*. (2005) for biofuels.

Results and discussion

By water mashing and mechanical dehydration, all of the combustion-relevant nutrients could be reduced (Figure 1). In particular, content of Cl decreased by 0.81 from 3.7 (SI) to 0.7 g kg^{-1} DM (PC) on average. Content of K was reduced by 0.72 from 10.6 to 2.9 g kg^{-1} DM respectively 151.8 to 63.4 g kg^{-1} XA. Guideline values for unproblematic thermal utilisation are given as < 1.0 g Cl kg^{-1} DM and < 70 g K kg^{-1} XA (Obernberger *et al*., 2006); combustion quality of the PC was significantly improved compared to the untreated biomass. Reduction of S was lower and averaged from 1.6 (SI) to 1.0 g kg^{-1} DM in the press cake. Content of N decreased from 15.4 (SI) to 12.7 (PC). Guideline values could be almost achieved for S (< 1.0 g kg^{-1} DM), but not for N (< 6.0 g kg^{-1} DM), suggesting a potential of NOx emissions (Obernberger *et al*., 2006). Reduction of ashes was also comparatively low and averaged 0.30. The ash softening temperature was increased from 1085 (SI) to 1186°C (PC, not shown), mainly caused by the reduction of K which is responsible for slagging in large part. Furthermore, reduction of the total ash content resulted in an increase of the higher heating value from 18.7 (SI) to 19.0 MJ kg^{-1} DM (PC). Dry matter content increased from 310 (SI) to 489 (PC) g kg^{-1} fresh matter.

Conclusions

Combustion characteristics of biomass from semi-natural grasslands could be significantly improved by water mashing and subsequent mechanical dehydration. Although the reduction of the total ashes was low, ash melting and corrosion-effecting nutrients like potassium and chlorine could be reduced by about 0.75. Nitrogen and sulphur content also decreased leading to less potential for emissions. Furthermore, mechanical dehydration led to increased dry matter content in the fuel improving overall efficiency of thermal use.

Acknowledgement

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Cessation of cutting and fertilization and its effect on upland grassland

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Abstract

The effect of the management cessation on dynamics of plant species composition was studied in an upland grassland with *Festuca rubra* in the Jizera Mountains, Czech Republic. The study was set up on an abandoned former fertilisation experiment where all management was finished in 1999. Initial treatments were: 1) control without fertilisers, 2) P, K fertilisers only, 3) low N and P, K fertilisers, and 4) high N and P, K fertilisers. The experiment consisted of an intensive (1993-96) and a moderate (1997-99) period where three cuts with higher N fertiliser and two cuts with lower N fertiliser were applied, respectively.
Seven years of different grassland management by cutting and fertilisation led to significant diversification of meadow vegetation. However, within eight years of abandonment the differences between swards caused by different rates of fertilisers had disappeared and *F. rubra* dominated in all swards. Cessation of fertilisation and defoliation increased uniformity of grassland communities with previously differing species composition arising from different levels of fertilisation. Former differences in biomass quality and soil-available nutrients completely disappeared also. The results of this study stress that at least some type of temperate meadows with *F. rubra* dominance can be resistant to short-term perturbation by fertilisation.

Keywords: grassland, fertilisation, intensive management, cutting, abandonment

Introduction

Studies of grassland resilience after fertilisation are indispensable for the possibility of recreation of grassland on formerly intensively managed grassland sites. However, the majority of published studies concerning resilience of grasslands are from specific conditions and little attention has been paid to the study of common upland grasslands, although they are one of the most frequent of all grassland types in Central Europe. This is the reason why we made investigations in an old fertilisation experiment (Fiala, 1997) that was abandoned for eight years. The advantage of this study was that we had baseline data obtained before management application and there were well documented data from the former experiment.
The aim of our study was to analyse the effect of management cessation on upland meadow composition which had been managed differently in the past.

Materials and methods

The experiment was carried out in the Jizera Mountains (50°50/N, 15°05/E) 11 km north-west from the town Liberec, Czech Republic. The altitude of the site is 420 m with average an annual mean temperature of 7.2°C and annual precipitation 803 mm (Liberec meteorological station). The geological substratum is granite underlying cambisol. The following soil attributes were measured in 1993, pH (KCl) = 4.5, P content = 15 mg kg^{-1}, K content = 86 mg kg^{-1}, Mg content = 42 mg kg^{-1} (Fiala, 1997). The dominant species were *Festuca rubra*, *Alopecurus*

pratensis and *Agrostis capillaris*. The fertilisation experiment was established in 1993. The experiment had consisted of intensive (1993-96) and moderate (1997-99) periods with three cuts under higher N fertilisation and two cuts under lower N fertilisation applied, respectively. The investigated treatments (fertilized - PK, N1PK, N2PK and unfertilized control- Co) in different study periods are described in the Table 1. The experiment was arranged in four blocks; however, only three of the blocks could be evaluated in 2007. Each plot was 11.0× 2.7 m with an unfertilised 0.9 m buffer zone.
The cover of all present vascular plant species rooting in the monitoring plot was visually estimated directly in percentages. To avoid edge effects, data were collected within the inner 20 m² (10×2 m) of the plot. Relevés collecting was performed annually in May before the first cut in managed period. Relevés were collected in years 1993, 1995, 1996, 1997, 1998, 1999, 2001 and 2007. The vegetation data were processed by unconstrained and constrained ordination techniques, Detrended Correspondence Analysis (DCA) and Redundancy Analysis (RDA) in CANOCO program (ter Braak and Šmilauer, 2002).

Table 1. Description of study treatments

Study period	Management intensity	Number of cuts per year	Treatment abbreviations and dose of fertilisers per year Co	PK	N1PK	N2PK
1993-1996	intensive	three cuts	none	30 kg P + 60 kg K ha^{-1} year^{-1}	90 kg N + 30 kg P + 60 kg K ha^{-1} year^{-1}	180 kg N + 30 kg P + 60 kg K ha^{-1} year^{-1}
1997-1999	moderate	two cuts	none	30 kg P + 60 kg K ha^{-1} year^{-1}	60 kg N+ 30 kg P + 60 kg K ha^{-1} year^{-1}	120 kg N + 30 kg P + 60 kg K ha^{-1} year^{-1}
2000-2007	abandonment	no cut	none	none	none	none

Results and discussion

There was fast diversification of sward vegetation immediately after the treatments were introduced (Figure 1), which lasted during the whole management periods (1993-1999). The introduction of intensive management (1993-1996) resulted in significant changes in sward composition (Table 2, years 1995, 1997, 1999) and continued also under moderate management (1997-1999). The percentage of explained variability of plant species composition due to different treatments was relatively high and varied from 59.2 to 68.3 for the first axis and from 70.2 to 85.2 for all canonical axes. It confirms results from long term de-intensification experiment (Hejcman *et al*., 2010), that higher frequency of cuts supports plant species that are commonly connected with intensive cutting management, even under relatively low N application and low content of plant-available P in the soil. However, the differences in plant species composition due to the previous management disappeared immediately after abandonment (Table 2, years 2001, 2007) and at the end of the experiment samples were similar to each other (Figure 1). Similarly, Pavlů *et al*. (2005) found that the cessation of defoliation resulted in increased uniformity of grassland communities with previously differing species composition arising from different grazing systems.

Conclusions

Seven years of different grassland management by cutting and fertilisation led to significant diversification of meadow vegetation. Consequent management cessation increased uniformity of grassland communities and only several dominant plant species prevailed there.
The results of this study stress that at least some type of temperate meadows with *F. rubra* dominance can be resistant to short-term perturbation by fertilisation.

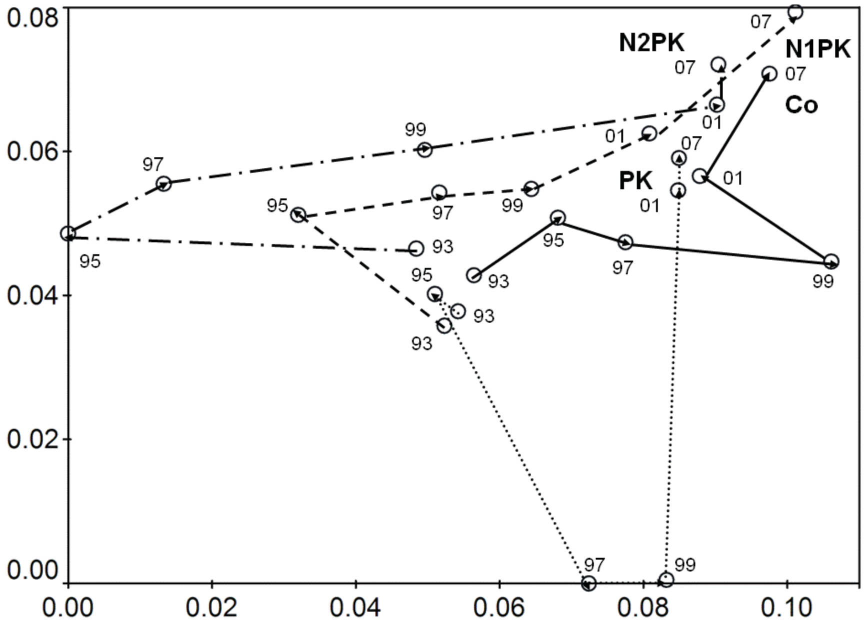

Figure 1. Detrended Correspondence Analysis (DCA) ordination of vegetation samples from different treatments Co (–), PK (····), N1PK (- -), N2PK (·-·-) between years 1993-2007 (93, 95, 97, 99, 01, 07). Centroids, representing replicate averages, are used.

Table 2. Results of the RDA analyses of cover estimates. Co, PK, N1PK, N2PK = treatments abbreviations, see Table 1; % expl. var. = species variability explained by one (all) ordination axis (measure of explanatory power of the explanatory variables); F-ratio = F statistics for the test of particular analysis; *P*-value = corresponding probability value obtained by the Monte Carlo permutation test. Tested hypothesis: Is there a difference between treatments in particular year?

Year	Type of management	Explanatory variables	Covariables	% expl. var.1st axis (all axes)	*F*- ratio1st axis (all axes)	*P*-value 1st axis (all axes)
1993	baseline data	Co, PK, N1PK, N2PK	blocks	19.7 (45.4)	1.5 (1.7)	0.379 (0.069)
1995	intensive management	Co, PK, N1PK, N2PK	blocks	68.3 (70.2)	12.9 (4.7)	0.025 (0.031)
1997	intensive management	Co, PK, N1PK, N2PK	blocks	63.0 (76.5)	10.2 (6.5)	0.028 (0.020)
1999	moderate management	Co, PK, N1PK, N2PK	blocks	59.2 (85.2)	8.7 (11.5)	0.001 (0.001)
2001	abandonment	Co, PK, N1PK, N2PK	blocks	31.0 (37.2)	2.6 (1.2)	0.352 (0.341)
2007	abandonment	Co, PK, N1PK, N2PK	blocks	9.6 (16.8)	0.6 (0.4)	0.900 (0.888)

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Sustainable management of *Mesobrometum* without animals?

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Abstract

The objectives of a long-time trial were to formulate and evaluate alternatives to grazing of *Mesobrometum* with sheep in regions with insufficient livestock densities. Therefore, a trial was carried out during 1991-2010 on *Festuco rupicolae - Brachypodietum pinnati* with either one utilization per year, or no utilizations (fallow) and all without fertilization. The treatments were: (1) annual mowing; (2) mowing / mulching, alternating from year to year; (3) annual mulching; (4) mulching / fallow, alternating from year to year; (5) mulching / fallow / fallow, first year mulching followed by two years fallow. There were no differences in dry matter yield and digestibility between mowing and mowing alternating with mulching. Exclusive mulching caused higher biomass production and also higher amounts of nitrogen and potassium in the biomass than mowing alternating with mulching. It is concluded that annual mowing is suitable for preservation of *Mesobrometum* on stands without sheep. Mowing and mulching alternating from year to year, as well as annual mulching, can serve as alternative managements when maintenance of botanical composition is the main objective.

Keywords: *Mesobrometum,* dry matter yield, forage quality, biodiversity

Introduction

Extensively managed grassland communities on dry sites are of great ecological importance. For hundreds of years grazing with sheep was the foundation for the maintenance of *Mesobrometum*. However, sheep farming based on grazing pastures is economically not sustainable on these pastures today and thus the sheep population is declining continuously in Thuringia. Therefore, the objective of this study was to evaluate alternative management concepts to grazing *Mesobrometum* with sheep in regions with insufficient livestock densities.

Materials and methods

Experimental plots were established on a *Mesobrometum* grassland community, on basalt soil, in the Thuringian Rhoen (Germany) and investigations were conducted between 1991 and 2010.The experiment comprised five treatments with four replications of each treatment (plots) according to the experimental design shown in Table 1.

Table 1. Experimental design

Treatment	Management	(declaration)
1	mowing	Annual (cutting and removing from meadow)
2	mowing / mulching	alternating, from year to year
3	mulching	Annual (shredding with biomass remaining on meadow)
4	mulching / fallow	alternating, from year to year
5	mulching / fallow / fallow	alternating, mulching followed by two years fallow

The experimental treatments comprised either one utilization per year, or in some years no utilization (fallow) and treatments were without fertilization. Dry matter (DM) yield and forage quality (DM digestibility, energy content) as well as the content of nutrients in the forage DM (nitrogen [N], phosphorus [P] and potassium [K]) were analysed. Determination of plant species was conducted according to the method of Klapp-Stählin (Voigtländer and Voss, 1979). The data were interpreted by means of analysis of variance.

Results

There were slight differences in Table 2 shows that P offtake and DM yield were the same for the 2 main treatments, so the sentence ‚slight differences' is incorrect forage quality and N and K off-takes in the harvested biomass) depending on whether mowing took place every year or mowing and mulching alternated from year to year (Table 2). DM yield and P off-take did not differ between treatments 1 and 2.

Table 2. Dry matter yield, forage quality and NPK in herbage of *Mesobrometum* harvested by mowing

Treatment		Dry Matter yield per cut kg ha^{-1}	Energy MJ NEL kg^{-1} DM	DM-digestibility %	amount in harvested biomass N	P	K
					kg ha^{-1} and cut		
1	annual mowing	2,720	5.48	53.9	40.2	3.9	45.6
2	mowing / mulching	2,710	5.37	55.2	38.1	3.8	49.2

Table 3. Biomass above ground (mulch) and amount of N, P and K in the biomass

Treatment		Above-ground biomass yield as dry matter (mulch) kg ha^{-1}	amount in the biomass (mulch) N	P	K
			kg ha^{-1}		
2	mowing / mulching	3,080	42.4	4.3	59.1
3	annual mulching	3,320	47.4	4.3	62.6
4	mulching / fallow	4,370	62.4	7.1	77.6
5	mulching / fallow / fallow	4,330	62.3	6.6	66.3
	Tukey HSD ($P < 0.05$)	470	7.5	0.7	8.8

The results of the various mulching systems are shown in Table 3. Annual mulching in comparison with mulching and mowing alternating from year to year resulted in a higher above-ground biomass and slightly higher amounts of N and K in the biomass; however, no statistically significant differences were detected. Mulching every second or third year was associated with significantly higher biomass production and remarkably higher amounts of N, P and K in the biomass compared to mulching every year. Between treatments 4 and 5 no significant differences in harvested biomass, but in the biomass of treatment 5 lesser amounts of P and particularly of K in the biomass were observed.

The botanical composition of this species-rich community was influenced by the management treatments (Table 4).

Table 4. Changes in botanical composition of *Mesobrometum* between 1991 and 2010 in relation to management treatments

	Proportions of herbage species groups (%)						Numbers of species in each species group					
	grasses		herbs		legumes		grasses		herbs		legumes	
Treatment	1991	2010	1991	2010	1991	2010	1991	2010	1991	2010	1991	2010
1	25	52	60	31	15	17	17	18	27	28	3	3
2	43	48	42	39	15	13	15	13	27	28	4	5
3	41	60	42	32	17	8	14	18	20	23	4	3
4	46	53	38	37	16	10	19	13	32	22	4	4
5	35	45	51	41	14	14	18	14	22	21	4	5

The different types of management caused alterations in the botanical composition including numbers of species observed. By mowing as well as mowing / mulching the number of species was stable (mowing 47-49 species, mowing / mulching 46 species) over 20 years.
However, there was a change in the proportions of the functional groups. Grasses became dominant and proportions of herbs and legumes decreased. The *Mesobrometum* was conserved but the following increased: *Festuca rubra*, *Agrostis tenuis*, *Trisetum flavescens*, *Briza media*, *Carex flacca*, *Carex pallescens*, *Tragopogon pratensis*, *Hieracium pilosella*.
Annual mulching resulted in an increase of the total number of species from 38 to 44, whereas mulching every second or third year resulted in losses of species, from 55 to 39 and from 44 to 40, respectively. Concerning, the composition of biomass, the proportion of grasses increased considerably, whereas the proportions of herbs and legumes declined in these three treatments, particularly the annual mulching treatment.
By annual mulching, the *Mesobrometum* was essentially conserved, but the proportions of *Holcus mollis*, *Koeleria pyramidata*, *Tragopogon pratensis*, *Galium verum* and *Plantago lanceolata* increased while *Briza media* was maintained.
By mulching every second or third year after fallow, the *Mesobrometum* changed into a *Festuca rubra - Agrostis tenuis* community. In this case the proportions of *Knautia arvensis*, *Achillea millefolium* and *Vicia cracca* increased markedly.

Discussion

The objective of this long-term study was to evaluate alternative management concepts to sheep grazing with regard to the conservation and protection of one of the most important grassland communities in the Biosphere reserve Rhoen.
The fertilization effect of mulching was evident and was significantly higher after fallow in comparison with annual mulching. Consequently, the community of *Mesobrometum* changed into a *Festucetum* community. Amounts of nutrients in the harvested above-ground biomass (the mulch) of more than 60 kg N ha^{-1}, 6.5 kg P ha^{-1} and 65 kg K ha^{-1} were obviously sufficient for this development.
Annual mowing or mulching as well as alternating mowing and mulching from year to year, was associated with small amounts of N, P and K in the biomass and therefore the *Mesobrometum* was conserved.
On nutrient-poor sites, the biodiversity of species-rich grassland communities like *Mesobrometum* may be maintained by annual mowing as well as mulching. This was clearly demonstrated by the present study as well as by Briemle (2005) who also recommended this as an appropriate measure.

Conclusions

- Annual mowing is suitable for the preservation of *Mesobrometum* on sites without sheep.
- Alternate mowing and mulching from year to year, as well as annual mulching are alternative measures for the protection of the community of *Mesobrometum*.
- Mulching every second or third year after fallow is not recommended.

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Sustainable management of *Nardetum strictae* - without animals?

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Abstract

There is a need to for a management system appropriate for *Nardetum strictae* for situations where there are insufficient livestock, and which results in an optimal combination of plant species composition, yield and forage quality. Therefore, a trial has been carried out since 1991 on *Nardetum strictae* with one cut, taken at different times of year, without fertilization. Treatments were: 1 - one cut annually on 20 June; 2 - one cut annually on10 September; and 3 - one cut biennially on 30 July. Data recorded comprised dry matter yields, forage quality parameters (contents of crude fibre, crude protein, minerals and energy, dry matter digestibility) and botanical composition. Results show that one cut annually (on 20 June) without any fertilization appeared suitable for preservation of *Nardetum strictae* in regions with insufficient livestock densities.

Keywords: *Nardetum*, yield, forage quality, botanical composition, Thuringia

Introduction

Extensively managed grassland communities in mountain regions are of great ecological importance. In the past, maintenance of *Nardetum strictae* was predominantly based on grazing by cattle. However, in the Thuringia Mountains livestock numbers have declined considerably in the last decades. Therefore, a long-term trial was carried out to evaluate alternative management practices to grazing of *Nardetum* with cattle, for regions with insufficient livestock densities.

Materials and methods

The experimental plots were located in the Thuringian Mountains (Germany), on acid soil conditions (Podsol) with a pH of 4.4, at 820 m above sea level. The investigation was conducted between 1991 and 2009. The grassland community was a *Nardetum strictae*. The experiment comprised three treatments with five replications each. The treatments were:
1 - One cut annually (20 June)
2 - One cut annually (10 September)
3 - One cut biennially (30 July).
In all treatments no fertilization took place. Dry matter yield and the parameters of forage quality (crude fibre, crude protein, DM digestibility and energy) as well as the mineral content were analysed. Determination of plant species was conducted according to the method of Klapp-Stählin (Voigtländer und Voss, 1979). Data were interpreted by means of analysis of variance.

Results

Significant differences in dry matter yield and forage quality were observed between the three treatments (Table 1).

Table 1. Dry matter yield and forage quality (mean values 1991-2009)

Treatment	cutting date	dry matter yield kg ha^{-1}	crude fibre g kg^{-1} DM	crude protein g kg^{-1} DM	energy MJ NEL kg^{-1} DM	DM digestibility %
1	20 June annually	2110	245	118	6.12	63.0
2	10 Sept. annually	3120	289	82	5.15	45.5
3	30 July biennially	3890	276	93	5.52	51.4
	Tukey HSD (P < 0.05)	380	16	7	0.30	3.3

Compared to the other treatments, cutting annually on 20 June resulted in the lowest DM yield but the highest energy content and DM digestibility. Cutting biennially on 30 July resulted in the highest dry matter yield per cut in combination with quality parameters that were intermediate between those of the two annual cutting dates. Cutting in autumn (10 Sept) increased DM yield but reduced forage quality compared with June cutting. The cutting time also affected mineral concentrations in the herbage, with the exception of copper and phosphorus (Table 2).

Table 2. Mineral concentrations of harvested biomass in relation to date of cut (mean values 1991-2009)

Treatment	P	K	Mg	Ca	Mn	Fe	Cu	Zn
	g kg^{-1} DM				mg kg^{-1} DM			
1	2.7	15.2	2.6	7.3	437	116	6	67
2	2.6	9.9	3.0	12.6	327	335	6	57
3	2.6	13.4	2.5	9.5	350	147	6	71
requirement	2.9 2)	20.0 1)	1.6 2)	4.7 2)	45 3)	50 3)	10 3)	45 3)

1) K recommended for optimal grassland growth

2) P, Mg required amount in the ration for beef cattle (daily milk yield 15 kg per cow, life weight 650 kg), German Society for Nutrition

3) Mn, Fe, Cu, Zn recommendations for young cattle (German Society for Nutrition)

Mg, Ca and Zn concentrations were sufficient for beef cattle in herbage of all treatments, whereas P, K and Cu concentrations were considerably lower than the required values. The Nardetum is characterised by very high contents of Mn and Fe in the biomass. The botanical composition was considerably influenced by the treatment (Table 3).

Table 3. Botanical composition in relation to cutting date (mean values 1991-2009)

Treatment		composition of biomass (%)			number of species			
		grasses	herbs	legumes	grasses	herbs	legumes	total
1	20 June annually	52	47	1	9	12	2	23
2	10 Sept. annually	54	41	5	8	15	3	26
3	30 July biennially	54	44	2	8	13	2	23

The cutting date caused differences in the proportions of grasses, herbs and legumes. The proportion of herbs declined whereas that of legumes increased at the cutting date in September. The same trends were detected in the number of species.

By annual cutting on the 20th of June, the community remained a typical *Nardetum strictae*. Mowing annually on the 10th of September caused a change of the community into a *Meo-Festucetum*. Cutting biennially on the 30th of July resulted in the development of an *Agrostis tenuis - Poa chaixii* community and *Hypericum maculatum* became dominant.

The changes in the composition of the grassland community were reflected in different amounts of N, P and K in the harvested biomass (Table 4).

Table 4. Amounts of N, P and K in harvested biomass (mean values 1991-2009)

Treatment	cutting date	amount in harvested biomass N	P	K
		kg ha^{-1}		
1	20th June annually	39.7	5.8	32.0
2	10th Sept. annually	40.8	8.0	31.3
3	30th July biennially	56.8	10.4	52.1
	Tukey HSD ($P < 0.05$)	4.9	1.1	5.4

The amount of N harvested in biomass ranged from 41 to 57 kg ha^{-1}, harvested P was from 6 to 10 kg ha^{-1} and harvested K was from 31 to 52 kg ha^{-1}, depending on the cutting date and frequency. The highest amounts were found for the treatment with biennial mowing on 30 July.

Discussion

Grassland communities, like *Nardetum strictae* on poor and acid soils, were strongly influenced by the date of cutting. Late mowing, at the end of July or at the beginning of September, caused a decrease in forage quality and an alteration of the grassland community, compared with cutting in June. Mowing on 20 June resulted in a remarkably high forage quality and the mineral concentrations in the forage were, in most cases, sufficient for beef cattle.
Our results demonstrate that annual mowing on 20 June without any fertilization can be an alternative to the extensive grazing with cattle or sheep proposed by other authors (Tidow, 2002; Waesch, 2003).

Conclusions

- One cut per year on 20 June, without any fertilization, is the best way for maintenance of *Nardetum strictae* in a typical setting in regions with insufficient livestock densities.
- Cutting once per year is indispensable for sustainable maintenance.

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Monitoring the management of hill pastures grazed by rotationally stocked cattle

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Abstract

The management adopted in a multi-paddock rotational stocking unit for cattle production in Central Italy characterised by summer drought was analysed. The pasture surface was divided into paddocks provided with mobile water-points and was grazed by a herd of Marchigiana cattle. In each paddock, dry matter yield and forage quality were assessed before and after the utilisation throughout the grazing period 2005. These variables allowed assessment of the available and consumed net energy in relation to the herd requirements. The low energy consumed by the herd, compared with energy requirement recorded in some conditions, highlighted the high risk of underfeeding of grazing cattle. Increase of fibre and reduction of the forage digestibility at the end of the grazing periods highlight the need to take into account the herbage utilisation rate and to provide adequate feeding supply for herd requirements.

Keywords: energy balance, hill pastures, rotational stocking, cattle

Introduction

Grazing systems recently adopted in many marginal hill areas of Central Italy for cattle production are able to produce positive effects on production costs and animal welfare (D'Ottavio *et al*., 2008). In order to promote sustainable grazing systems many different aspects still need to be verified (D'Ottavio and Santilocchi, 2007). Among these, an important aspect is to assess the sward characteristics in order to satisfy the energy requirements by the animals during the grazing period. This study aims to monitor the management adopted in a multi-paddock rotational stocking unit for cattle production in order to verify that the energy by the herd is being satisfied throughout the grazing season.

Materials and methods

The study was performed at the 'Putido' farm in Fabriano (Ancona province, 43°28'N, 12°54'E), on clay soils and at a mean altitude of 350 m a.s.l.. The climate is characterised by average annual temperature of 12.6°C, annual precipitation of 945 mm and summer drought. The studied pastures were drill-sown at the beginning of September 2003 with a mixture of *Festuca arundinacea* (42%) *Dactylis glomerata* (22%), *Lolium perenne* (22%), *Lotus corniculatus* (8%) and *Trifolium repens* (6%) at a seed rate of 50 kg ha^{-1}. The pasture area of about 19 ha was divided into 4 paddocks (pk) by mobile electric fences and provided with water-points. The more productive areas were allocated for hay production when grass growth exceeded livestock requirements. After the harvest (generally performed by the end of May), these areas were introduced into the stocking rotation determining a surface increase of paddocks 2 and 3 during the second grazing cycle. The pastures were grazed by a herd of Marchigiana cows starting from late spring 2004.
In the 2005 grazing season, dry matter (DM) yield and herbage consumption were estimated according to Frame (1981). Undisturbed herbage accumulation during grazing was measured inside six 1 m^2-exclosure cages randomly located in each paddock and the results used to esti-

mate accumulation under grazing at each location. Pre- and post-grazing herbage production were estimated on six 1 m^2-plots randomly chosen in the close surroundings of each exclosure. Pre- and post-grazing herbage samples were dried at 65°C for 48 h and separately analysed to determine: Crude Protein (CP, Kjeldahl method), Ash, Crude Fibre (CF, Weende method), NDF (Neutral Detergent Fibre), ADF (Acid Detergent Fibre), ADL (Acid Detergent Lignin) (Van Soest method, according to Martillotti *et al*., 1987) and Organic Matter digestibility (OMd, Aufrere and Doureau, 1988) by using pepsin and cellulase. According to I.N.R.A. (1980), Net Energy for Lactation (NEL, expressed as MJ), of the pre- and post-grazing herbage production were assessed. According to I.N.R.A. (1980), the herd energy requirement was related to 12 suckling and 20 dry cows, 10 calves and 2 bulls of 650, 200 and 800 kg of live bodyweight, respectively, estimated according to the reference information on the Marchigiana breed. For cows and bulls an energy increment of 20% of maintenance requirement due to grazing activity and, for suckling cows, a increment of 3.28 MJ per litre of milk produced (assuming a 7 l daily production) were considered. Herd energy requirement was assumed constant throughout the season, although some increases could derive from the growth of calves.
Within each paddock, means comparison of forage chemical composition and digestibility between the beginning and the end of the grazing periods was performed by using *t* test.

Results and discussion

In the 2005 grazing season, the total energy requested by the herd was 2111 MJ (Figure 1). The balance on a daily basis between the required and the consumed energy by the herd throughout the grazing season highlighted different and contrasting results. These were explained as mostly depending on the different grazing cycles and paddock characteristics.
During the first cycle, the energy consumption by the herd was uniform in its requirement only in paddock 1, and in 2 and 3 consumption was much lower than the requirement. In paddock 2, this result was related to the very low utilisation rate of *Agropyron repens* (this unsown grass was the most abundant species due to its establishment and spread in the paddock after sowing). In pk 3, it was related to the low forage quality, compared with paddock 1, utilised at the beginning of the grazing season (CP: 12.3 *vs.* 9.0%; NDF: 48.2 *vs.* 56.5% in pk 1 and 3, respectively) and to the considerable quality decrease recorded between the beginning and the end of the grazing period compared to the other paddocks (Table 1).

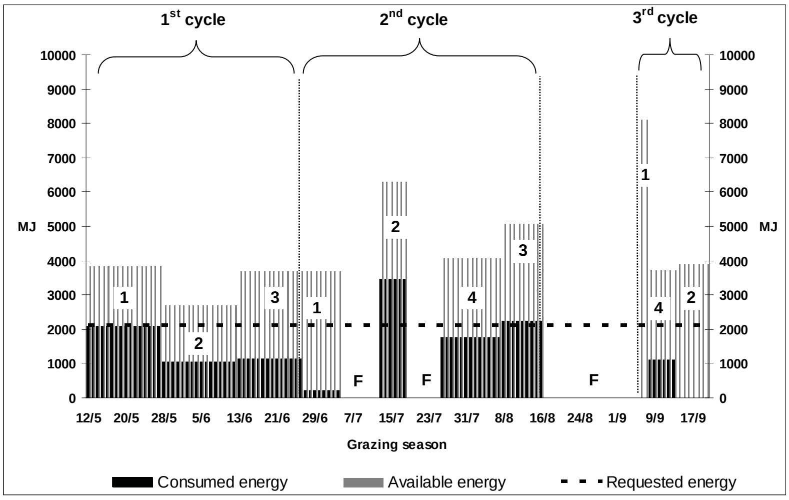

Figure 1. Grazing calendar and energy balance in grazing season 2005 (numbers in white rectangles indicate paddock number; F: hay feeding). Data for consumed energy in paddocks 1 and 2 in 3rd cycle are missing.

During the second cycle, the energy consumption in paddock 1 was lower than the requested and very much lower than the available. According to Ziliotto and Testolin (1982), this result was mostly associated to the low use of herbage precociously aged after the utilisation in late spring (NDF: 60.1%; OMd: 44.9%). The higher energy consumption recorded in paddocks 2, 4 and 3 were probably due to the still valuable forage quality recorded at the beginning of the grazing periods (CP and

OMd never lower than 11.4 and 53.8% respectively). The marked decrease of forage quality recorded at the end of the grazing period in these paddocks (Table 1) highlighted the main utilisation of young leaf tissues re-grown after the last grazing. Two grazing interruptions caused by the forage scarcity were adopted during this cycle when hay was provided in a separate paddock (F, Figure 1).

After the second cycle, the scarce forage production caused a grazing interruption of 19 days (F, Figure 1). During the third cycle, the low energy consumption recorded in paddock 4 was associated with the low forage quality and digestibility (NDF: 59.8%; OMd: 38.8%) and with their rapid decrease (Table 1). Missing data for paddocks 1 and 2, caused by too-short grazing periods (2 and 6 days in paddock 1 and 2 respectively), did not allow the assessment of the NEL consumed by the animals.

Table 1. Differences of DM chemical composition and digestibility (% of DM) between the beginning and the end of the grazing periods in each paddock

Grazing cycle	Surface (ha)	Paddock	Grazing days	CP %	Ash %	CF %	NDF %	ADF %	ADL %	OMd %
1st	3.00	1	15	-3.41	+4.79	+0.53	+6.48	+6.84**	-0.70	-3.99
	2.76	2	15	+1.30	+1.81	+2.48	+8.35*	+6.97**	-2.08	-4.83
	2.56	3	13	+8.5**	+3.31**	+8.26*	+11.53*	+10.35**	+1.87	-8.93
2nd	3.00	1	8	+0.58	+0.14	+8.03	+6.47	+7.92	-1.39	+1.15
	4.51	2	12	-1.48**	+0.12	+7.87**	+8.26	+11.62**	+2.49*	-14.72*
	5.76	4	10	-2.23	+2.55	+8.05**	+15.61**	+11.16*	+2.90	-17.46**
	4.41	3	13	+2.06	+0.75	+13.15**	+15.96**	+17.57**	+4.07**	-20.26**
3rd	5.76	4	5	+0.87	+0.40	+6.21**	+8.81**	+11.85**	+2.86**	-9.29**

Within each paddock, differences were significantly different at the 0.05 (*) or at the 0.01 (**) level (*t* test). Data for paddocks 1 and 2 of 3rd cycle are missing.

Conclusions

The low energy consumption, compared with the herd requirement recorded in some paddocks and periods, highlighted the high risk of underfeeding the grazing cattle. With particular reference to the summer period, the increase of fibre components and the high reduction of the forage digestibility recorded at the end of the grazing periods highlight the need to take into account the herbage utilisation rate and to provide an adequate feeding sly in order to supply the herd requirements.

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Biogas production from *Galega orientalis* Lam. and galega-grass biomass

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Abstract

Galega (*Galega orientalis* Lam.) is a fodder legume with a long productive lifetime of more than 30 years, having a high productivity and the capacity to fix atmospheric nitrogen in the range of 200-453 kg ha^{-1}. Swards of five galega-grass mixtures (three binary- and two multi-species) swards were developed on a stagnic luvisol without mineral nitrogen fertilizer. Pure galega swards provided 12.16 Mg ha^{-1} organic dry matter (ODM). Galega mixed swards with cocksfoot (*Dactylis glomerata* L.), perennial ryegrass (*Lolium perenne* L.) or meadow fescue (*Festuca pratensis* Huds.) increased dry organic matter yield by 2.5%-8.5% compared with pure galega. Biogas yield from galega and cattle manure substrates was investigated in four laboratory-scale digesters of 5 l volume operated in batch mode at a temperature of 38±1.0°C. Substrate of 75% of galega and 25% of cow manure produced the highest biogas yield of 628 m^3 Mg_{DOM}^{-1} and biogas methane content was 61.2%. Galega in pure stands or in mixtures with grasses is an acceptable plant for fodder or biogas production.

Keywords: biogas, cocksfoot, galega, meadow fescue, perennial ryegrass

Introduction

Biogas can be used for heat and power generation or as a vehicle fuel and thus can help to fulfill Latvia's obligations to increase its share of renewable energy up to 40% by 2020. Usage of perennial forage plants, especially legumes, for biogas production can be an important alternative for farmers, due to the unstable animal breeding market in Latvia. Perennial legumes and grasses grown for fodder or biogas production have the following advantages compared with intensive annual energy crops, e.g. maize, sorghum, sunflower:

- capability to sustain in dry or wet conditions and in soils with low organic matter content
- lowered number of soil tillage
- less need for mineral fertilizers and pesticides
- increase in soil organic matter and nitrogen content in soil
- locally obtainable seed material
- suitability of existing traditionally used machinery.

Biogas made from perennial plants would not require any land-use change in Latvia if perennial crops are grown on unused agricultural areas, grasslands and pastures. Growing of perennial grasses can meet requirement for "maintainance of soil organic matter levels through appropriate practices" (EC Regulation, 2009). Earlier investigations reveal that growing of perennial legumes and grasses has positive impacts on the soil organic matter content. For example, galega after 4 years growing, leaves 7.4 t ha^{-1} organic residues in the soil which is 53% more than from winter wheat (Drikis, 1995). Galega in pure stands can be grown for years without reseeding, and provides annual DM yields from 9.56 to 11.0 t ha^{-1} (Adamovich, 2000). Galega is considered as the best fodder for milk cows, cattle breeding or for biogas production, due to excellent crude protein content. Biogas plants could be constructed in conjunction with the 629 cattle-sheds in Latvia that havemore than 100 animals. Biogas production in those plants could be based on cow manure and galega utilization as the feedstock. The proportion of galega and manure in substrates used as biogas plant feedstock strongly depends on the area for growing galega, actual number of cows in a farm, pasture period, season, climate conditions and other factors. The aim of this investigation was the evaluation of biogas output from different galega substrates and the estimation of potential biogas yield from galega and galega-grass per unit area for long-term planning purposes.

Materials and methods

Galega was grown in three two-component mixtures (40:60) with galega:cocksfoot (*Dactylis glomerata* L.) or galega:perennial ryegrass (*Lolium perenne* L.) or galega:meadow fescue (*Festuca pratensis* Huds.), and in two 3-component mixtures (40:30:30) of galega: cocksfoot: perennial ryegrass or galega:perennial ryegrass:meadow fescue to investigate fresh biomass and organic dry matter (ODM) yields. The total seeding rate was 1000 germinating seeds per m^{-2}. The plot size was 14 m^2 with 3 replicates. The plots were fertilised as follows: N 0, P 40 and K 150 kg ha^{-1}. Swards were established on stagnic - luvisol (pH_{KCl} was 6.7, mobile P 52 and K 128 mg kg^{-1} of soil) soils. Swards were cut three times per season during a 3-year period. Harvested biomass was weighed and analysed for DM content and organic dry matter (ODM) content in the DM.

The biogas yield was investigated using laboratory equipment consisting of four 5 l digesters, operated in batch mode at 38±1.0°C. Substrates of different pure galega to manure compositions (on fresh-matter weight basis) were treated in an anaerobic fermentation process in digesters. Substrates were analysed for organic dry matter, volatile solids and moisture content before filling into and after extracting out of digesters. Accuracy of measurement was ±0.02 for pH value, ±0.2°C for temperature, ±0.005 l for gas volume and ±0.1% for methane content in biogas. Operation of digesters was continued for 64 days to ensure that most of the extractable biogas was harvested.

Biogas output obtainable per unit of energy-crop area was calculated as follows:

$$V_{BN} = m_F k_{DM} k_{ODM} k_D v_{BN} \qquad (1)$$ where:

V_{BN} - volume of biogas obtainable from 1 ha energy crop area, N m^3,
m_F - fresh biomass harvested, in Mg ha^{-1},
k_{DM} - proportion of dry matter in harvested fresh biomass,
k_{ODM} - proportion of organic dry matter in dry matter of biomass,
k_D - biodegradation ratio of organic dry matter during the anaerobic fermentation process,
v_{BN} - specific volume of biogas in anaerobic process from 1 Mg degraded organic matter (DOM) at normalized (temperature T = 0°C, pressure P = 101.3 kPa, dry gas) conditions, N m^3 kg_{DOM}^{-1}. The experimental data was subjected to ANOVA analysis.

Results and discussion

Data of the variance analysis showed that in the 3-year period of utilization, DM yield for galega-grasses mixed swards was reliably ($P < 0.05$) dependent on the sward botanical composition. ODM yield of pure galega was 12.16 Mg ha^{-1}, which was 1.44 Mg ha^{-1} or 0.68 Mg ha^{-1} lower than most successful two-component or three-component galega-grass mixtures, respectively (Table 1). Average biogas yields strongly varied between digesters, depending on galega to manure ratio in substrates (Table 2). The lowest biogas and methane output was observed from cow manure, due to strong previous digestion of fodder organic matter by domestic animals. Average methane content in biogas from galega-cow manure substrates was 58%, and was acceptable for biogas usage for electricity cogeneration. Average biogas yield per unit of degraded organic matter (DOM) was 533 m^3 Mg_{DOM}^{-1} and average methane yield was 313 m^3 Mg_{DOM}^{-1}. These average values were used for estimation of biogas potential obtainable per unit of galega or galega-grass area, for long-term planning purposes, helped by equation (1). Technically possible biodegradation ratio of organic matter of 0.75 was presumed the same both for galega-grass mixtures or pure galega in calculations.

Fodder galega significantly surpasses other forage legumes in terms of productive longevity, but investigated galega-grass mixed swards, despite their shorter productive longevity, have higher organic matter and biogas yields.

Table 1. Biomasss, biogas and methane yields for galega and galega-grass mixed swards

	Fresh biomass Mg ha^{-1}	Dry matter Mg ha^{-1}	Organic matter in dry matter Mg ha^{-1}	Biogas m^{-3} ha^{-1}	Methane m^{-3} ha^{-1}
Galega 100%	50.81	13.07	12.16	4861	2819
Galega 40% + *Dactylis glomerata* 60%	53.14	13.4	12.46	4981	2889
Galega 40% + *Lolium perenne* 60%	54.41	13.87	12.90	5157	2991
Galega 40% + *Festuca pratensis* 60%	57.42	14.63	13.60	5437	3153
Galega 40% + *Dactylis glomerata* 30% + *Lolium perenne* 30%	53.43	13.63	12.68	5069	2940
Galega 40% + *Dactylis glomerata* 30% + *Festuca pratensis* 30%	55.67	14.18	13.19	5273	3058
$LSD_{0.05}$		0.32			

Table 2. Biogas and methane yield in dependence on galega:manure ratio in substates

	Percentage of manure in substrate				
Gases	100 (control)	75	50	25	Aver. (25-75)
Biogas m^{-3} Mg_{DOM}^{-1}	411	436	535	628	533±99
Methane m^{-3} Mg_{DOM}^{-1}	219	244	309	384	313±74
Methane content %	53.2	56.1	57.8	61.2	58±3.3

Note: DOM - degraded organic matter

Substrate of galega 75% and cow manure 25% in anaerobic fermentation process produced the highest biogas yield of 628 m³ Mg_{DOM}^{-1} with a methane content of 61.2% (Table 2).

Conclusions

Fodder galega in pure stands persists for periods of more than 30 years and provides organic dry matter yield 12.16 Mg ha^{-1} without nitrogen fertilizer application.

Organic dry matter yields obtained from galega-grasses mixed swards were higher by 2.3% to 10.7%, compared with pure galega swards at the same soil, fertilization and climate conditions. Average biogas yield 533 m³ Mg_{DOM}^{-1} and average methane yield of 313 m³ Mg_{DOM}^{-1} can be used for long-term planning of biogas plant size with feedstock of cattle manure, galega or galega-grass mixtures.

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Fertilization effects on understory and tree interactions in a mountain forest pasture after sowing

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Abstract

Around one million hectares have been afforested between 1994 and 1999 (ECC, 2004) due to European agro-environment policies (Regulation 2080/92) in Europe. Tree understory competition is one of the most important aspects that control tree growth after reforestation, which could be modified by the use of fertilizers. The use of sewage sludge as a fertilizer is currently promoted by EU (86/278/CEE) and Spanish (R.D 1310/1990) regulations due to the physical soil improvements it induces and recycling of nutrients from animal or vegetal wastes. The study objective was to evaluate the effect of using two sewage sludge doses on different dates in silvopastoral systems established in a very acid soil with *Pinus radiata* D. Don and after being sown with *Lolium perenne* L. var. Brigantia (25 kg ha^{-1}), *Trifolium repens* L. var. Huia (4 kg ha^{-1}) and *Dactylis glomerata* L. var. Artabro (10 kg ha^{-1}). High sewage sludge dose applied in April improved tree growth and pasture development, probably due to the better use of the soil resources.

Keywords: sewage sludge, herbaceous, shrubs

Introduction

Silvopasture is a form of agroforestry whereby trees are incorporated into managed pasture. Initial competition for natural resources between trees and pasture species is one of the most important interactions in silvopastoral systems (Chang and Mead, 2003). In terms of minimizing the competition between pasture and tree species for water and nutrients in the early stages of the development of silvopastoral system, the best selection of tree and pasture species should be made (López-Díaz *et al*., 2009). *Pinus radiata* is usually associated with silvopastoral systems (Benavides *et al*., 2009) and it is the most popular species for afforestation in the Province of Lugo. The Galician natural soil acidity limits tree and understory growth, which should be overcome with fertilization (Mosquera-Losada *et al*., 2011). Sewage sludge fertilizer is promoted by EU (86/278/CEE) and Spanish (RD 1310/1990) regulations due to the physical soil improvements it causes and recycling of nutrients from animal or vegetal wastes. The aim of this study was to evaluate the residual effect of the application of two doses of sewage sludge at two different dates on tree growth and understory interactions in a silvopastoral system established in a very acid soil reforested with *Pinus radiata*.

Materials and methods

The experiment was located in the San Breixo Forest Community (Guitiriz, NW Spain). A plantation of *Pinus radiata* D. Don was established in 1998 at a density of 1667 trees ha^{-1} after harvesting a 30-year-old *Pinus radiata* D. Don stand. Scrubland was the main understory vegetation. When the forestry plants were one-year old, in October 1999, an experiment with a randomized block design was carried out in 15 (5 treatments×3 replicates) experimental units of 12×8 m^2, each one consisting of 25 trees arranged in a 5×5 frame with a distance of 3 m between rows and 2 m between lines. Pasture was sown after sewage sludge applications and ploughing with a mixture of 10 kg ha^{-1} of *Dactylis glomerata* var Artabro, 10 kg ha^{-1} of *Lolium perenne* var Brigantia and 5 kg ha^{-1} of *Trifolium repens* var Huia. The treatments consisted of two doses of sewage sludge comprising 50 (B: low) and 100 (A: high) kg total N ha^{-1}, applied on two different dates (1. early February and 2. early April). Sewage sludge fertilization was applied on the surface during 2000, 2001, 2002 and 2003 years. Sewage sludge doses inputs were based on previous experimental results following the recommendations of the EPA (1994) which considers that ~25% of the total N is available in the year of application of the sewage sludge. A no-fertilization treatment was used as a control. Tree heights were measured using a pole in the nine inner trees of each experimental plot in order to avoid the "border effect" in August 2004. Pasture production was estimated by collecting four random samples (1×1 m²) per plot within the area occupied by 9 inner trees using battery-driven hand shears. The dates of sampling were spring and autumn of 2004. The proportion of herbaceous and shrub species was estimated by hand-separation of 100 g of fresh pasture in the laboratory, and their corresponding percentages were later estimated after oven drying (60°C for 48 h) and weighing. The SAS statistical software package (SAS, 2001) was used for all analyses. ANOVAs were applied to evaluate the effect of treatments on the different studied variables and LSD was used to determine differences between treatments once ANOVAs resulted significant.

Results and discussion

Figure 1 shows that low (February) and high (April) dose of sewage sludge increased tree height, when compared with the unfertilized treatment (P = 0.05). Pasture production was not significantly modified by treatments (data not shown) due to the lack of adequate climatic conditions during the period of study (low temperatures and rainfall). However, fertilization treatments increased the percentage of herbaceous species, this percentage being higher as the sewage sludge dose was increased and applied in April (dose * date interaction: $P < 0.05$) (Figure 2). In contrast, the proportion of the shrubs was higher under no-fertilized treatment ($P < 0.001$) and when a low dose of sewage sludge was used in April (Figure 2).

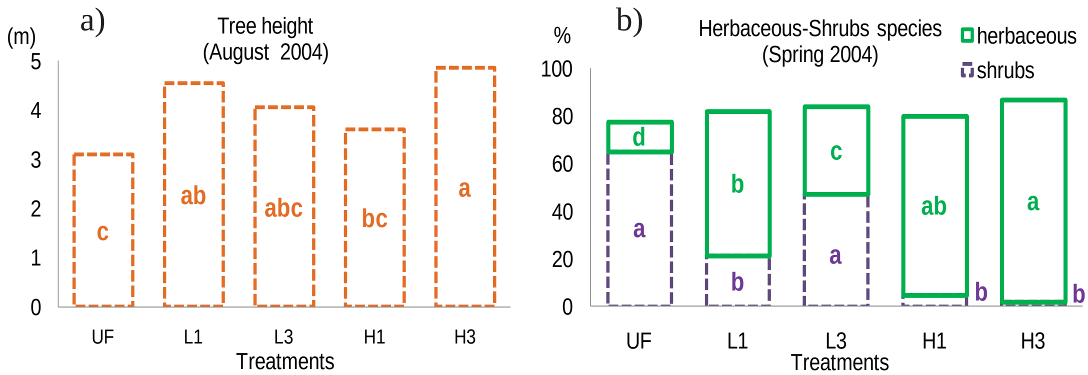

Figure 1. a) Tree height (m) and b) Percentage of total herbaceous and shrubs species obtained in study plots in 2004. Where UF: unfertilized treatment, L: low dose (50 kg N ha^{-1} total); H: high dose (100 kg N ha^{-1} total): 1, 3: different dates of application of sewage sludge in February and April, respectively. Different letters indicate significant differences between treatments.

The increase of fertilization with sewage sludge improved tree growth and reduced the shrub layer. Early applications of low doses of sewage sludge caused smaller proportion of shrubs in the understorey than late inputs of the same doses of sewage sludge, which reduce tree-understorey competition and promoted tree growth in early applications when compared with

UF treatment. In contrast, later inputs of high doses of sewage sludge improved tree growth and the development of pasture species due to the promotion of fertilizer use of both components.

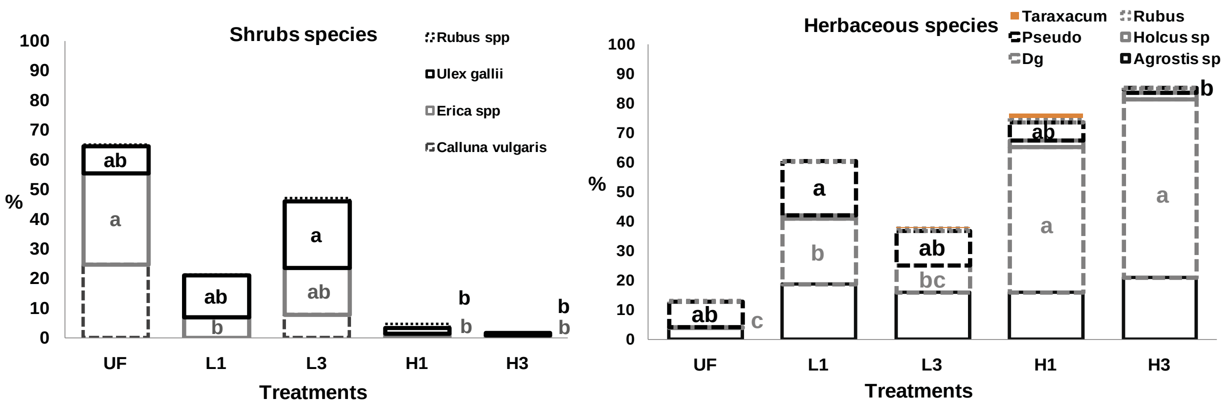

Figure 2. Percentage of the different shrubs and herbaceous species obtained in study plots in 2004. Where UF: unfertilized treatment, L: low dose (50 kg N ha^{-1} total); H: high dose (100 kg N ha^{-1} total): 1, 3: different dates of application of sewage sludge in February and April, respectively; Pseudo: *Pseudarrhenatherum longifolium*; Dg: *Dactylis glomerata*. Different letters indicate significant differences between treatments.

Conclusions

High sewage sludge dose applied in April improved tree growth and pasture development, probably due to the better use of the soil resources.

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Silvopastoral systems with *Betula alba* L.: effects of fertilisation and seasonal variation on alpha biodiversity

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Abstract

Changes in climatic conditions, such as droughts, and different types of management, such as fertilisation, can have important effects on biodiversity in a short time. The aim of this study was to evaluate the effect of two fertiliser treatments (mineral and no fertilisation) on species richness (i.e. alpha biodiversity) and the percentage of annual and perennial species, in two seasons (summer and autumn), in a silvopastoral system established with *Betula alba* L. and a sown pasture (*Dactylis glomerata* L., *Trifolium repens* L., and *Trifolium pratense* L.). While sown species were increased by mineral fertilisation, alpha biodiversity and the percentage of annual species were both reduced by this treatment. The presence of perennial species increased after a wet summer. In a silvopastoral system, mineral fertilisation contributed to reduced alpha biodiversity in a short time because it increased the presence of sown species.

Keywords: afforestation, species richness, annual species, perennial species, fertilisation

Introduction

Agronomic land afforestation has taken place extensively in the last decade all over Europe. After afforestation, tree development creates land heterogeneity which could enhance plant biodiversity due to the presence of herbaceous species, adapted or not, to shade. The use of this herbaceous layer by grazing animals in forest lands increases land profitability through the implementation of agroforestry systems. It is important to note that different options of soil management of these systems could modify biodiversity within a short time. The use of fertilisation in silvopastoral systems affects diversity due to the modification of the competition relationship of species (presence of monocots *vs.* dicots), different functional ecological traits (presence of annual *vs.* perennial species) or richness (Rigueiro-Rodríguez *et al*., 2011), and it usually favours the presence of sown species (Rajaniemi, 2002). All these effects can be modified by climatic conditions, especially by the presence of summer droughts, because they may reduce the cover of perennial plants and cause variations in species richness (Stevens, 2006).

Materials and methods

A silvopastoral system with *Betula alba* L. (2,500 trees ha^{-1}) was established in Lugo (Galicia, NW Spain) at 439 m. above sea level, in 1995. The experimental design was established using random blocks with three replicates. Every plot consisted of 25 trees distributed in a square of 5×5 trees. Pasture was established after soil preparation with *Dactylis glomerata* L. var. Saborto (25 kg ha^{-1}) + *Trifolium repens* L. var. Ladino (4 kg ha^{-1}) + *Trifolium pratense* L. var. Marino (1 kg ha^{-1}). Two fertiliser treatments were applied during the experiment: no fertilisation (NF), and mineral fertilisation (M) following a standard procedure for the region: 500 kg ha^{-1} of 8:24:16 ($N:P_2O_5:K_2O$) fertiliser complex in March and 40 kg of N ha^{-1} in May, every year throughout the experiment. Alpha biodiversity (species richness) was estimated in summer (July) and autumn (December) in the first two years of establishment (1995 and 1996) by taking a sub-sample after harvesting the area situated between the six inner trees. The samples were transported to laboratory, where species were hand separated and botanical composition was estimated based on percentage of dry matter. Species richness, percentage of sown and unsown species and functional groups (annual and perennial) were determinated. The results obtained were analysed with ANOVA following the model: $Y_{ijk} = \mu + F_i + C_j + B_k + \varepsilon_{ijk}$, where Y_{ijk} is the studied variable; μ the variable mean; F_i: fertilisation; C_j: harvest; B_L: the block; and ε_{ijk} is the error. The LSD test was used for subsequent pairwise comparisons ($P < 0.05$; $\alpha = 0.05$). The statistical software package SAS was used for all analyses (9.1 SAS Institute, NC, USA).

Results and discussion

The summer of the second year of study was wetter than the summer of the first year (16 *vs.* 46 mm in August in 1995 and 1996, respectively) (Figure 1), which could explain the low percentage of annual species in 1996 with respect to 1995 (Figure 2), as summer rainfall events increase the likelihood of a shift from annuals to perennials species (Vaughn *et al.*, 2011) in climates with drought summers.

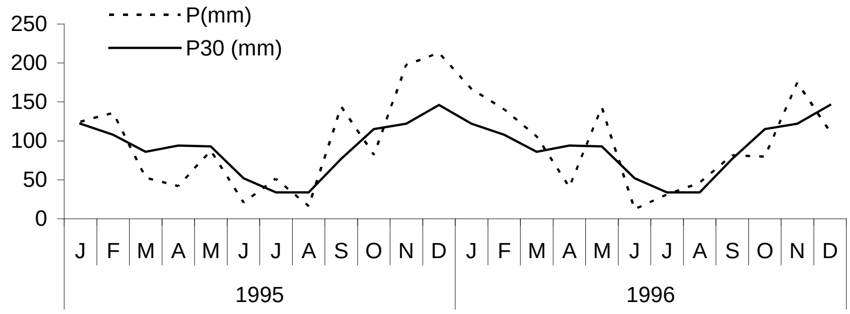


Figure 1. Monthly precipitation for the study area (P) in 1995, and 1996, and mean data for the last 30 years (P30).

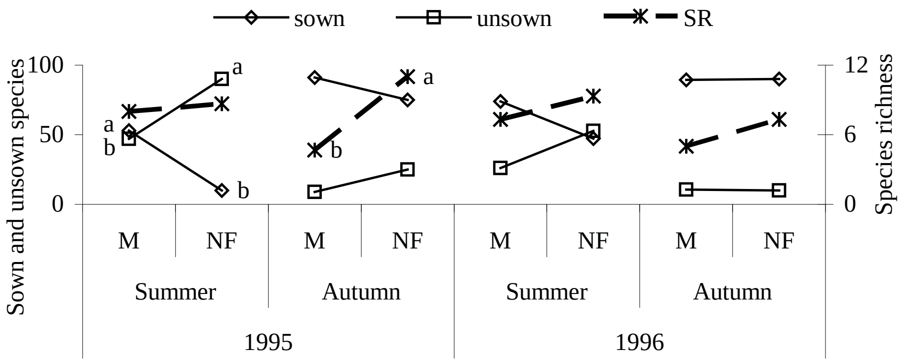
Mineral fertilisation increased the percentage of sown species ($P < 0.05$), mainly *D. glomerata* L. This sown species is characterised by strong growth in height, and higher dominance in the grasslands. These characteristics increase shading and reduce the possibility of colonization by other species, and hence reduce species richness ($P < 0.01$) under this fertiliser treatment (Figure 2). No fertilisation effects on sown species, unsown species and alpha biodiversity were observed in 1996, probably due to the high rainfall recorded in March and May (Figure 1), when fertilisation was applied, as this would have increased fertiliser loss by surface run-off.

Conclusion

In the management of silvopastoral systems it is important to note that, on the basis of the findings reported here, the application of mineral fertilisation favours the presence and growth of sown species but it reduces alpha biodiversity within a short time. On the other hand, the percentage of perennial species is favoured by wet summers.

Acknowledgments

We are grateful to CICYT and Xunta De Galicia for financial assistance and to Escuela Politécnica Superior for facilities.



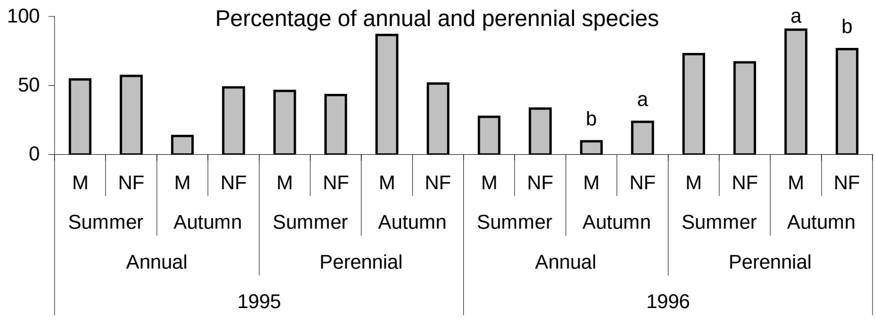


Figure 2. Species richness, percentage of sown and unsown species, and percentage of annual and perennial species in the two harvests (summer and autumn), two fertiliser treatments (M: mineral fertiliser; NF: no fertiliser), and in the two years of study (1995 and 1996). Different letters indicate significant differences between fertilisation treatments in the same harvest, and in the same year.

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Effect of the fertilization with different dose of sewage sludge on soil fertility and species richness in a silvopastoral system developed under *Quercus rubra* L.

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Abstract

Silvopastoral systems, compared with exclusively agronomic systems, provide environmental benefits such as increased biodiversity through the generation of different conditions of humidity, light and soil fertility, which encourage the establishment of different species in the pasture. In silvopastoral systems, the use of organic fertilizers such as sewage sludge can modify the productivity of the different components of the system (pasture and trees) as well as its botanical composition. The aim of this study was to evaluate the effects of different doses of municipal sewage sludge (providing inputs of 100 kg total N ha^{-1}, 200 kg total N ha^{-1} and 400 kg total N ha^{-1}) compared with a control treatment (no fertilization) on species richness of a pasture in a silvopastoral system (sown sward with *Dactylis glomerata* L., *Lolium perenne* L. and *Trifolium repens* L. under *Quercus rubra* L.) in sandy soils in Galicia (Spain). The results showed that the establishment of pasture and trees improved the soil conditions in the medium term due to the organic matter input into the sandy soil, which increased species diversity especially at the doses of 100 and 400 kg of total N ha^{-1} compared with the unfertilized and 200 kg of total N ha^{-1} treatments.

Keywords: agroforestry, biodiversity, waste, afforestation

Introduction

The EU has declared the ambitious objective of stopping the loss of biodiversity in Europe. The establishment of silvopastoral systems may contribute to achieving this target, since these systems can promote biodiversity due to the diverse heterogeneous environmental conditions that are created within them (vegetation structure, shading, and moisture) and also in terms of preservation and improvement of landscape diversity and maintaining traditional systems, compared with monocrop systems. Moreover, silvopastoral systems increas connectivity within landscape components and this benefits the mobility of animals thus reducing habitat fragmentation (Rigueiro-Rodríguez *et al*., 2010). In Galician silvopastoral systems, productivity (pasture and trees) can be limited by low soil fertility as a result of increased acidity (Zas and Alonso, 2002). The use of sewage sludge as fertilizer can increase the productivity of pasture and trees and modify the pasture biodiversity (Mosquera-Losada *et al*., 2009). When sewage sludge is used as fertilizer it is important to apply adequate doses of this residue. A sewage sludge application dose exceeding the crop needs could result in nitrate contamination of the ground water by leaching (EPA, 1994), and also promote nitrophilous species instead of others. The objective of the present study was to evaluate the effects of different doses of sewage sludge (providing inputs of 100 kg total N ha^{-1}, 200 kg total N ha^{-1} and 400 kg total N ha^{-1}) on species richness of the pasture as compared with an unfertilized control in a silvopastoral system under *Quercus rubra* L..

Materials and methods

The experiment was conducted on agriculturally abandoned 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 2001, with bared-root plants of *Quercus rubra* L. planted at a density of 1,112 trees ha^{-1}. The experiment was a randomized complete block design with three replicates and four treatments. Each experimental unit had an area of 144 m^2 and 25 trees planted with an arrangement of 5×5 stems, forming a perfect square. Treatments consisted of (a) no fertilization (0N), (b) fertilization with anaerobically digested sludge with an input of 100 kg total N ha^{-1} in March 2002 and 2003 (100N), (c) fertilization with anaerobically digested sludge with an input of 200 kg total N ha^{-1} in March 2002 and 2003 (200N) and (d) fertilization with anaerobically digested sludge with an input of 400 kg total N ha^{-1} in March 2002 and 2003 (400N). 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 (R.D.1310/1990) regarding heavy metal concentration for sewage sludge application. To estimate the species richness, four samples of pasture were randomly taken at a cutting height of 2.5 cm per plot (0.3 m×0.3 m) in June 2002 and May, July and December 2006. In the laboratory, two pasture samples were separated by hand to determine the proportions of the different plant species and the senescent material. These two samples were then dried for 72 hours at 60°C to determine the botanical composition on a dry-weight basis. Total annual species richness was calculated by summing the number of all species found in each experimental unit on a year basis. Species were also recorded in terms of their annual or perennial specific characteristics, also on a year basis. Data were analysed using ANOVA and differences between averages were shown by Tukey's HSD test using SAS (SAS, 2001).

Results and discussion

Species richness was significantly higher in 2006, (average across all treatments: 5 species) than at the beginning of the experiment in 2002 (average across all treatments: 4 species) ($P < 0.001$). This result can be explained by the establishment of the pasture and trees, which implied the incorporation of pasture litter, including leaves and roots from *Quercus rubra* L., into the sandy soil (Ferreiro-Domínguez *et al*., 2011). The organic matter input into the soil from the pasture and trees is known to improve the physical and chemical characteristics of sandy soils (Nieder *et al*., 2003) and subsequently to impact species-richness over time, since the less-restrictive edaphic conditions lead to an increase in the number of species (Mosquera-Losada *et al*., 2009). Moreover, the silvopastoral system of this study was established under *Quercus rubra* L., which is a deciduous species and allows better light penetration than conifers like *Pinus radiata*, which usually reduces diversity in the region once canopy closure happens (Rigueiro-Rodríguez *et al*., 2011).

Species richness was significantly affected by the fertilization treatments in 2002 ($P < 0.05$) and 2006 ($P < 0.01$) as can be seen in Figure 1. In 2002, the low dose (100N) of sewage sludge increased species richness more than the medium dose (200N) of fertilizer. This result can be explained by the fact that the low dose of sewage sludge results in a lower soil chemical fertility than the other treatments with sewage sludge and, as reported by Thompson *et al*. (2001), the increase in soil chemical fertility reduces the invasion of weeds and therefore the number of species. Similar results were also found by Rigueiro-Rodríguez *et al*. (2011) in silvopastoral systems established under *Pinus radiata* D. Don and *Betula alba* L. in agrarian soils in Galicia. On the other hand, in 2006, species richness was larger when sewage sludge was applied than with no fertilization (0N), and the effect of the treatment with a medium dose (200N) of sewage sludge was similar to the unfertilized treatment. Moreover, it is important to note the increment in the number species that was observed in this treatment (200N) in 2006 (5 species) compared with 2002 (2 species), probably due to the positive effect of the fertilization with sewage sludge on species richness. Fertilization with sewage sludge implied an input of organic matter and macronutrients to the soil (Mosquera-Losada *et al*., 2010) which leads to improvement of the physical and chemical characteristics of sandy soils and allows the establishment of sown species and, therefore, the increment of pasture species richness.

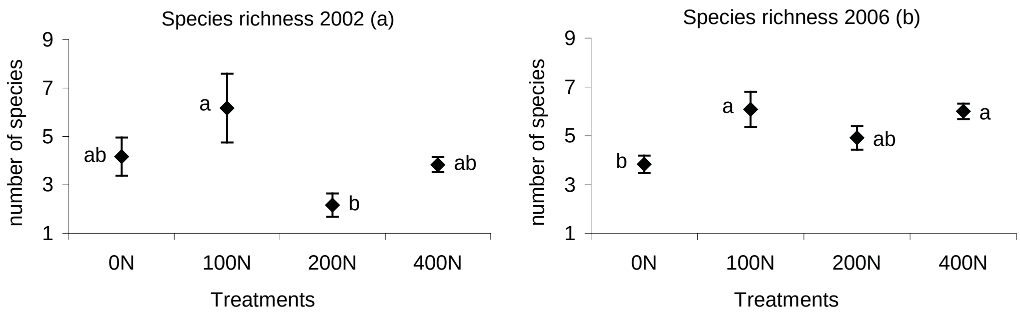

Figure 1. Species richness under each treatment in 2002 (a) and 2006 (b). 0N: 0 kg total N ha^{-1}; 100N: 100 kg total N ha^{-1}; 200N: 200 kg total N ha^{-1} and 400N: 400 kg total N ha^{-1}. Different letters indicate significant differences between treatments in each year. Vertical lines indicate mean standard error.

Conclusions

Pasture species richness increased over time due to the positive effect of the establishment of the pasture and trees on the soil physical and chemical fertility in sandy soils. However, the improvement of the soil chemical fertility, as well as the lack of fertilization, reduced the invasion of non-sown species and therefore the number of species.

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Stocking rate and pasture production and biodiversity under a *Prunus* silvopastoral system

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Abstract

Silvopastoral systems are considered a good tool for clearing the understory in forest areas, while also obtaining high-quality meat products. Moreover, low tree-densities, which allow higher pasture production than high tree-densities, are claimed to provide high-quality wood products. This study aims to evaluate the effect of two different stocking rates of sheep on pasture production and biodiversity, and their seasonal distribution, under a high-value 10-year-old *Prunus* plantation. In the spring pasture production was high at the low stocking rate, but in the first harvest in autumn it was higher at the high stocking rate than the low stocking rate. This could be explained by the higher biodiversity found under high stocking rate, during the last period of the year.

Keywords: agroforestry, biodiversity, waste, afforestation

Introduction

Multipurpose use of forests is a key activity to increase economic returns from recently afforested areas and could be achieved through the implementation of agroforestry systems. Moreover, silvopastoral systems are promoted by the European Union (Council Regulation 1698/2005; EU, 2005) through the establishment of agroforestry systems. The use of *Prunus avium* in silvopastoral systems is appropriate, because of the high value of timber of this tree species, and because the low shade it generatesalso promotes pasture production. Moreover, a reduction of recurrent clearings that is needed to increase the size of the trunks of the trees could be achieved through grazing, thereby reducing production costs as compared with mechanical clearings. Trees could also enhance pasture production and species richness by avoiding the negative effects of drought and by the heterogeneity they generate in soil conditions, due to modification of the soil humidity regime and the light inputs that pasture could receive in environments with dry summers (Moreno and Obrador-Olán, 2007). The aims of the experiment reported were to evaluate the effect of two sheep stocking rates on seasonal pasture production and richness in a silvopastoral system established five years after afforestation with 5-year-old *Prunus avium* trees.

Materials and methods

The experiment was carried out in the locality of Boimorto (A Coruña) in NW Spain at an altitude of 380 m above sea level. Annual mean temperature and annual total rainfall are around 11.8°C and 1600 mm, respectively. Soil initial pH (water) was around 5.9. Afforestation with five-year-old *Prunus avium* bare-root trees was carried out in the year 2003 at a density of 400 trees ha^{-1}. The experiment was started in 2010, when the diameter at breast height and tree height were 7.1 cm and 7.40 m, respectively. The field experiment was planned following a randomized block experimental design with two treatments (high (and 8 sheep ha^{-1}) and low stocking rate (4 sheep ha^{-1})) and two replicates, and started in May 2010 and finished in January 2011. The size of each experimental unit was one hectare. Pasture was continuously grazed. Pasture production was determined monthly using exclusion cages, after taking 8 samples of 0.3×0.3 cm, four of which were taken below the tree and four in the areas furthest from the tree in the north, south, east and west positions. Net pasture production was estimated from the difference in pasture production within the cage in the month M, and the pasture production obtained outside the cage in the previous month (M-1). Samples were transported to laboratory, weighed and dry matter obtained (100 g; 48 h×60°C). Pasture species were determined after hand separation of all species in a subsample of 100 g. Species richness, or number of species appearing below and far from the tree, was then determined. Each position was calculated by the mean of the 4 orientations taken below and far away from the tree. ANOVA was performed using position and treatments as factors within each period and a Repeated ANOVA statistical method was carried out to determine differences between periods (months) (SAS, 2001). Means were separated by using Duncans test, if ANOVA was significant.

Results and discussion

Seasonal pasture distribution (Figure 1) was within the range usually found in grasslands in the region of Galicia (Mosquera-Losada *et al.*, 1999). Pasture production was higher in the two first periods than in the summer, due to the traditional period of drought found during the summer, and was higher than in the autumn when low temperatures reduced pasture development (Figure 1).

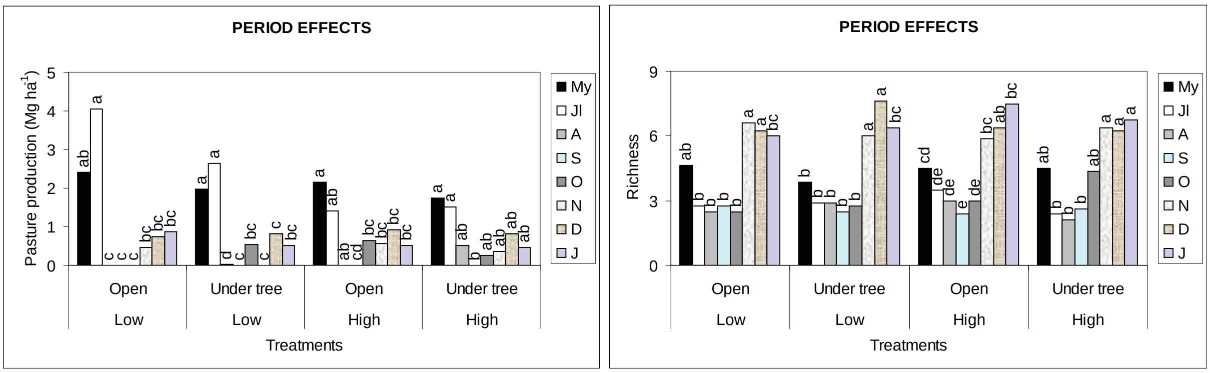

Figure 1. Period (month) effects on pasture production and species richness for different treatments. Different letters indicate significant differences between months of sampling within each position (open and under the tree) and stocking rate (low and high) treatments in each month. My: May, Jl: July; A: August; S: September; O: October; N: November; D: December; J: January.High = high stocking rate: 4 sheep ha^{-1}; Low = low stocking rate: 8 sheep ha^{-1}.

During the spring, pasture production was higher at the low stocking rate compared with the high stocking rate, which indicates a low use of pasture under the low stocking rate conditions (Figure 2). In contrast, pasture production was higher in the high stocking rate than in the low stocking rate in the first harvest of autumn. High stocking rate (Richness: 4.37) also significantly doubled biodiversity at the start of the autumn under the trees, compared with low stocking rate (Richness: 2.75), which could have increased production (Rigueiro *et al.*, 2010). A high stocking rate could generate gaps in the pasture due to trampling and high consumption intensity. These gaps could be colonized by new species after the summer drought when autumn rainfall starts (Buttler *et al.*, 2009). On the other hand, pasture production under the trees was increased at the end of the spring when rainfall events are scarce, because the effect of drought could be reduced due to the tree protection (Moreno and Obrador-Olán, 2007).

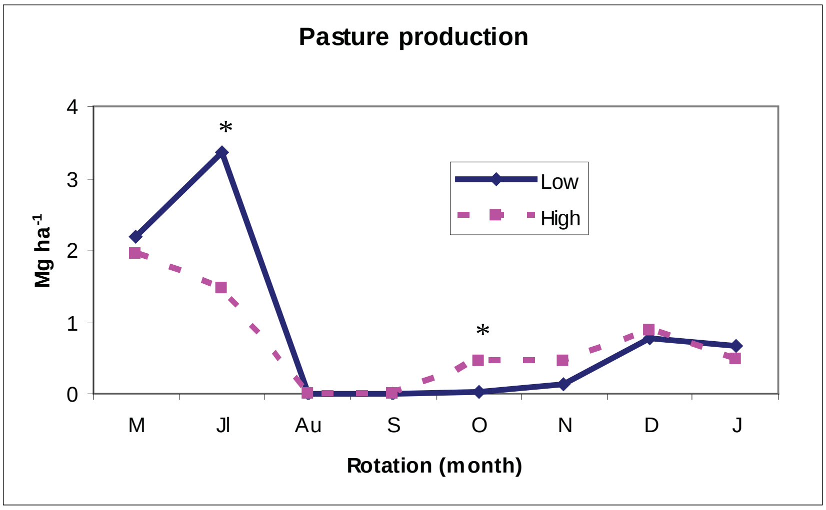

Figure 2. Treatment effects on pasture production in the different treatments (High = high stocking rates (8 sheep per ha); Low = low stocking rate (4 sheep per ha)). * indicates significant differences between treatments in each month. M: May, Jl: July, Au: August, S: September, O: October, N: November, D: December, J: January

Conclusion

Pasture production could be promoted as a result of an increase in stocking rate due to the promotion of biodiversity this treatment caused. Pasture production was increased at the end of the spring under the trees because of the reduction of drought effects.

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Production of above-ground phytomass of turf grass species during their extensive exploitation

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Abstract

Dynamics of phytomass development of turf grass species *Lolium perenne* L. (*L.p.*), *Festuca rubra* sp. (*F.r.*) and *Poa pratensis* (*P.p.*) during an intensive 5-cut system was studied in a field experiment (2007-2009) and compared with mulching and interaction with N+PK fertilization. Dry matter production of *P.p.* (454.1 g m^{-2} without fertilization and 586.7 g m^{-2} with fertilization) was significantly lower than for *L.p.* (502.3 g m^{-2} to 680.6 g m^{-2}) and F.r. (450.8 g m^{-2} to 624.6 g m^{-2}). N-fertilization at 50 kg and 100 kg ha^{-1} $year^{-1}$ increased phytomass production on average by 29.3-39.9%. Compared with unfertilized variants, quickly-available N and slowly-available N increased phytomass production by 39.8% and 29.5%, respectively. Plant stand-height was significantly increased due to N-fertilization only in *L.p.*. Compared with mown stands, the height of mulched stands was significantly higher in *L.p.* and *F.r.*. Mulching decreased weight of roots and increased weight of stubbles.

Keywords: cut, height, mulch, phytomass weight, sward structure, turfgrass

Introduction

The area of non-productive landscape area in the Czech Republic is about 450 thousand hectares of which 170 thousand ha are grasslands of extensive character. Methods are sought for their rational use and management. From 2007-2009, methods of grassland establishment, different levels of N+PK fertilization and various forms of N-fertilization were studied at Mendel University in Brno, and the effect of cutting height on production characteristics and sward structure in turf grass species were considered (Knot and Hrabě, 2007) both under field conditions and on artificial substrates (Vrzalová *et al*., 2007). This paper presents results of clipping yield and roots, stand height and sward structure of intensively used turf grasses *Lolium perenne* L., *Festuca rubra* sp. and *Poa pratensis* concerning different N+PK nutrition, N-fertilization form and utilisation system (cutting, mulching).

Material and methods

A small-scale trial was established at the Research Station of Fodder Crops in Vatín (MENDELU) with experimental plots of 4 m² replicated 3 times. The station is in the potato-growing region; average annual temperature is 6.1°C and a total annual precipitation is 737 mm. The experiment was established in 2006. We have used results from 2007-2009.

The experimental design includes the following variants

Grass species: 1. *Lolium perenne*, 2. *Festuca rubra*, 3. *Poa pratensis*
Fertilization: 1. KO - control without fertilization; 2. RN_{50} - 50 kg ha^{-1} N+PK (in spring); 3. RN_{100} - 100 kg ha^{-1} N+PK (½ in spring and ½ after the third cut; 4. DN_{50} - 50 kg ha^{-1} N+PK (in spring); 5. DN_{100} - 100 kg ha^{-1} N+PK (½ in spring and ½ after the third cut), RN = quickly available nitrogen, DN = slowly available nitrogen.
Utilisation: I. Cutting (C) five times a year, II. Mulching (M) five times a year. Sward height was measured before each harvest in four replicates on each plot. All data were analysed by ANOVA and Tukey's test ($P \leq 0.05$).

Results and discussion

Productivity of the three turf grass species managed at an extensive 5-cut system is high. *Lolium perenne* L. with the phytomass production ranging from 502.3 g m² (without N-fertilization) to 680.6 g m^{-2} (N+PK fertilized variants) significantly exceeded the production of *Poa pratensis* L. (454.1 and 586.7 g m^{-2}) (Table 1). As compared with grasslands without N-fertilization, the N+PK fertilization increased the production of harvested phytomass in *L.p.* by 35.5%, *F.r.* by 39.23% and *P.p.* by 29.3%. The effect of the type of N-fertilizer on production is both of economic and ecological importance (reduced costs of production recycling, lower export of nutrients from the plot). Compared with 32.2-47.5% of the quickly-acting N-form, the retarding influence of the slow releasing of N-fertilizer (DN) increased the phytomass production within a range from 26.7-32.4%.

Grassland management systems are focused on the promotion of the development of root phytomass at a cost of above-ground phytomass. According to Hrabě and Halva (1993), this occurs in grass stands with a lower level of NPK fertilization. Our results (Figure 1) corroborate the trend in turf stands. Plant stands of unfertilized turfs invest more energy into root phytomass whose share in the sward (stubble) biomass and production of roots is 2/3. The application of mineral N at up to 100 kg ha^{-1} stimulates the growth of roots and contributes to a greater C deposition in soil. This situation occurs also in the case of mulching systems where N-subsidy is higher because it includes nutrients from decomposing phytomass.

Table 1. The effect of N-fertilization level and N-form on the weight of harvested phytomass of turf grass species, on average in 2007-2009 and through 5 cuts

	Harvested phytomass (g m^{-2})					
Species	without fertilizer	RN 50	RN 100	DN 50	DN 100	RN+DN Mean
Lolium perenne	502.3[a]	638.2[ab]	759.4[b]	609.2[ab]	715.7[ab]	680.6B
Festuca rubra	450.8[a]	613.4[b]	679.5[b]	632.2[b]	586.1[ab]	624.6AB
Poa pratensis	454.1[a]	605.0[ab]	637.9[b]	537.9[ab]	566.1[ab]	586.7A
Mean (Rel.%)	100.0	132.0	147.6	126.4	132.7	-

Values followed by the same letter in lines ([a]) and column (A) are not significantly different ($P \leq 0.05$)

Turf height: Results presented in Table 2 corroborate significant interspecific differences in overgrowth rate and height of stands in the cutting period; e.g., the average height of mown *L.p.* stands (191.4 mm) was nearly 2-times higher that that of *P.p.* (130.0 mm).

Table 2. Effect of cutting and mulching on height of turf grass species, Vatín 2007-2009, ave. Cuts 1-5

		Height (mm)					
Species	Exploitation	without fertilizer	RN 50	RN 100	DN 50	DN 100	RN+DN average
Lolium perenne	Cut	161.8[a]	180.90[b]	204.37[c]	184.39[b]	195.83[bc]	191.4BC
	Mulch	193.3[a]	208.29[a]	223.73[a]	214.45[a]	221.00[a]	216.9D
	Rel.% (mulch/cut)	119.4	115.1	109.5	116.3	112.9	113.3
Festuca rubra	Cut	147.73[a]	164.10[a]	174.73[a]	164.38[a]	170.96[a]	168.5B
	Mulch	177.86[a]	190.00[a]	201.96[a]	189.38[a]	195.71[a]	194.5CD
	Rel.% (mulch/cut)	120.4	116.4	115.6	115.2	114.5	115.4
Poa pratensis	Cut	92.49[a]	110.32[a]	110.27[a]	105.05[a]	106.49[a]	108.0A
	Mulch	112.34[a]	126.34[a]	138.74[a]	127.11[a]	130.94[a]	130.8A
	Rel.% (mulch/cut)	121.5	114.5	125.8	121.0	123.0	121.1

Values followed by the same letter in each lines ([a]) and column (A) are not significantly different ($P \leq 0.05$)

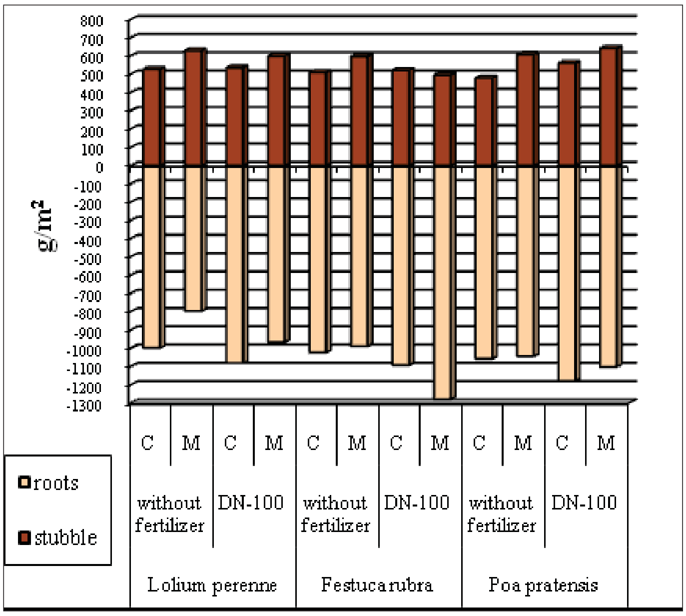

Figure 1. Effect of cutting and mulching on weight and structure of the sward (stubble+roots) of turf grass species, Vatín 2007-2009, autumn Cut 5

Unlike mowing, mulching increases the proportion of stubble in the sward weight. Knot and Hrabě (2007) suggest this is caused by increased proportion of the dead ‚stubble'. Qian and Follett (2002) concluded that C deposition in soil is greater than its release in the period 20-30 years after the establishment of grass stands, which could be corroborated by our research.

N-fertilization significantly increased the height of stands only in *L.p.* (+18.3%) while in other species the height increase was non-significant. Mulching significantly increased the height of turf in *L.p.* and *F.r.*. In the relative comparison of stands without fertilization, the difference amounts up to +20.0% and with N-fertilization it is rel. +13.3%-21.0%. Ong (1978) assumes that apart from the influence of nutrients released from the phytomass, the reason may be in the lower production of tillers and hence in the promoted length-growth of the lower number of stalks.

Conclusions

In the extensive system of 5-cuts per year, turf grass species produce from the economic point of view an undesirably high weight of harvested phytomass. Mulching of turf as an option to cutting does not disturb significantly the structural composition of biological production and economic characteristics. Mulching meets the requirement for economic acceptability, while retaining the ecological balance of the extensive grassland ecosystem.

Acknowledgements

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Condensed tannins in willow (*Salix* spp.): a first step to evaluate novel feeds for nutritionally improved animal products

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Abstract

Tannins are plant polyphenols that can positively affect the physiological processes in ruminants and the metabolism of rumen microbial populations. These activities can generate useful benefits for animal welfare, production, product quality and the environment, and are likely to depend on the structural features of tannins. Condensed tannin traits vary as a result of their flavanol compositions, which can consist of different proportions of combination of catechin, epicatechin, gallocatechin or epigallocatechin, the synthesis and polymerisation of which is genetically controlled by plants. The EU project 'Tannin StrACTure QTL' aims to link tannin traits and their biological activity to plant genomes, using willow (*Salix* spp.) as the model plant. Willow leaves are known to contain condensed tannins, possess good nutritive value and thus could play a role as an alternative, sustainable feed for ruminants in extensive farming systems, especially during summer drought periods. This work reports the tannin composition determined by direct thiolysis of 40 diverse accessions of the UK National Willow Collection. Results highlight the great variability existing in the tannin composition among the different willow genotypes. This is likely to reflect differences in biological activity and therefore influence the magnitude of benefits to be expected in livestock farming systems.

Introduction

Condensed tannins (CT) are polyphenols increasingly considered in recent ruminant and plant research. CT can in fact interact with the physiological processes of the animal and with the metabolism of the microbial population in the rumen. Both these processes can generate useful benefits for ruminant nutrition and health (Dixon *et al*., 2005), productivity (Grainger *et al*., 2009), and product quality (Vasta *et al*., 2010).

However, some tannins can also have dose-dependent negative nutritional effects. Thus, all tannins were often mistakenly described in the past as anti-nutritional factors (Makkar, 2003). Actually, plants produce a wide range of different tannin structures, differing enormously between plant species, varieties and plant parts (Mueller-Harvey, 2006). This may explain why some tannin-containing forages are much more effective than others. Therefore, investigations into the beneficial or detrimental effects of CT need to consider all aspects of their structural variation.

Within the EU project 'Tannin StrACTure QTLs', willow (*Salix* spp.) has been selected as a model plant species to investigate the biological effects of plant CT structural traits. The UK National Willow Collection, maintained at the Rothamsted Research Institute, is a worldwide and unique willow germplasm collection that currently includes about 1300 accessions cultivated in an experimental field in Hertfordshire, United Kingdom, representing over 100 different willow species. Willows contain CT (2-3% of leaf dry matter), and their leaves and twigs have been used in the past as ruminant feeds and feed supplements in extensive systems in Northern Europe (Waller *et al*., 2001) and Bhutan (Roder, 1992), while researchers from New Zealand have investigated their potential as substitutive feed to deal with summer drought (Moore *et al*., 2003).

This work reports the CT composition of 40 diverse accessions of the UK National Willow Collection, determined by direct thiolysis. This method is suited to quantify the variable proportions as terminal or extension units of the CT monomers, named flavan-3-ols (catechin, epicatechin, gallocatechin, and epigallocatechin), that define CT structural traits.

Materials and methods

Leaves from 40 different accessions of willow (Figure 1) were collected in September 2008 from experimental plots sharing similar climatic and topographic conditions in the National Willow Collection (BBSRC Rothamsted Research, Harpenden, Hertfordshire, UK), then oven-dried at 40°C for 48 hours, ground to pass a 1 mm sieve, and stored in darkness. The thiolysis extraction was performed directly on the dried-leaves samples (200 mg each) and, after HPLC separation, CT structural information (Total extracted condensed tannins, mean Degree of Polymerization - mDP, Procyanidin/Prodelphinidin ratio - PC/PD, *cis*/*trans* ratio) were obtained (Gea *et al*., 2011). Standardized CT traits values were used as variables in a hierarchical cluster analysis (R Statistics 2.11.1), using Euclidean distance as dissimilarities between objects and Ward's algorithm as groups linkage method.

Results and discussion

Results (Figure 1) showed a great and partially unexpected range of variability for each tannin trait among the accessions. Total CT content varied from 0.15 (accession n:831, *Salix koriyanagi*) to 3.29 g/100g DM (n:485, *S. scouleriana*). mDP, related to CT molecular weight, varied from 2.13 (n:956, *S. eriocephala*) to 18.22 (n:987, *S. hookeriana*). PC/PD ratio varied from 17.6/82.4 (n:207, *S. alba*) to 91.1/8.9 (n:1013, *S. phylicifolia*). Also *cis*/*trans* ratio showed large variations among accessions, ranging from 3.4/96.6 (n:987, *S. hookeriana*) to 85.2/14.8 (n:485, *S. scouleriana*).

The dendrogram resulting from the hierarchical cluster analysis clearly separated the screened accessions into 2 main groups (Figure 1); the first (group A) composed by samples with high concentration of PC flavanols (PC > 50%), the second (group B) by samples having higher percentage of PD.

The group A could be further divided into 3 sub-groups; sub-group A1 comprised accessions with low CT content (< 0.89%) and low mDP (< 7.0), sub-group A2 had species with very low CT content (< 0.59%), high mDP (> 10.5), and very high PC content (> 73.9%), whilst sub-group A3 grouped willows with high CT content (> 1.0%) and very high values both of PC (> 80%) and *cis* flavanols (> 62.4%).

The group B was divided into 4 subgroups; the heterogeneous B1, comprising most of hybrid accessions. Sub-group B2 contained *S. miyabeana* and *S. triandra*, characterized by very high mDP (> 11.8) and very low PC (< 32.7%) and *cis* flavanols content (< 14.0%). The small sub-group B3 was made by accessions with high CT content (> 1.29%) and very high mDP (> 15.8%), while the last sub-group contained species very rich in CT (> 2.10%), in PD (> 67.4%), and in *trans* flavanols (> 70.8%).

As a result of this screening, a wide range of different combinations of CT traits exists in willow germplasm. Further investigations are now necessary to link in plants the CT structural traits and their biological activity. The project 'Tannin StrACTure QTLs' will investigate willow as a model plant to reach this goal. The results will be useful for future research investigating how to improve, in a sustainable way, animal nutrition, health, and the quality of derived products.

Acknowledgements

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code	accession	total CT	mDP	PC	PD	*cis*	*trans*	group	sub-group
820	*S. amplexicaulis*	0.21	7.0	78.5	21.5	42.1	57.9		
1000	*S. myrsinifolia*	0.38	3.8	75.8	24.2	22.8	77.2		
22	*S. dasyclados*	0.72	6.6	63.8	36.2	56.4	43.6		
562	*S. dasyclados*	0.50	4.8	49.9	50.1	48.2	51.8		A1
577	*S. dasyclados*	0.89	5.4	47.8	52.2	50.6	49.4		
831	*S.koriyanagi*	0.15	2.2	53.6	46.4	72.0	28.0		
942	*S.eriocephala*	0.37	2.2	57.8	42.2	43.3	56.7	A	
399	*S. fragilis*	0.32	12.2	79.7	20.3	66.9	33.1		A2
937	*S. cordata*	0.59	10.5	73.9	26.1	54.9	45.1		
947	*S.eriocephala*	1.90	5.9	80.3	19.7	62.4	37.6		
207	*S. alba*	1.11	5.8	91.1	8.9	77.6	22.4		
436	*S. daphnoides*	1.19	6.3	89.8	10.2	71.4	28.6		A3
218	*S. alba*	1.06	8.0	84.2	15.8	82.2	17.8		
488	*S. sitchensis*	1.21	9.4	80.0	20.0	83.0	17.0		
530	*S.dasyclados*	1.47	6.8	48.1	51.9	9.2	90.8		
261	*S.babylonica*	2.18	7.4	43.5	56.5	15.0	85.0		
531	*S.dasyclados*	1.96	6.3	56.9	43.1	11.4	88.6		
956	*S. eriocephala*	1.44	2.1	44.7	55.3	30.8	69.2		
1116	*S. rehderiana X S. dasyclados*	1.52	5.2	58.0	42.0	53.1	46.9		
615	*S. schwerinii*	1.42	7.0	46.7	53.3	43.3	56.7		
1037	*S. eleagnos*	1.30	8.0	52.0	48.0	35.4	64.6		B1
602	*S. dasyclados x S. viminalis*	1.05	5.9	38.6	61.4	29.2	70.8		
628	*S. viminalis x S. schwerinii*	1.33	7.8	32.5	67.5	25.4	74.6		
672	*S. viminalis*	1.23	6.5	32.9	67.1	15.7	84.3		
1087	*S viminalis x (S.viminalis x S. schwerinii)*	1.36	6.3	35.1	64.9	23.7	76.3		
608	*S. rehderiana*	1.93	9.0	37.3	62.7	48.6	51.4		
1083	*S viminalis x (S.viminalis x S. schwerinii)*	1.58	9.7	22.9	77.1	19.4	80.6	B	
1124	*S viminalis x (S.viminalis x S. schwerinii)*	1.67	8.4	37.1	62.9	29.8	70.2		
885	*S. miyabeana*	1.03	13.8	32.7	67.3	14.0	86.0		
941	*S. miyabeana*	1.28	16.2	25.2	74.8	7.9	92.1		
25	*S.triandra*	1.18	11.6	25.7	74.3	4.1	95.9		B2
56	*S. triandra*	0.89	13.1	21.7	78.3	6.3	93.7		
61	*S. triandra*	0.77	11.8	24.9	75.1	8.9	91.1		
15	*S. pentandra*	1.29	15.8	42.6	57.4	55.7	44.3		B3
987	*S. hookeriana*	2.20	18.2	34.1	65.9	85.2	14.8		
476	*S.atrocinerea*	2.47	13.0	21.7	78.3	27.5	72.5		
1013	*S.phylicifolia*	2.10	15.9	17.6	82.4	29.2	70.8		

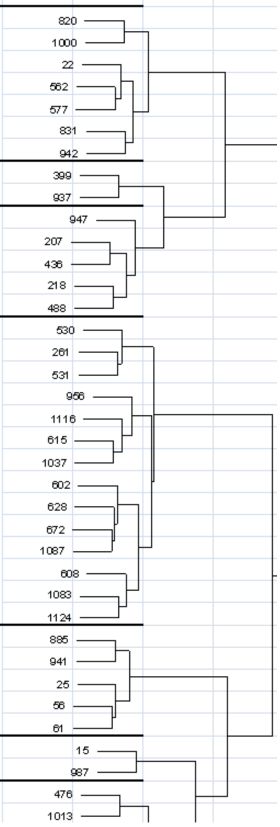

Figure 1. CT structural traits of the 40 willow accessions; total CT content (total CT, g/100g dry matter), mean Degree of Polymerization (mDP), Procyanidin (PC) and Prodelphinidin (PD) in percentage on the total of flavanols, *cis* and *trans* forms in percentage on the total of flavanols. The group and sub-group partition is based on the hierarchical cluster dendrogram 'cutting'.

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Forage use and grass/clover quality on organic dairy farms in Flanders

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Abstract

In 2008 all 25 organic dairy farms in Flanders, Belgium were invited to participate in a survey in the frame of a project determining N and P-excretion of organic dairy cows. About 70% of all organic farmers participated. The result is an overview of farm structure, forage production, diets, production factors and cow parameters on organic dairy farms. The dairy farms are characterized by a very big variation in farm structure and intensity of management, but grass/clover was omnipresent in all dairy rations year-round. 77 grass/clover fields for grazing purposes were sampled and analysed for forage quality parameters in 2009. During the grazing season the quality of the available grass/clover is very variable and mainly determined by clover content and growth stage.

Keywords: inquiry, protein content, grazing, milk production

Introduction

Organic cows represent only 0.4% of the dairy cows in Flanders. Nevertheless, given the differences in production of organic dairy farms versus conventional farms, questions have arisen about whether organic farms should have specific N and P excretion figures for dairy cattle. This project started in 2008 with a survey to understand the specific nature of organic dairy production. The results were used in the design of the trials determining the excretions and in the final calculations (De Campeneere *et al*., 2010) and presented here. Additionally, grass/clover for grazing was sampled on the participating farms and analysed for comparison with forage quality on conventional dairy farms.

Materials and methods

Every organic dairy farm in Flanders certified and controlled by BLIK (the official organization responsible for certification and inspection body of organic production) received the questionnaire. Farms willing to participate were visited by an ILVO assistant to help with completing the forms when necessary, and to collect the answers. This questionnaire yielded a data set about total farm, grassland and forage crop area, seasonal forage and concentrate use, dairy herd and milk production characteristics on organic farms. Besides the questionnaire, in 2009, 77 fresh grass/clover samples were taken on pastures grazed by dairy cows in 4 periods covering the grazing season April-November. Samples were analysed by NIRS to determine chemical composition and digestibility and energy (fodder unit milk, VEM) and protein content (true protein digested in the small intestine, DVE and rumen-degraded protein balance, OEB) were calculated. DVE and OEB are parameters of protein quality developed by Taminga *et al*. (1994).

Results and discussion

The survey was representative of organic dairy farming because 18 of the 25 dairy farms participated and represented more than 75% of the organic dairy cows. Half of the current organic farms converted into organic farming since 2000.

Table 1. Forage crops on 18 organic farms

Forage crops	On ... farms	average area (ha)
Grassland	18	34.1
cutting grass/clover (leys)	18	12.2
grazing + cutting	18	21.9
under conservation	11	9.5
Maize silage	11	4.6
Maize CCM	4	3.2
Fodder beets	8	1.0
Cereals	16	7.5
barley	9	3.1
triticale	9	3.5
spelt	6	5.0
oat	6	2.3
wheat	3	4.7
rye	1	2.5
Peas	1	8.0

Within a farm, the average area used for dairy cattle is 46 ha (standard deviation, SD 22) with 2 farms below 20 ha and 1 farm above 80 ha. About 75% of the forage area is covered by grassland: 2/3 permanent and 1/3 temporary (Table 1). Typical for organic farming is the use of grassland under nature conservation: on 60% of the farms on average 9.5 ha (SD 6.2) per farm. Weed control in maize is more difficult under organic conditions. It limits the number of farms growing maize (60%) and the area per farm. Furthermore, some farmers do not want to use maize in the ration for other reasons. Cereals are much more important in the dairy cow's ration than in conventional dairy farming: almost every dairy organic farm grows cereals, a majority for grain and straw (> 80% of the farms) and some for ear or total plant silage (on 50% of the farms). Fodder beets are not very popular because weed control requires a lot of labour/ha and to a certain extent there is a good alternative: pressed/dry pulp. Only one farm grows a legume crop for the dry grain (peas) although protein-rich concentrates are very expensive. Taking also into account calves, heifers and other cattle, the average cow density based on N-excretion figures for each type, is 1.5 (SD 0.4) cow/ha forage crop (grass, maize, cereals). Day and night grazing is the major grassland use during the growing season in organic farming whereas a 6-8 hour graze during the day for dairy cows in production on conventional farms is quite common. Supplementation with hay in spring is a normal practice on 75% of the organic farms and prewilted grass/clover silage is an important component of the ration during the whole year: even in summer, half of the farms are feeding prewilted silage to the grazing cows and in winter it is the major forage. Farms with silage maize in the crop rotation use maize silage mainly during winter but some prefer to use it in the grazing season. Cereals are fed mainly during winter and autumn. Cereals are mainly used as concentrates: 1-2 kg cow^{-1} day^{-1} as a standard and on 50% of the farms adapted to the milk production.

Organic farmers breed for a robust cow type with a high intake level of roughage and a limited need for concentrate to produce milk during a high number of lactations. They use black and red Holstein, mainly crossed with Brown Suisse and Montbéliarde and sometimes with a breed of Normandy and Jersey. Parameters of milk production and quality are presented in Table 2. There is a considerable variation in milk production between the farms - from 3500 to 8800 l cow^{-1}- with an average of 6160 l for the 18 farms (Table 2). This is considerably lower in comparison with conventional farming, where the average milk production was about

Table 2. Milk production parameters in organic farming in Flanders

milk production	6160 l/cow/year	dry period	50 days
fat content[(1)]	41.5 g/l	concentrates	870 kg/cow/year
protein content [(1)]	34.0 g/l	urea in milk	286 mg/l
number of lactations	4.2	production groups	on 1/6 of the farms
age at first calving	27 months	forage mixing machine	on 1/6 of the farms
period between 2 calves	390 days		

[(1)] 1 farm with Jersey cows not included

8000 l cow[-1] in 2008. Milk yield per cow is closely related to the level of concentrates in the ration (R^2 = 0.62 on these organic farms). On average 870 kg concentrates per cow per year are used on these farms, which is low in comparison with 1,200 kg for conventional farming. On the organic farms, cows are older at first calving and the calving interval and dry period. The formation of production groups and the use of a forage mixing machine is not a common practice on organic farms.
Forage quality characteristics of grass/clover during the grazing season in 2009 are summarized in Table 3. Klop *et al*. (2008) sampled conventional pastures under different growing conditions and the average composition was comparable to the results of this study except for a higher crude fibre content and a lower digestibility in organic conditions. These characteristics are mainly determined by growth stage. An overview of grass quality (De Boever, 2009) confirms the values for CF, ash and water soluble carbohydrates but indicates that VEM and digestibility of these organic grass/clover samples is lower than expected. CP content on organic farms was high despite the low N-fertilizer input and very variable because of the big variation in clover content between parcels and within a growing season. In organic farming conditions, cattle are generally grazing grass in a more mature growth stage in comparison with intensive conventional farming. This explains the lower energy content and digestibility of the sampled grass.

Table 3. Determination of clover %, content of dry matter (DM), crude protein (CP), crude fibre (CF),ash and water soluble carbohydrates (WSC) and sugar, organic matter digestibility (% dOM), VEM (net energy lactation), DVE (digestible intestinal protein) and OEB (rumen degraded protein balance) of grass/clover during the grazing season on organic dairy farms

2009	Clover	DM	CP	CF	Ash	WSC	digestibility	VEM	DVE	OEB
n = 77	% soil cover	g/kg	g/kg DM				% OM	/kgDM	g/kg DM	
Mean	31	197	193	229	106	110	74.9	885	92	33
StD	19	33	26	21	10	32	3.1	57	12	25
Min	5	135	115	170	80	45	64.9	735	59	-12
Max	80	296	289	290	129	206	83.7	1028	121	91

Conclusion

The questionnaire gave a good overview of the wide variation in farm structure, diet composition, forage production, dairy herd and milk parameters on Flemish organic dairy farms. Grass/clover and cereals are the main components of the diet during the whole year. Grassland use is focused on grazing. Organic farmers use a robust cow type with a high roughage intake level and a limited need for concentrates to produce milk during many lactations. Analysis of grassland samples during the grazing season reflects the high clover impact on CP and the high variability of the clover content in the sward in space and time. In organic farming conditions cattle generally graze grass at a more mature growth stage in comparison with intensive conventional farming.

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Suitability of alternative grass species for grassland management in Austria under changing climatic conditions

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Abstract

Climate change causes increasing drought and heat stress, endangering the agricultural use of grassland especially in the marginal alpine areas. A changing species spectrum towards heat tolerant grasses, forbs and legumes has therefore to be expected in the long term. The aim of this study was to test and compare various grass species both under humid and dry site conditions in Austria in terms of yield, forage quality and endurance.
The grass species studied were *Dactylis glomerata*, *Festuca pratensis*, *Festulolium loliaceum*, *Festuca arundinacea*, *Festuca rupicola*, *Festuca rubra*, *Poa angustifolia*, *Poa compressa*, *Poa pratensis*, *Bromus inermis* and *Bromus erectus*. The cultivars *Festuca arundinacea* and *Festulolium loliaceum* performed promising in terms of productivity and endurance and should therefore be further tested for grassland seed mixtures on dry sites of Austria. Also *Bromus erectus* and *Bromus inermis* adapted well to dry site conditions and should therefore be considered as potential components in grassland seed mixtures for referring sites.

Keywords: climate change, drought adapted genotype, grasses, forage quality

Introduction

In Austria, grassland management is mostly based on ruminants of which dairy cows taking the highest importance. Efficient and sustainable dairy production requires sufficient yields and high forage quality to minimize the use of farm-external and expensive concentrates. For satisfying growth, permanent grassland with *Lolium* species needs around 900 mm of precipitation, distributed equally over the whole year (Dietl *et al*., 1998). Climate change causes increasing drought and heat stress, endangering agricultural use and ecosystem function of grassland, not only in alpine areas (Weißhuhn *et al*., 2011). Thus, different adaptation strategies have to be developed and implemented into agricultural practice. In the long term, a changing species spectrum towards drought tolerant grasses, forbs and legumes can be expected. The aim of this study was therefore to test a set of various grass species for their suitability for grassland under changing climatic conditions concerning productivity, forage quality and endurance.

Material and methods

In a field study different grasses were cultivated in pure stands on two different sites over 3 years. Admont, located in the Enns valley, has a montane humid climate with the northern alpine characteristic of a relatively high precipitation. Piber, located in the western part of Styria has a montane climate with slight continental warm, semi-dry summer and comparatively low precipitation (see Table 1).
Exact field trials, designed as a partially randomized block with plots of 5.56 m² onthe humid site at Admont and 7.14 m² on the dry site at Piber, were carried out between 2005 and 2008 each with three replications. The sowing time was 31 August 2005 on the humid site at Admont and 15 August 2005 on the dry site at Piber with differing seeding rates of 20 to 40 kg ha^{-1} depending on the various species and their seed weight. At the beginning of the experiment, all plots were fertilized with 50 kg N ha^{-1}, 40 kg P_2O_5 ha^{-1} and 100 kg K_2O ha^{-1}.

Table 1. Mean air temperature (MAT) during the growing season (March to October), total annual precipitation and soil chemical properties of the two experimental sites

Site	Province in Austria	Altitude (m) Exposition	average 2006-2008 MAT °C	Precipitation mm	Soil chemical properties pH $_{CaCl2}$	P (CAL) mg kg^{-1}	K (CAL) mg kg^{-1}
Admont (humid)	Upper Styria	640; plain	11.8	1,286	5.2	49	76
Piber (dry)	Western Styria	450; E	12.4	881	5.5	25	78

The development and performance of 18 grasses were tested on both sites. Different origins (cultivars and genotypes) were chosen, coming from regions with dry conditions (among others e.g. Lower Austria, Marchfeld). Species studied were *Dactylis glomerata* (Tandem), *Festuca pratensis* (Pradel, Leopard), *Festulolium loliaceum* (Hycor), *Festuca arundinacea* (NS VISOKI VIJO, Keszthelyi-50, Molva, Belfine), *Festuca rupicola* (NÖ/Marchfeld), *Festuca rubra* (Echo)., *Poa angustifolia* (commercial seed, Gumpenstein), *Poa pratensis* (Oxford), *Bromus inermis* (Keszthelyi-51, OÖ-Unterheuberg, commercial seed) and *Bromus erectus* (commercial seed, NÖ Marchfeld). *Poa compressa* (commercial seed) disappeared after the first year from the plots and was therefore omitted from the trial. The trials were minerally fertilized every year with 150 kg N ha^{-1}, 80 kg P_2O_5 ha^{-1} and 160 kg K_2O ha^{-1} split in three applications. The cover of weeds was surveyed in the year 2008 before the second cut as an estimate of endurance. Biomass production (DM-yield) of the different species and cultivars were analysed over a period of three years under a 3 cut regime. The cumulated yearly yields were averaged over the investigation period and taken in comparison. *In vitro* digestibility of organic matter dOM was analysed according Tilley and Terry (1963) andaveraged over all cuts of the year 2006. Results concerning weeds are presented as averages.

Results and discussion

Established cultivars which are used in quality seed mixtures for Austrian grassland (ÖAG, 2011), were compared to potentially new cultivars. In order to make reasonable assessments, potential new cultivars were each compared to established ones, as far as possible origin from the same species group. For species without comparable cultivars (e.g. *Bromus erectus* and *Bromus inermis*), *Dactylis glomerata* was used; *Festulolium loliaceum* was compared to *Festuca pratensis*.

The average DM-yield over the sites of the tested cultivars was 11.8 t ha^{-1} year^{-1} but it has to be considered that in some variants weeds strongly contributed to the biomass production. At the dry site at Piber, a generally higher DM-yield over the years 2006 to 2008 and a lower dOM could be achieved than on the humid site at Admont.

All cultivars of *Bromus erectus* showed higher values regarding weed infestation in comparison to *Dactylis glomerata*, which clearly indicates the strong competitiveness of *Dactylis glomerata*; DM-yield and dOM were comparable to *Dactylis glomerata* at the dry site at Piber which indicates the good adaption to dry sites. At the humid site Admont, *Bromus erectus* cultivars showed a clearly higher weed infestation, lower DM-yield but comparable dOM in comparison to the dry site at Piber (Table 2).

Related to *Dactylis glomerata*, generally higher values regarding weed infestation were assessed for *Bromus inermis*. In comparison to *Bromus erectus* the *Bromus inermis* cultivars showed higher weed cover and higher DM-yield whereas dOM was comparable.

The *Festuca arundinacea* cultivars showed better results on both sites regarding weed infestation and DM-yield compared with *Festuca pratensis*, dOM was lower. However, there are some new cultivars with high digestibility on the market, worth to be examined in further trials.

The cultivar of *Festuca rupicola* showed worse results on both sites. Related to *Festuca rubra*, it could not profit from its specific competitiveness on extreme dry and nutrient low sites under the existing trial conditions.

Table 2. weed cover in %, dry matter yield (t ha^{-1} year^{-1}) and digestibility of the organic matter (dOM) of the different grass species examined

Established cultivars	number of cultivars	weed cover (2008) Admont	weed cover (2008) Piber	DM (2006-2008) Admont	DM (2006-2008) Piber	dOM (2006) Admont	dOM (2006) Piber
Dactylis glomerata	1	3	3	11.5	13.0	64	63
Festuca pratensis	2	26	34	11.6	13.1	69	61
Festuca rubra	1	21	45	12.3	13.6	65	53
Poa pratensis	1	29	77	8.8	11.0	66	58
potential new cultivars							
Bromus erectus	2	40	34	9.7	13.2	64	65
Bromus inermis	3	48	40	10.4	12.2	65	63
Festuca arundinacea	4	29	24	11.6	13.2	66	58
Festuca rupicola	1	75	63	8.0	12.2	58	58
Festulolium loliaceum	1	25	8	13.4	15.1	64	67
Poa angustifolia	2	27	73	8.9	11.7	61	61

The cultivar *Festulolium loliaceum* showed significant better values in comparison to *Festuca pratensis* on the dry site at Piber. The weed infestation only reached 8% after three years, DM-yields and dOM showed the highest values on the dry site at Piber. In comparison to the other potential new cultivars, *Festuca loliaceum* could therefore be an alternative grass species for the use in seed mixtures on dry sites. However on the humid site at Admont *Festulolium loliaceum* showed values comparable to *Festuca pratensis*.
The *Poa angustifolia* cultivars showed comparable but slightly higher values than *Poa pratensis* on the dry site at Piber. Here the weed infestation of both species exceeded 70% representing the highest values of the whole trial. On the humid site Admont, the values were comparable.

Conclusion

Clear differences among the potential new cultivars have been found on the two different sites. The cultivars of *Festuca arundinacea* and *Festulolium loliaceum* performed promising under the dry conditions in terms of productivity and endurance and should therefore be further tested for grassland seed mixtures on dry sites of Austria. To guarantee high forage quality on dry sites of Austria in the future, breeding of varieties from *Bromus erectus* and *Bromus inermis* should also be taken in consideration. The cultivars of *Festuca rupicola*, *Poa pratensis* and *Poa angustifolia* performed very badly and are therefore no alternatives to already established cultivars. For continuative information about yield, energy content and endurance of promising species and varieties they should be implemented into seed mixtures for grassland and again tested at several sites.

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Productivity and mathematical estimation of the vertical structure of swards

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Abstract

This research involved the synthesis of three experiments studying the productivity and vertical structure of a perennial grass and leguminous plants grown in monocultures or mixtures, and for modified cutting regimes in the conditions of North Russia. The results show that vertical structure and productivity of swards depend on plant morphology and ecological characteristics of the species and their combination in the swards and cutting regimes. Vertical structure of different swards is estimated mathematically by calculating the indicative coefficient ‚centre of equilibrium‘. Index of coefficient ‚centre of equilibrium‘ varied from 4.3 to 35.2. There were effects of vertical structure and coefficient ‚centre of equilibrium‘ on productivity of swards (r = 0.58-0.73).

Keywords: sward, productivity, vertical structure, coefficient ‚centre of equilibrium‘

Introduction

The system-defined approach is widely used in science and enables us to construct and study swards as an integral biosystem with all the components closely connected to each other.
Natural swards are more stable, as they generally need a long period of time to be formed and they are influenced by various ecological factors. These conditions presuppose their stability and biodiversity. Nevertheless, sometimes agrocenoses can be less able to compete compared with natural swards. Non-limiting environmental conditions are created to level the competition between plants in swards and to increase productivity. Scientists suppose that the competition of plants for light is an important ecological factor enabling high productivity of swards. Thus it is necessary to pay special attention to individual features of the spatial structure of plants. Vertical structure of plants determines the architecture of swards. Scientists (Nassiri *et al*., (1998), Duru *et al*., (2000), Verdenal *et al*., (2008)) consider that spatial and geometrical structure of stands greatly influences plant growth as well as the quality and quantity of yield. The aim of the research presented here is to study specific features of vertical structure of plants in various agrocenoses; to provide mathematical estimation of vertical structure of plants for monocultures and mixtures in order to state their quantitative differences; to study the degree of cooperation between architectonics and productivity of swards in different environmental conditions.

Materials and methods

The experiments were carried out for different agro-climatic conditions in the North of European Russia. The average annual air temperature was about 3.0°C (12.1°C during the growing season) and average annual rainfall was 600 mm (365 mm during the growing season). The following plants were used for three experiments:

1. *Phleum pratense* L., *Phalaroides arundinacea* Rausch., *Festuca arundinacea* Schreb., *Bromopsis inermis* (Leyss.) Holub.
2. *Phleum pratense* L., *Dactylis glomerata* L., *Trifolium pratense* L.
3. *Phleum pratense* L., *Festuca pratensis* Huds., *Dactylis glomerata* L., *Lolium perenne* L., *Trifolium repens* L.

In the different experiments we examined all the above-mentioned plants for monocultures and grass-mixtures of two/ three/four/ five species. The grass-clover mixtures were sown in a 70:30 and 80:20 ratio. The first experiment was carried out on ameliorated peat soil during two cuttings, whereas the second and third experiments were carried out on mineral soils during two or three cuttings. Mineral fertilizers were applied at the following rates: on the mineral soil annual amounts of nitrogen (100-180 kg N ha^{-1} y^{-1}), phosphorus (80-100 kg P ha^{-1} y^{-1}), potassium (90-120 kg K ha^{-1} y^{-1}) and on the peat soil 100-150 kg N ha^{-1} y^{-1}, 90 kg P ha^{-1} y^{-1}, 120 kg K ha^{-1} y^{-1}. Plot size was 3 m^2. The vertical structure of swards was defined before each harvest by sampling at ground level an area of 0.10 cm^2 or 0.25 cm^2. The harvested materials were cut into 10-cm layers. Vertical structure was estimated mathematically by calculating the indicative coefficient ‚centre of equilibrium' in accordance with the formula of De Vries M. D. (Sabardina *et al.*, 1967):

$$\left\{100 - \frac{100\left[m-a+\frac{9}{11}(l-b)+\frac{7}{11}(k-c)+\frac{5}{11}(i-d)+\frac{3}{11}(h-e)+\frac{1}{11}(q-f)\right]}{a+b+c+d+e+f+g+h+i+k+l+m}\right\}:2$$

a - phytomass stands for the highest layer (100-120 cm); b - phytomass - for the following lower layer, and so on to m; m-phytomass-for the lowest layer (up to 10 cm above the ground). The indicative coefficient ‚centre of equilibrium' denotes the following: 100 shows that ‚centre of equilibrium' occupies the highest layer a; 0 - the lowest layer m; 50 - the middle position between layers f and e.

Results and discussion

Scientists (Sabardina *et al*., 1967, Kozlov *et al*., 1978, Kulakouskaya, 1997) consider that the indicative coefficient ‚centre of equilibrium' indicates the quantitative differences in the canopy structure of swards. In the first experiment, higher indices of ‚centre of equilibrium' (33.2-35.2) were found in the monocultures of grasses (*Phleum pratense, Phalaroides arundinacea, Bromopsis inermis*) in comparison with grass-mixtures (22.3-27.1) and they correspond to dry matter (DM) yield from 5900 to 4700 kg ha^{-1} y^{-1} in the conditions of the first cut.

Table 1. Plant height (cm), ‚centre of equilibrium' and dry matter yield (t ha^{-1}) obtained from 1-2 cuts on average over four years from different swards.

	Plant height (cm)		‚Centre of equilibrium'		Dry matter yield (t ha^{-1})		
Treatment	1 cut	2 cut	1 cut	2 cut	1 cut	2 cut	Total DM
1. *Ph. pratense*	61.1	45.3	13.5	12.9	4.3	2.6	6.9
2. *D. glomerata*	78.4	66.0	15.5	11.8	4.8	3.0	7.8
3. *Ph. pratense+D. glomerata*	57.9	48.0	13.3	9.3	4.1	2.1	6.2
4. *Ph. pratense+Tr. pratense*	68.3	53.3	13.7	8.4	4.1	2.1	6.2
5. *D. glomerata+Tr. pratense*	62.8	45.9	16.8	10.4	4.6	2.7	7.3
6. *Ph. pratense+D. glomerata +Tr. pratense*	62.9	48.6	14.9	12.0	4.8	3.3	8.1
$LSD_{0,05}$	6.1	5.7			0.7	0.6	0.8

The results of the research prove that there is the deviation of ‚centre of equilibrium' in different horizons of swards due to botanical composition and number of species. It is established that increase of rate of nitrogen fertilizer causes deviation of phytomass concentration to a higher layer in the sward and increased productivity in all studied variants. The same results

were obtained in the second experiments on mineral soils. Maximum values of indicative coefficient ‚centre of equilibrium‘ of swards were determined in the first cut and varied from 31.7 to 33.9, which correspond to DM yield from 4600 to 5100 kg ha^{-1} y^{-1} in different years. According to the results (Table 1), the correlation between indices and plant height (cm), ‚centre of equilibrium‘ and DM yield (t ha^{-1}) was established (r = 0.53-0.71).
The third experiment proved that the use of grasses having lower cauline leaves transferred phytomass concentration to the lower horizons. This results in the decrease of the indicative coefficient ‚centre of equilibrium‘ of swards. It is necessary to point out that yield losses can increase due to a disturbance in the height of cutting. Minimal indices of ‚centre of equilibrium‘ of swards are denoted in conditions of three cutting and greater content in swards of bottom plants (*Lolium perenne*, *Trifolium repens*), and in the conditions of cold and moist weather. In this case the indicative coefficient ‚centre of equilibrium‘ of swards is 4.3-4.7, which stands for DM yield from 500 to 1000 kg ha^{-1} y^{-1}. This experiment revealed a correlation (r = 0.52) between the yield and the content of *Trifolium repens* in swards. In most studied variants plant height, indicative coefficient ‚centre of equilibrium‘ of swards and productivity are higher in conditions of warm and dry or moist weather, and decrease in cases of cold and moist weather. Fractions of plants (stems, leaves, and flowers) were studied in various swards. These parts denote vertical distribution of swards and affect the quantity and the quality of the moved forage. As a result, the multiple interactions of productivity and structure of swards were established. The outcome of the research also showed the high coefficient of correlation between DM yield of first and third cutting (r = 0.60-0.75), the middle index of correlation with the content of stems and leaves (r = 0.43-0.64), but negative correlation with the content of flowers. These results partially support the results obtained in the research Kozlov *et al*., (1978). Influence of the degree of the vertical structure of swards (indicative coefficient ‚centre of equilibrium‘ of swards) for DM yield in all the experiments was rather high (r = 0.58-0.73).

Conclusion

Productivity and the vertical structure of swards and indicative coefficient ‚centre of equilibrium‘ varied depending on the morphogenetics of the plants and their height, floristic composition and number of species in grass mixtures, intensity of cutting of swards, climatic conditions, and quantities of mineral fertilizers used. Influence of degree of the vertical structure of swards (indicative coefficient ‚centre of equilibrium‘ of swards) for dry matter yield in all the experiments was rather high (r = 0.58-0.73).

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Long-term comparison of progeny of different lines of HF-bulls in pasture-based farms

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Abstract

In the past decades in Germany, low-input pasture-based farms have focused on bulls bred for high-input production systems. Genetic evaluation of those bulls is mainly based on phenotypic daughter records kept with little or no grazing, and feed rations that are supplemented by high levels of concentrates. In contrast, New Zealand (NZ) genetic evaluation, as well as the breeding goal is focused on superior Holstein-Friesian (HF) genetics evaluated in pasture-based systems. Previous studies have shown that cows from NZ are more efficient in terms of milk yield per hectare, overall profitability, fertility and nitrogen balance. The aim of our research project is the comparison of two lines of Holstein-Frisian genetics (NZ vs European/North American) in pasture-based dairy farms in Germany and Austria for a multitude of traits over a period of 12 years. A total of 2031 A.I. semen portions of NZ bulls and 1493 portions of German bulls were used to cover cows in Germany, and are expected to yield 508 and 373 female calves respectively. This resulting F1 generation will allow for a direct comparison of performance under the same husbandry conditions.

Keywords: pasture, grazing system, HF-genetics, dairy cow

Introduction

The breeding values of artificial insemination bulls used for pasture-based dairy farms in Germany rely on the performances of their daughters. However, the majority of these daughters have been fed little or no pasture, but instead were fed indoors with relatively high concentrate rates and silage feed (high input system).

In contrast, New Zealand (NZ) HF-bulls have been bred according to the specific needs of the pasture-based dairy farms with little feeding of concentrates (low-input system). In several experiments regarding pasture-based cattle husbandry, the NZ genetics showed advantages when directly compared with the European genetics. The NZ cattle showed higher fertility (Horan *et al.*, 2004), better land utilization rates (Thomet *et al.*, 2010), superior economic performances (Mc Carthy *et al.*, 2010) and, in the case of seasonal calving, improved nitrogen balances (Ryan *et al.*, 2010).

Therefore, it can be expected that the use of NZ HF-lines will result in improved performances with regard to health, yields, economics and environmental impact of pasture-kept cows in Germany. However, before general recommendations can be given, cows of NZ genetics must prove that their long-term performance at different sites and husbandry systems in Germany is indeed superior. Besides a general comparison of the population, a multitude of characteristics have to be investigated. For example, it is of interest to investigate how hoof health will develop at winter time when cows are housed indoors.

The following hypothesis is to be investigated:
Offspring of NZ-bulls will show superior performance in German pasture-based systems compared to offspring of European/ North American HF-bulls selected according to on-farm selection strategies or according to their total merit index

Material and methods

The HF-cattle breed (most favoured cattle breed in organic farms in Northern Germany) of German/ North American and NZ origin have been chosen. The advantage for future breeding programmes is that NZ has a very large HF-population. The breeding associations involved in Germany (Rinder Union West, Münster) and in New Zealand (Livestock Improvement NZ Genetics, Hamilton) are providing lists of suited bulls including their breeding values. The necessary data (basic-, performance-and health data) are stored at the national genetic evaluation centre in Verden, Germany (Vereinigte Informationssysteme Tierhaltung) and are provided to the University of Göttingen, Department of Animal Sciences, for further genetical-statistical analysis.

Offspring resulting from the following crosses will be compared in the participating farms:
1. 20% of the herd: Inseminated with selected bulls from NZ
2. 20% of the herd: Inseminated with selected bulls from the German breeding programme.
3. 60% of the herd: Selection of bulls according the farmers` choice.

Number of farms participating: 50 farms in Germany and Austria
Selection of bulls: 6 HF-bulls of NZ origin and 6 HF-bulls of German origin.

Time frame 2010-2021: The investigation will include the F_1-and the F_2-generations, the latter will be followed up until the 3rd lactation:
Artificial insemination 2010, calves F1 generation 2011, cows F_1-generation 2014, calves F_2-generation 2015, cows F_2- generation 2018 1.
Lactation; cows F_2-generation 3. lactation until 2021.

Preliminary evaluations

A total of 2031 portions of semen from NZ bulls and 1493 portions of semen from German bulls were used for AI (see Table 1). The choice of semen by the farmers shows a clear preference in favour of NZ bulls. It is expected to receive 508 female calves from NZ bulls and 273 calves from German bulls. For both breeds the percentage of successful inseminations (preliminary results) is 44% and 45% (almost the same). How successful the inseminations were will ultimately be seen at the end of the calving season.
Notes for summer 2010: The rates of conception were, in general, not good, probably due to the weather conditions. These observations have been made on the farms and within the breeding associations as well.

Table 1. Amount of artificial insemination (AI) and percentage of successful inseminations

	NZ bulls	German bulls
No. of AI portions used	2031	1493
anticipated number of female calves (according to AI-index of 2)	508	373
Percentage of successful AI[1] (preliminary results)	44 %	45 %

[1] Because results of pregnancy tests are not completely available at this time, the actual results should be higher

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Surface decomposition of mown residues of grasses and white clover

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Abstract

The aim of this research was to study the decomposition of white clover (*Trifolium repens*) and a mixture of grasses (*Phleum pratense* and *Lolium perenne*), separately and in combination, on the surface of grassland plots either fertilized ($N_{80}P_{26}K_{50}$) or not fertilized ($N_0P_0K_0$). The nylon bag technique was used to investigate the decomposition dynamics. It could be concluded that the residues of white clover were more easily degradable than residues of grasses. P and K fertilization decreased the rate of decomposition of grass and clover residues. Including white clover in the mixture did not accelerate the rate of decomposition of grasses, and the grass-white clover mixture decomposed at a similar rate to grasses without clover.

Keywords: decomposition, fertilization, grasses, plant residues, white clover

Introduction

In set-aside fields, where swards are used for conservation purposes, common practice is to leave mown plants to decompose on site. Plant residues release compounds during decomposition which enrich the soil with organic matter and therefore reduce the demand for fertilization (Kopp and Guillard, 2002). It is unclear how fast the residues left on the ground surface will decompose, and whether this depends on the botanical composition and the fertilization of the swards. The goal of the current work was: (i) to compare rates of decomposition of grasses, white clover, and grass-white clover mixtures; and (ii) to study the influence of fertilization on decomposition rate of plant material.

Materials and methods

A field experiment was carried out at the Eerika Experimental Station of the Estonian University of Life Sciences (58°23‘32“ N, 26°41‘31“ E) in 2006 and 2007 on a mixed grass-white clover sward (species proportion in seed mixture: *Phleum pratense* 34%, *Lolium perenne* 38% and *Trifolium repens* 28%). Fertilization treatments were as follows: $N_0P_0K_0$ hereafter N_0, and $N_{80}P_{26}K_{50}$, hereafter N_{80}, with 4 replicates of each. All P and K fertilizers were applied to the plots at the beginning of May and N fertilizer in July. In 2006, decomposition of grasses and white clover was studied in a mixture in which the proportions of grasses and white clover was not determined, and it developed randomly by sampling. In 2007, the grasses and white clover were separated from the mixture and their decomposition studied separately. In both experimental years, a sample of 100 g of fresh herbage was collected after the first cut (30 May in 2006 and 31 May in 2007). From each sample, a subsample of 20 g of fresh herbage, equivalent to approximately 5 g of dry herbage, was put into a 20×20 cm nylon bag with a 1.5 mm mesh size, and the remainder of the sample was used to determine the dry matter (DM), total N content and C/N ratio. The DM content was determined by drying the sample in a forced-draught oven for 6 hours at 105°C. The total N content and the C/N ratio of oven-dried fine-powdered samples were determined by a dry combustion method in a varioMAX CNS elemental analyzer (ELEMENTAR, Germany). Initial DM content (g) in the bag was calculated by multiplying the sample's fresh weight and DM content. Each of the bags with the fresh plant residues was placed and fixed with clamps into the thatch layer of the plot from which it had been harvested. The decomposition of the residues was determined for each replicate of each of the fertilization treatments. The bags were sampled after 2 and 8 weeks of decomposition. The residue was oven-dried for 6 hours at 105°C and the biomass residue that remained in the nylon bags was expressed as a percentage of the initial dry weight and was calculated using the formula: weight loss (%) = $100\times(X_0\text{-}X_t)/X_0$, where M_0 is the initial plant material dry matter mass (g) in the bag and M_t is plant material dry matter mass (g) in bag at time t, when bags were removed from the field. ANOVA was used to test the effect of fertilization and Fisher's LSD test to distinguish means. All calculations were carried out using the statistical package Statistica 9 (StatSoft.Inc).

Results and discussion

The initial N content and C/N ratio of decaying residues depended on the species and mixtures (Table 1). The residues of white clover contained more N and had a narrower C/N ratio than residues of the mixture of grasses.

Table 1. The nitrogen (N) and C/N ratio of different plant species and mixtures from different fertilization treatments at the beginning of decomposition

	Mixture of white clover and grasses		White clover		Mixture of grasses	
Parameter	N_0	N_{80}	N_0	N_{80}	N_0	N_{80}
N, mg g^{-1}	33.0b[1]	34.0b	38.8c	42.4d	20.3a	18.6a
C/N	n.d.[2]	n.d.	12a	11a	22b	24b

[1] Different letters in each row indicate significant difference of mean values at $P < 0.05$ (Fisher's LSD test).
[2] n.d. - not determined

Rate of decomposition of residues depended on the type of material ($F_{(2,54)} = 35.3$, $P = 0.00001$). During the 8 weeks after cutting there was a significantly higher decomposition of residues of white clover compared with grasses and the grass-white clover mixture (Table 2). The difference in rate of decomposition was already apparent in the first two weeks.

Table 2. Weight loss (%) of plant residues during the different periods of decomposition

	Period of the decomposition							
	Week 0-2				Week 2-8			
Mixtures of plant species	N_0	Std.er.	N_{80}	Std.er.	N_0	Std.er.	N_{80}	Std.er.
White clover	37.6b[1]B[2]	1.1	21.8aB	4.3	40.1aB	3.7	46.6bB	5.6
Grasses mixture	22.9bA	3.1	7.9aA	0.4	32.0aA	3.0	35.8bA	6.0
Grasses mixture+white clover	25.6bAB	4.1	15.9aAB	1.8	28.1bA	1.6	24.7aA	3.2

[1] Different lowercase letters in rows indicate that means of the treatment N_0 and N_{80} are significantly different at $P < 0.05$ during period of decomposition (week 0-2 or week 2-8)
[2] Different uppercase letters within column indicate significant difference of the mean values at $P < 0.05$.

Decomposition of plant residues was faster on unfertilized plots than on fertilized plots $F_{(1,54)} = 35.6$, $P = 0.00315$). After the second week of decomposition the average weight loss was already 13.5% higher in N_0 when compared to the N_{80} treatment. In the fertilized treatments the decomposition process intensified after the second week of decomposition, and difference

between N_0 and N_{80} then decreased. By the end of the trial 77.6% of the residues of white clover in the N_0 had decomposed and 68.3% in the N_{80} treatment; in the grass-white clover mixture the values were 53.6% and 40.6% respectively, and in the grass mixture 54.8% and 43.8%.
Recent investigations have shown that species belonging to different functional groups (as legumes, grasses and herbs) decompose at different rates (Gaisler and Pavlû, 2009). Our results confirm this; in our trial also the residues of white clover were decomposing at a faster rate than grass residues in all the observed periods.
Litter-mixing studies performed to date have found mixing to affect decomposition rates positively, negatively or not at all (Gartner and Cardon, 2004). Our results revealed that the white clover did not affect significantly the decomposition process of grasses. The decomposition rate of a mixture of grasses and white clover, and that of grasses alone, was similar during the 8 weeks.
Addition of P and K fertilizers 20 days before the beginning of the trial lowered the decomposition rate of both white clover and grasses and it also shifted the peak of decomposition by 2 weeks. This could be due to a faster growth and development of fertilized plants compared to the N_0 treatment. During ageing, the content of easily decomposable carbon compounds in plants will decrease (Wilman and Wright, 1983) slowing the decomposition process.

Conclusion

The speed of decomposition of mown plant material left on the sward surface for decomposition depends on the botanical composition of the sward. Including white clover in the mixture did not accelerate the decomposition process of grasses. P and K fertilization slowed down the decomposition process of plant material.

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Effect of returning of mown grass residues on the productivity of grass-clover sward and the nitrogen content in plants and soil

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Abstract

Decomposing residues can be an important source of plant nutrients, especially of nitrogen (N). The objective of this research was to study the effect of return of residues, from fertilized and unfertilized grass-white clover, on (i) the sward's productivity, and (ii) N uptake by plants and total N content in plants and soil. The study was carried out on a grass-clover sward (seed mixture composition *Trifolium repens*, *Phleum pratense* and *Lolium perenne*). The factors of the experiment were as follows: (i) two residue treatments: residues either removed after cutting (RRM) or returned (RRT) to the plots; (ii) two fertilizer treatments: $N_0P_0K_0$ (N0) and $N_{80}P_{26}K_{50}$ (N80). Our research revealed that return of plant residues increased the N uptake, the sward productivity and content of soil total N and total carbon.

Keywords: mulching, nitrogen, productivity, set-aside

Introduction

It is not wholly clear how much mineral nitrogen (N) returned with plant residues is recycled by plants and deposited in the soil. This problem has so far been investigated mainly in the context of lawns (Starr and DeRoo, 1981; Kopp and Guillard, 2002; Kauer *et al*., 2009), where the results have been highly variable. The cutting of set-aside grasslands occurs much less frequently and therefore the plants are in more advanced stages of development compared with lawn plants. The N concentration of plants will decrease with ageing (Buxton and Marten, 1989), causing a delay in decomposition of plant residues (de Neergaard *et al*., 2002) and N immobilization from soil. Plants compete for N together with soil microorganisms (Kuzyakov *et al*., 2000) and can use only the N that is not immobilized by microorganisms. The objective of this research was to study the effect of returning litter, i.e. mulching (from mown grass-white clover) on (i) total N content in plants and soil; (ii) N uptake; and (iii) grass-clover sward productivity, depending on fertilization.

Materials and methods

The experiment was carried out at the Estonian University of Life Sciences experimental field in Tartu County, Estonia. The soil of the experimental field was *Stagnic Luvisol* (WRB classification; FAO, 1998) and the contents of total carbon (totC) and total N (totN) in the 5 cm top layer of sward soil were 14.7 mg C g^{-1} and 1.49 mg N g^{-1}, respectively. The sward had been established in 2003 with a grass-clover mixture (*Phleum pratense* 34%, *Lolium perenne* 38% and *Trifolium repens* 28%). The experiment was arranged as a randomized block with four replications. Each plot size was 1×7 m. The experimental treatments were divided based on fertilizer application as follows: $N_0P_0K_0$ (hereafter N0 or control variant) and $N_{80}P_{26}K_{50}$ kg ha^{-1} (N80). N fertilizer was applied in July. P and K fertilizers were applied in spring, at the

end of April just after the beginning of the growing season. In years 2004-2008 the sward was cut 4-5 times during the growing season. After cutting and weighing the cut plant residues were either returned (hereafter RRT) to the plots or removed (hereafter RRM).
In 2007 the returned and removed plant residues were analysed for total N, and the plant N uptake was calculated as follows: N uptake = dry matter yield * total N content in residues. In 2008 soil samples were collected from the 0-5 cm layer in RRT and RRM, for both fertilization variants (N0 and N80). TotN and totC content of oven-dried soil and totN content of plant samples were determined by a dry combustion method in a varioMAX CNS elemental analyser (ELEMENTAR, Germany). ANOVA was used to test the effect of fertilization and Fisher's LSD test to distinguish means. The statistical package Statistica version 9.1 (StatSoft. Inc. 2010) was used for all the statistical analyses.

Results and discussion

The returning of plant material to the sward increased the productivity of pasture. The influence of mulching was bigger ($P < 0.05$) in the control treatment where the average yield per year increased 74%, and by fertilization 48% compared with the N0 treatment with clippings removed. By returning of clippings the N uptake increased in N0 variant by 77% and in N80 variant 36%. The totN content in plants was also higher when residues were returned (Table 1).

Table 1. The average total N (totN) content (mg g^{-1}) in plant residues, average dry matter (DM) yield (kg ha^{-1}) and N uptake (kg ha^{-1}) of grass-clover sward plots with residues returned (RRT) and with residues removed (RRM) after cutting at two fertilization rates.

Fertilization rate kg N ha^{-1}	TotN content in residues mg g^{-1}		DM yield of sward kg ha^{-1}		N uptake by plant kg N ha^{-1}	
	RRT	RRM	RRT	RRM	RRT	RRM
0	24a[1]A[2]	24aA	7788bA	4470aA	190bA	107aA
80	26bA	24aA	7723bA	5210aB	204bA	150aB

[1] Different small letters within each row indicate significant difference of the mean values at $P < 0.05$
[2] Different capital letters within column indicate significant difference of the mean values at $P < 0.05$

The content of soil totN and totC in the surface 5 cm increased significantly over 5 years (Table 2). The increasing of totN and totC in soil was biggest (49% and 44% respectively) in the N80 fertilized plot where the clippings were deposited on site. In the unfertilized treatment where the clippings were not returned the content of totN and totC increased 23% and 31%, respectively.

Table 2. The total N (totN) and total C (totC) content in 5 cm top layer of sward soil plots with residues returned (RRT) and with residues removed (RRM) after cutting at two fertilization rates.

Fertilization rate, kg N ha^{-1}	TotN, mg g^{-1}		TotC, mg g^{-1}	
	RRT	RRM	RRT	RRM
0	2.1b[1]A[2]	1.8aA	21bA	19aA
80	2.2bB	2.0aA	21bA	20aA

[1] Different small letters within each row indicate significant difference of the mean values at $P < 0.05$
[2] Different capital letters within column indicate significant difference of the mean values at $P < 0.05$

The sward productivity in RRT variant was similar for both fertilized and unfertilized variants, indicating that by returning plant residues the additional fertilization was quite inefficient, although the fertilized treatment (80 kg ha^{-1}) received an additional 204 kg N ha^{-1} from returned plant material. It seems likely that the sum of mineral N fertilizer and N derived from returned plant material exceeded the requirements of growing plants. In earlier investigations with turfgrass clippings we have obtained similar results, in which additional mineral fertilization with the returning of grass clippings has been effective only up to certain amounts (Kauer *et al*., 2009).

Our results indicate that the returning of plant residues to growing place positively influences soil total C and N contents as well as N uptake, and increased productivity is observed. This result supports the findings of Starr and DeRoo (1981), Kopp and Guillard (2002), and Qian, *et al*. (2003) who obtained similar results by returning of lawn clippings. We think that this significant influence of returned plant material was initiated by high proportions of white clover in the plant mixture. White clover usually decomposes faster than grasses and the release of nitrogen is also bigger (Raave *et al*., 2011). The other reason for fast decomposition of plant residues was cutting of the sward on several occasions during the vegetation growth period. This management keeps the plant material young and the content of heavily decomposable structural compounds relatively low; therefore it did not inhibit the decomposition process and the mineralization of nutrients (Kauer *et al*., unpublished).

Conclusion

Leaving grass-clover residues on the site increased soil N content, N uptake by plants and sward productivity. The effect of returned plant residues was bigger on unfertilized swards.

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Session 3

Grassland as a source of biodiversity and public goods

Establishment and use of High Nature Value Farmland

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Abstract

The conservation and maintenance of biodiversity on agriculturally used areas has become a special concern of agrarian and environmental policy. Therefore, restoration projects with the objective of creating semi-natural grassland have become of increasing importance throughout Europe in recent years. Procedures that are as close to nature as possible have gained special significance. Species-rich semi-natural grassland is the only existing natural source that can provide the source material for restoration and reintroduction of High Nature Value Farmland (HNVF). In recent years, a large number of different harvesting methods and application techniques have been developed for exploitation and application of seed and plant material of regional semi-natural grasslands. In order to ensure and guarantee its use according to nature protection targets throughout Europe, binding European guidelines and an approved certification procedure for such material have to be developed.

Keywords: semi-natural grassland, ecological restoration, biodiversity

Introduction

All over Europe, agricultural intensification and, additionally, the abandonment of large areas, led to a strong decrease in biodiversity (Pötsch and Blaschka, 2003). The 1992 Rio de Janeiro Convention on Biological Diversity and recent EU regulations promote the protection of biodiversity and seek to address the strong reduction in biodiversity in Europe. To implement this aim, the availability of regional, native plant material is of extreme importance. This requirement is not sufficiently met in Europe, where seed of native ecotypes is still seldom available in large amounts. Extensively managed semi-natural grasslands, which are the most widespread type of High Nature Value Farmland (HNVF), can be regarded as the most important seed source. They are normally rich in species of native provenance and for this reason can be harvested to obtain valuable seeds useful for restoration and revegetation. The typical high diversity of HNV grasslands, in terms of species and site conditions, is their strong point but, at the same time, they pose the main challenge for an economically efficient harvesting system. Moreover, the normally used techniques to create forage meadows or to revegetate degraded areas with the help of commercial seed mixtures are not comparable to ecological restoration done with seed material from semi-natural grassland.
In 2009, an EC-funded Central-Europe project started in order to promote High Nature Value Farmland (HNVF) as a valuable resource to support sustainable rural development. As a main target, the project “Semi-natural Grassland as a Source of Biodiversity Improvement” (SALVERE) intends to contribute to the practical realisation of EU regulations regarding

biodiversity by utilising semi-natural grasslands as potential donor sites of seed to be used for the establishment of HNV areas (Scotton, 2009; SALVERE, 2011). Based on experiences made and information gained within this project, we present in this paper a short overview on the current situation of HNVF in Europe, the current state-of-the-art in the selection of donor sites, the exploitation of seed material, techniques and know-how for the establishment of semi-natural grassland, as well as the existing, or still-necessary regulations.

Definition, relevance and state of development of High Nature Value Farmland (HNVF)

Since 2000 the agro-environmental indicator "High Nature Value Farmland" (HNVF) has been discussed and developed at the European scale, centered on the IRENA -Indicator No. 26 (EEA, 2006). Originally developed as an indicator referencing for the importance of certain farming practices for biodiversity in cultivated landscapes, it gained importance and relevance in 2005 as it was selected as an indicator for the Common Monitoring and Evaluation Framework (CMEF) of Rural Development Programmes (RDPs) according to Council Regulation (EC) No 1698/2005. Member states are obliged to report on the national area and maintenance of HNV farming and forestry for the mid-term evaluation in 2010 as well as to the *ex-post* evaluation of the Rural Development Programmes in 2015 (EC, 2006). According to the CMEF, HNVF is used as a "Baseline Indicator" for reference at the beginning of the RDPs, followed by an interpretation as "impact indicator" and as "result indicator".

Proposals for defining and mapping High Nature Value Farmland have been developed by the European Environment Agency (EEA) together with the Joint Research Centre (JRC) since 2003 (Andersen *et al*., 2004; EEA, 2005; JRC/EEA, 2006). In 2007 a report and separate guidance document to the Member States on the application of the HNVF indicator was published on behalf of the European Commission, DG Agriculture (IEEP, 2007; EC, 2009).

Following this document, the core of the HNVF concept is the link from management practices to biodiversity dependent on farmland habitats. Thus, the concept of HNVF can be seen as a two-fold approach: looking on the one hand to the state of the resource in terms of quantity and quality, and on the other hand to the driving forces, i.e. management practices that produce, influence and maintain the natural values.

The resource HNVF

From the ecological point of view, High Nature Value Farmland is a concept that may lead the focus on certain farmed areas, and which tend to be marginal in terms of their agronomic production capacity and to be outside of market-oriented policy interests. It raises the awareness to large areas of Europe used as extensive grassland, or in a diverse mosaic of small landscape elements and low intensity use. HNVF is defined as follows:

"High Nature Value farmland comprises those areas in Europe where agriculture is a major (usually the dominant) land use and

- where that agriculture supports or is associated with either a high species and habitat diversity, or
- the presence of species of European, and/or national, and/or regional conservation concern,
- or both."

Those areas have high overall biodiversity and landscape value, and are dependent on regular use, often in a traditional way. They have been seen as the ecological backbone of European cultural landscapes. Three types of HNVF are recognized (Andersen *et al*., 2004; IEEP, 2007; EC, 2009):

- Type 1 - Farmland with a high proportion of semi-natural vegetation.
- Type 2 - Farmland with a mosaic of low intensity agriculture and natural and structural elements, such as field margins, hedgerows, stone walls, patches of woodland or scrub, small rivers etc.
- Type 3 - Farmland supporting rare species or a high proportion of European or world populations.

However, because of their low agro-economic value, those farming systems are prone to abandonment or - whenever possible - intensification; for example, through irrigation and fertilizing. Both development paths would endanger the natural values. The concept of HNVF pulls those systems from behind the curtain and seeks to make them a topic in public discussion. The future agricultural policy is asked to pay attention to those extensive, large, and potentially threatened farming systems and areas. Policy should support agriculture in a way that those farming systems can be kept up and natural values can be maintained, even in a competitive agricultural surrounding.

The indicator HNVF

In the Evaluation Framework HNVF is seen as an indicator, against which the effectiveness and efficacy of the Rural Development Programmes should be tested. This requires a more operational definition of HNVF and a decision about what HNVF is and what it is not. Although theoretically well elaborated in different studies, this separation is not easy in practice, and may it have great implications on the resulting HNVF area.

Due to the diverse situation in member states regarding data quality and availability, and important differences in ecological conditions as well as in farming practices, a number of different approaches for the implementation of this indicator have evolved. Each state has reported its own baseline figure using different information sources and applying adapted criteria for the generation of the required area numbers. But those numbers are not really comparable throughout Europe because they are based on diverse methodologies. Some states apply a mapping concept, e.g. Germany, which tries to calculate the HNVF area through the monitoring of a number of stratified random sample plots. Others like France and Finland use a typology of their farms and evaluate the farming systems. The area calculation is largely influenced by statistical analysis of farm data and modelling of relationships. If land-use data are available in sufficient detail and completeness, the area can be calculated drawing on information systems like IACS (Integrated Administration and Control System) or LPIS (Land Parcel Information System), e.g. is done in Austria and Greece. Thus the required parcels can be selected through the application of criteria from land cover and management and summed up to the total area.

HNVF as a policy tool

At the policy level, HNVF has gained importance with its selection as an indicator for the evaluation of RDPs. The IRENA-process and studies done subsequently by the European Environment Agency (EEA) tried to determine the HNVF area for each member state. A map was produced showing the probability of HNVF throughout Europe. The intention of this map was to create an overview on the situation in Europe and more the kind of a target-identification for necessary policy support in those regions. When DG-Agriculture and regional development took over and defined the CMEF indicator in 2005, the understanding of its concept was still fuzzy and the method for implementation not well defined. Meanwhile it has developed towards a monitoring and evaluation approach, but there is still some obscurity on the target of the evaluation - farming practices at farm level, farming systems in terms of farm typologies, agro-environmental measures and RDPs, or the biodiversity at the landscape level? Therefore, as mentioned above the implementation in member states shows great differences according to what the national emphasis is on. The use of this HNVF indicator as a trigger for European policy measures such as financing would need a lot of harmonization and coordination work. It does not seem feasible to reach a Europe-wide integrated CMEF indicator within the next few years. Nevertheless HNVF, and in particular the reported changes over the programme period, will definitely serve as a reference for the programme evaluation and thus influence the development of the next RDP periods.

However, the concept of HNVF has triggered a process in the political discussion. The values of certain low input/low output farming systems have moved into the public view and the concept of ecosystem services focuses on additional societal benefits of agriculture besides the agricultural production. In this context High Nature Value Farmland stands for valuable nature and bio-diversity.

Aims of semi-natural grassland restoration

Currently, 76% of grasslands of European interest are assessed as being in an unfavourable conservation status (EU2010 Biodiversity Baseline Report). Therefore, the protection of natural grasslands containing regional sub-species and ecotypes in region-specific compositions is of top priority in nature conservation. To reach this goal, not only the high ecological and aesthetic values of species-rich grasslands should be acknowledged but also their potential as donor sites for regional seed mixtures.

In general, restoration of species-rich grasslands is limited by several abiotic and biotic constraints. The success of restoration measures depends on abiotic factors such as nutrient status, pH-value of soil, and hydrology, as well as the availability of appropriate seed sources. Hence, restoration success is impeded by depleted seed banks of restoration sites, decrease or loss of target species in the surroundings and limited dispersal in fragmented landscapes. Early restoration efforts in the 1970s and 80s were mostly focused on the removal of nutrients, re-wetting and the re-introduction of an adequate management. In many cases such measures alone were frustratingly unsuccessful and did not lead to the re-establishment of target communities even after successful lowering of nutrient levels and productivity (Bakker and Berendse, 1999). Therefore, the introduction of target species is of decisive importance for restoration success. Seed mixtures directly harvested in genuine, natural grasslands can be used in ecological restoration, thereby contributing to the preservation and enhancement of regional biodiversity. Since the 1990s, different methods for ecological restoration have been used successfully by several working groups all over Europe (for reviews see Walker *et al*., 2004; Kirmer and Tischew, 2006; Klimkowska *et al*., 2007; Kiehl *et al*., 2010).

The most important grassland types and their suitability as donor-sites

Seed mixtures should be harvested in species-rich grasslands containing a species composition typical for the selected target community and for the region concerned. It is decisive to choose donor and receptor sites with similar site conditions (hydrology, substrate, nutrient status) to ensure that the plant species are optimally adapted to local climatic and edaphic conditions. Especially hydrology and nutrient status are decisive parameters to determine suitable donor communities:

- dry, nutrient-poor to mesotrophic sites: dry grasslands (Bromion)
- moist, mesotrophic sites: mesic grasslands (Arrhenatherion)
- wet, nutrient-rich sites: eutrophic floodplain grasslands (Deschampsion)
- wet, nutrient-poor sites: oligotrophic floodplain grasslands (Molinion) and fen grasslands

Criteria for the selection of donor sites

The main obstacle for the implementation of near-natural revegetation methods is the identification of suitable donor sites for seed harvesting. In Germany, donor-site registers have already been established in four federal states: Saxony-Anhalt (Hefter *et al*., 2010), Thuringia (Kirmer and Korsch, 2009), Schleswig-Holstein, and North Rhine-Westphalia.
For example, in 2003 the first donor-site register was installed in Saxony-Anhalt. The internet-based database comprises open habitats and grasslands with high nature conservation value, suitable for harvesting seeds and seed-rich plant material. The listing of an area as a donor site in the database does not include permission to harvest seeds. Any kind of harvesting (e.g. mowing, threshing, collecting seeds) requires a formal authorisation through the respective nature conservation authority and the approval of land owners and users. At the moment, the database contains almost 400 potential donor sites. It is embedded into an information system of nature-oriented greening measures (www.spenderflaechenkataster.de). This internet platform presents an overview of different restoration methods and gives information for their planning and implementation, as well as for the costs and the legal framework.
The internet-based database offers users multiple research functions for finding suitable donor sites, e.g. a general map and a search module. The donor site register allows a quick assessment of the suitability of potential donor sites according to nature conservation values and economic aspects. Registered donor sites must fulfil specific criterions:
- representative species composition (typical for the vegetation type and the region)
- low amount of problematic species (neophytes, strong competitors)
- not established or modified with standard seed mixtures containing cultivars from propagation
- ± regular management (preferably mowing)
- no change of use expected

Such a database enables an efficient inquiry about suitable donor sites and facilitates planning and realization of nature-oriented greening measures (e.g. harvesting of seeds via mowing, threshing, brushing, vacuuming). The use of species-rich donor sites in restoration or revegetation measures supports habitat protection, protects the biological diversity and preserves the floristic and genetic identity of the region.

Harvesting methods for site-specific seed and plant material

The selected grasslands may only contain a very low amount of problematic or neophytic species. The optimal harvesting time is when most target species have set seeds. In Arrhenatherion communities, a first harvest can be done between end of June and end of July. If the site was mown in early May, the harvesting cut can be delayed until the end of August. Bromion communities are harvested best between mid-July and beginning of September. Seed harvest in Molinion and Deschampsion communities should be done between end of August and end of September because of late-fruiting target species (e.g. *Cnidium dubium*). An additional harvesting cut in May is recommended to transfer early flowering species (e.g. *Cardamine* spp., *Ranunculus* spp.). In general, a later and/or second cut favours the transfer of herbaceous species whereas an early and/or first cut favours grasses. If harvesting time and method are different to the normal management regime, the site should not be harvested every year.
A lot of different harvesting techniques, partly well known for centuries and partly developed during the last decades, are used for the exploitation of regional plant and seed material (Krautzer *et al*., 2004; Kirmer and Tischew, 2006; Krautzer and Pötsch, 2009; Kiehl *et al*., 2010). The most common processes and methods are summarised below.

A widely used method is the mowing of suitable donor sites at the time when most of the desired species are at an optimum stage of seed maturity (June - August). To avoid excessive seed 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) for distribution. Another possibility is to dry and store the mown material for later use. Nevertheless, this method requires increased manipulation and therefore higher costs. In addition, a large part of the seed material may be lost (ÖAG, 2000). The hay-flower sowing method uses seed-rich remains from the threshing floors of hay barns, which sometimes keep sufficient seed quantities and qualities.
With brushing and threshing methods (Edwards *et al*., 2007; Jongepierova *et al*., 2007; Scotton *et al*., 2009) site-specific seeds can be collected from suitable donor sites. To obtain the greatest possible number of mature seeds from the preferred species, particular attention has to be paid to the harvesting time. Seed mixtures with the highest species diversity are generally achieved by consecutive harvesting of donor sites according to species-specific seed maturation rates and schedules. In the Alps for example, seed yields are usually between 50-150 kg ha-1. The relationship of donor area to restoration area thus varies from approximately 1:1 to 1:4. If application of threshed seed material is not possible immediately after harvest, it must be dried and stored at a dry location.
A good method that is currently practised in several countries is the nursery or large-area production of seed of suitable species with agricultural and horticultural techniques. Above all, species that are used often and in large amounts can be produced at comparatively reasonable costs and implemented on appropriately large project areas. This method, for example, has been used successfully in Austria, Germany and Switzerland for restoration projects (Krautzer and Wittmann, 2006; Kirmer and Tischew, 2006; Rometsch, 2009). Similar approaches are now being implemented in the French Pyrenees (Malaval, 2006) in Iceland (Aradottir and Johannsson, 2006) and latterly in Norway (ECONADA, 2011).
In cases of land use change, the transfer of seed-rich top soil (mainly the first 5 cm, and at most the top 20 cm) from suitable donor sites is an occasionally used method, especially in cases of technical interventions (e.g. road construction, landscaping). Another possibility is the transplanting of turfs, in which soil-plant segments from donor sites to restoration sites are being transferred. Wherever possible the transplanting of turfs should take place as early as possible at the beginning of the vegetation period or after the start of the autumn vegetation pause, thus just after the melting of snow or directly before the onset of winter. With proper planning, grass turfs from building and construction sites can be directly transferred to restoration sites without intermediate storage (Krautzer and Klug, 2009).

Quality of native seed material

Exploitation, production and trade of regional seeds without any common rules lead to an unmanageable market for consumers. Wild forms compete against cultivars of the same plant species. Among declared “wild seed products” one will find a wide range of labels in terms certifications, assertions, documented provenances and qualities. On behalf of nature conservation, a system of rules is needed in order to support transparency of a European wild species seed market. On the other hand, seed consumers expect some minimum thresholds for quality aspects related to the composition of harvesting or propagation material, the concentration of pure seeds in harvesting materials and their germination capacity. Therefore, also a sufficient declaration on such quality aspects is important if native seed material is offered on the market.

Quality in terms of nature conservation

The idea of trading wild seeds is due to the consideration of a regional limitation of introducing wild plants as a crucial point of genetic adaptation. The commercial seed market offers several interesting species suitable for restoration, 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). Only harvesting material and seeds that are collected, propagated and used in the same region will ensure ecosystem services, which will not be provided by cultivars and non-local propagation material (Blaschka *et al*. 2008). Therefore there is a need to define biogeographical regions to fulfil those benefits.

However, in Germany, Austria and Switzerland a sufficient definition of biogeographical regions already exists (VWW, 2011; REWISA, 2011; CPS, 2009). One of the most important aspects is the non-conformance of those biogeographical boundaries with political ones! However, a well-defined national system is inadequate when transnational trade occurs. Nowadays, the defined regions end at the borders of the member state, even though the physiographic province extends into the neighbouring country. A basis for a (still missing) international definition of European biogeographical regions could be the already existing system at the European Environment Agency (EEA, 2009). However, for a functioning European market-system with a regional supply of wild seed, transnational zones for production and use of native seed material have to be defined.

Quality in terms of consumers' expectations

Contractors are interested to get sufficient information about the quality of sowing material, especially in terms of seed proportion and germination capacity. Corresponding data are particularly in demand for large-scale restoration projects and trade. The viability or cost-effectiveness of the necessary assessments has to be proven from case to case.

The actual number of seeds in fresh green hay, hay mulch, stripped material or threshings, as well as the expenditures connected to the exploitation of the material, is dependent on various factors, such as the type of meadow, management, time of day, harvesting time in the course of the year, potential seed production and mechanisation (see Table 1).

Table 1. Share of grasses and herbs, amount of harvested seeds and expenditure of time for differing harvesting methods in Arrhenatherion and Molinion communities (expenditure for drying and cleaning is not included)

Harvesting method	Harvest time	Grasses:Herbs [%]	Pure seeds harvested [kg/ha]	Duration [h/ha]
Fresh green hay	End of June	80:20:00	100-200	1-2h*
Hay mulch	End of June	70:30:00	40	3-4h**
Threshings (plot thresher)	End of June	80:20:00	60-150	5-10***
Threshings (large thresher)	End of June	60:40:00	50-200	1,5-3*
Stripped seeds	End of June	80:20:00	20-60	1,5-3***

* depending on technical equipment; ** including work processes for the drying of hay; *** depending on vegetation type

The species number and the composition of the harvested material are strongly dependent on the type of vegetation. Another influencing factor is the harvesting date. Later harvesting generally deceases the share of grasses in the mixture and thus fosters the establishment of herbaceous species (Hölzel and Otte, 2003). A harvesting date set too early hinders the full development of the seeds.

The assessment of purity, thousand-seed weight and germinating capacity of seed material harvested on donor sites is very complex and costly. Therefore, such information in practice will only be collected if the material is sold on the market or used at a large scale. However, determination of the purity of the harvested seed and plant materials is important to ascertain the volume of pure seeds that are contained in the material, which then defines the actual seed capacity of the entire material. The composition and quality of hay, hay mulch, stripped material or threshings differs greatly from year to year. The share of chaff and impurities, such as earth, can be very high.

Assessments on the germination capacity of harvested material are still in progress. First results from the SALVERE-project group indicate germination capacities between 40 and 70% from Arrhenatherion meadows. On meadows with a high share of species with seed dormancy (e.g. litter meadows), the actual germination capacity of harvested seed material can decrease notably (Haslgrübler, 2011).

Site preparation on receptor sites

A first step in grassland restoration and establishment and an important factor for restoration success is the site assessment and site preparation on receptor sites, thus creating optimal conditions for germination and establishment of introduced species. The special demands and threats of the habitat to be created, in terms of soil properties, nutrient supply, erosion tendency, competition phenomena with other plant species, sowing and planting time, availability of the seed and plant materials, etc., are to be determined as exactly as possible (ÖAG, 2000). Therefore, the choice of proper techniques for harvesting and application of species-rich grassland requires an assessment of the main factors of natural geographic region, climate, soil, erosion risk and other possible restoration targets (e.g. agricultural utilization, use as recreational area).

Site preparation in terms of regenerative measures

For successful species introduction into species-poor grassland, the sward has to be cut to a height of 3-5 cm, if necessary. Subsequently, the sward has to be opened. For large-area treatment, the use of curry comb, harrow, rotary hoe or flail chopper is recommended. During recent years, different specialised machinery for grassland regeneration has been developed and is available in grassland dominated areas. Several assessments showed that the stronger the intervention and disturbance of the sward, the higher the rate of successful species establishment (Walker *et al*., 2004, Hölzel *et al*., 2006).

Site preparation of arable land or ploughed grassland

The turning of the soil via ploughing or rotary hoeing is the standard method for the restoration of former intensively utilized grassland or arable land. Those soils are generally characterized by a high concentration of plant-available nutrients. One simple but time-consuming method to impoverish the soil is crop production period of 1-2 years without any fertilization.

Especially, restoration areas formerly used as arable land can potentially contain enormous amounts of weeds. Timely harrowing of soil under dry conditions fosters the accumulation of annual weeds which can then be combated mechanically by harrowing or grubbing several times before sowing. In humid regions, dry weather conditions are especially necessary for success when using these measures. In more continental regions with low precipitation, the germination of weeds from the soil seed bank may depend on moist conditions after grubbing. If those recommended methods of mechanical weed control are not applicable, the use of low persistence herbicides (e.g. glyphosate) could be considered (Pywell *et al*., 2007).

Sites with very nutrient-rich and weed-infested topsoil (particularly soil from arable land) can be very positively influenced by preliminary deep ploughing or topsoil inversion. To be used here could be a so-called trench excavator (deep plough), which requires a very powerful tractor. Thus the soil will be turned over to a depth of 40 cm to a maximum of 80 cm. Nutrient-rich and seed-rich layers are replaced and nutrient-poor substrate is turned up. The use of a trench excavator is not always permitted (e.g. Federal Soil Protection Act in Germany).

Site preparation after technical intervention

Many receptor sites requiring subsequent restoration are created through infrastructural interventions. Ground work (soil removal, intermediate storage and creation of an appropriate substrate layer) must only be carried out when the soil is suitably dried and during appropriate weather conditions. Soils with a clay content of over 30% are especially prone to soil compaction and are to be handled accordingly with care (BMLFUW, 2009). The general decision on the re-use of the topsoil-layer, with respect to its thickness, will depend on the content of nutrients and/or seeds of weeds and unwanted species. The extent of the applied soil layer, the space in which roots can penetrate, the water-storage capacity and the nutrient content of the substrates can be appropriately assessed during planning, and adjusted according to the desired type of vegetation (or vice versa).

Establishment of semi-natural grassland

Practically relevant restoration of semi-natural grassland has been successfully realised on the most differing sites for many years in different European countries (examples given in Kirmer and Tischew, 2006; Donath *et al*., 2007). The selection of a suitable method depends on the given aim (e.g. erosion prevention, development of extensive vegetation, compensation measures) and the site conditions of the receptor site. In general, the restoration method to be selected is that which enables the desired target community to can be developed with the least possible expenditure. Availability, practicability, costs, possible subsequent use and maintenance are to be taken into account. Fundamentally, the method should be adapted to the particular areas of origin to take into account climatic conditions and also the life cycle of insects, which are adapted to the regional blossoming period and special content material of plants local to an area.

A lot of successful techniques and strategies for the establishment of semi-natural grassland have been developed during the last years. Table 2 gives an overview of the most recommended techniques and materials depending on the most common initial situations. The use of seed-rich top soil or plant material from donor sites is, in practice, reduced to the rare situations where valuable donor sites are destroyed during construction work.

Under moist climate conditions, as well as in mountainous areas, restoration with seeds or seed mixtures should take place at the beginning of the vegetation period to make optimum use, on the one hand, of the winter moisture on drier sites, and on the other hand to guarantee development of the seedlings into plants that are capable of surviving the winter during the vegetation period. But in principle the application of extensive grassland areas throughout the entire vegetation period is possible, whereby persistent dry periods (e.g. in high summer) can lead to failures. In practice the time of restoration is generally in late summer to early autumn because, in that period, construction measures are to a great extent completed. According to the authors' experience, moist conditions and deep topsoil applications favour the development of grasses, whereas herbs have an advantage on nutrient-poor and dry sites.

Table 2. Strategies for the establishment of semi-natural grassland.

Initial situation	Materials	Recommended techniques
species-poor grassland	propagated regional seeds sieved threshings	overseeding device band rotavator
ploughed grassland/arable land/ fallows	green hay hay mulch threshings hay flower propagated regional seeds	load wagon and manual or mechanical distribution rotavator agricultural sowing and spreading devices cover crop seeding
raw soils (e.g. road construction, landscaping, open cast mining areas)	green hay hay mulch threshings hay flower propagated regional seeds	load wagon and manual or mechanical distribution agricultural sowing and spreading devices cover crop seeding hydro-seeding
raw soils endangered by erosion	green hay hay mulch threshings hay flower propagated regional seeds	mechanical or manual distribution recommended seeding technique plus additional protection by a mulch layer or geotextiles

Many species of the extensive litter meadows (fen meadows, litter meadows, etc.) are so-called frost germinators. Therefore, with these types of vegetation sowing in winter has proved successful, whereby the seed must be sown from the middle of November to the beginning of December as long as the soil has no snow cover (Krautzer and Klug, 2010).

Restoration success

Semi-natural, species-rich grasslands are generally created over a very long period through extensive forms of use. Achieving the strived-for target state is therefore only possible through appropriately adapted utilization over a long period, sometimes after a decade or even longer. It is important that in the first year following the application as many grassland species as possible are regularly germinated and young plants are to be recognised. Some types of grassland species will appear only in the second or third year after the application or become visible even later, because their seeds have a distinct dormancy or the young plants are very difficult to find. But on no account should a high share of problematic species, such as common couch grass, creeping thistle, dock species or white clover be visible. The cover of grasses should generally be not too high, and before the first cut should not exceed 40-60%. The share of various functional groups should also be in a balanced ratio (grasses, legumes, other herbs). For most vegetation types, the vegetation cover should have achieved 40-60% after the first vegetation period, depending on vegetation type, to guarantee a receptor state. If this is not the case, subsequent sowing is required.
With increasing development time, the degree of cover derived from target species and the increasing similarity to the reference- or target state is decisive for success of the measures. The success of sowing (restoration) is decisively influenced by conditions on the receptor area. In the first year after the application, according to vegetation type (moist meadows, litter meadows, semi-dry grassland) the transfer rate is about 30-50%. On raw soil the transfer rates are generally higher and can reach 60% in the first year after the application. The transfer rate is dependent on differing factors, e.g. quality of the seed, soil preparation, site conditions, weather after the application, natural seed potential of the soil (weeds) and restoration method.

Regulations and implementation in Europe

To protect the market for licensed varieties, the important fodder plant directive was launched in 1966 (EEC, 1966). With some amendments it is today the main directive, which causes problems between many national nature conservation laws and those for seed breeding protection. In 2010 a new Commission directive was passed, which approves the trade of a small amount of 5% of „wild“ seeds among the cultivars. The European member states have to implement the directive by the end of November 2011 (EEC, 2010). This is the latest time for the start of a competition in trade between wild seeds and cultivars. There are only few points in the new directive supporting the use of wild forms but many formal conditions, like detailed registrations and declarations of every single mixture, which will hamper the development of a wild-seed market. To improve the situation of semi-natural grassland in all European member states, it is inescapable to start activities according to those directives, like careful implementation into national laws to protect the initiatives dealing with native seeds that are in the process of emerging. Member states should also start to influence the recently started process of a review of the European seed legislation. At a national level, only Germany adapted its nature protection law in view of the harvest, propagation and trade of native seeds (BNatSchG, 2010).

Prospects for the future

Semi-natural grasslands are the most important category of High Nature Value Farmland and provide a high level of biodiversity. Due to land abandonment and intensification this type of grassland is seriously endangered; the maintenance and development of semi-natural grassland has, therefore, become a special concern of agrarian and environmental policy. Semi-natural grassland can also be used as a natural source of biodiversity for different purposes and can itself contribute to the development and restoration of High Nature Value Farmland.

Ecological restoration of semi-natural grassland is a relatively new field of activity, and as a result there are still considerable gaps in our knowledge and know-how. Approaches to the technical aspects vary considerably, and the development of special restoration methods, especially for extreme site conditions, is partly far from sufficient. The legal standards and requirements also vary greatly from one country to another. What is commonly accepted or promoted in some countries is strictly forbidden in others. Above all, despite prohibitions and restrictions written into various nature-protection laws, the use of non-native plant species is often ignored or overlooked due to lack of the knowledge about alternatives or ability to properly identify plant material being offered for sale or used on site. There is also a considerable lack of information among the authorities concerning what became technically possible during the last years. According to the subject, the European environmental legislation seems to bet the right address to implement rules for seed supply intended for use in nature conservation. If there is no political majority for being incorporated into a European directive, there is at least practical use to launch just a recommendation for a regional wild seeds market at the European level.

However, the drawing up of binding European rules for the origin, quality, exploitation and establishment of semi-natural grassland as an essential part of the High Nature Value Farmland concept is urgently needed.

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Plant functional traits and nutrient gradients on grassland

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Abstract

Research on plant functional traits has significantly improved our understanding on competitive ability of species, resulting species abundance and productivity of grassland. The traditional way of interpreting environmental and management effects on floristic composition based on taxonomy and phyto-sociological associations is increasingly accompanied by an approach that is based on the link between morphological, physiological and phenological plant properties (*syn*. plant functional traits) and their functions. The present paper summarizes the variation and power of plant functional traits along soil nutrient gradients on grassland, including a case by case conceptual generalization of mechanisms of interacting traits at plant and canopy scale. We also identified links between functional ecology and grassland science in order to make out research opportunities.

Keywords: plant functional trait, soil fertility, competition, ecological niche, scale dependency, conservative *vs.* exploitative species, plasticity

The change in paradigm: from plant species to plant functional traits

Worldwide, managed grassland vegetation covers as much as 52.5 million square kilometers or 40.5 percent of the terrestrial area excluding Greenland and Antarctica (World Research Institute, 2011) and so contributes significantly to agricultural land and total biomass production on earth. Apart from the provision of biomass for animal feed, grassland provides ecosystem services (ES) such as habitat for wildlife, carbon fixation, prevention of erosion and nutrient storage.

On the other hand, human activities including agricultural land management have changed global climate, land cover and biodiversity (Steffen *et al*., 2005). On permanent grassland, management intensification has enhanced soil fertility, altered floristic composition and increased productivity at local, national and continental scales (Stevens *et al*., 2010). However, the higher economic and environmental costs of the productivity model prevent it from being sustainable over the long term (Lemaire *et al*., 2005). Predicting trade-offs between sustainable production and impacts on other ES, such as grassland biodiversity, under future environmental changes remains a challenge to ecologists and grassland scientists.

On permanent grassland, knowledge of factors affecting plant species composition and their abundance is the key to the understanding of productivity and forage quality and so also to successful management. Variation in floristic composition reflects intra- and inter-specific competition along environmental and management gradients. The science of grassland ecology has tried to understand the underlying mechanisms of competition, but has mainly focused on species, their requirements and adaptation, rather than on their phenological, morphological and physiological properties in relation to their functions within plant communities (Woodard *et al*., 1997). Attempts have been made to better understand responses of species to environment and management, e.g. through Ellenberg's indicator values (Ellenberg *et al*., 1991). Further, the phyto-sociological classification is based on the taxonomic system of plants and

their presence (or absence) in plant communities rather than on functional relationships. So, at plant-community level, the link between form and function has remained less regarded.
Although there is an indication that functional classification goes back to the time of Theophrastus (~300 BC) (Gitay and Noble, 1997), it happened during the past 20 years that the scientific community (mainly ecologists and agronomists) has developed a new approach towards a better understanding of the response of plant communities to biotic and abiotic factors (Suding *et al*., 2003). It is based on the assumption that the combination of functional traits of individual plants is related to its function within the community. Compared to traditional explanation of plant co-existence deduced from plant species composition, the introduction of plant functional traits bears comparison with a paradigm change. The use of the plant functional-trait approach also enables the development of a logical hierarchical system of vegetation performances and their terms, allowing the scaling up of functionalities from plant and habitat to ecosystem, and even to a global scale.
On managed grassland, nutrient supply is one of the most important tools to promote productivity and at the same time is a major driver for change in species assemblage and its related functions and services. Although the response of species to nutrient gradients is never an exclusive one but mostly interrelated to other gradients, several studies are indicating a predictable set of functional response traits for a given nutrient level. The intention of this paper is to present and discuss the advantages of the plant trait approach and to summarize the most important approaches leading to a better understanding of species response to nutrient gradients.

Definition of functional traits and its physiological and morphological basis

Here we follow a definition by Violle *et al*. (2007) who explain plant functional traits as morpho-physio-phenological properties which affect fitness indirectly via their impact on growth, reproduction and survival, the three components of individual performance. The response of the individual plant to environmental conditions and management is observed by type, frequency, combination and plasticity of functional traits. Likewise, plants may themselves also affect the biotic and abiotic environment, by changing soil physical properties and soil biota through, for instance, the root system (Maire *et al*., 2009) or enrichment of soil N through symbiotic N_2 fixation (Herridge *et al*., 2008). It is evident that traits identified as response traits may at the same time affect environment and resources of other species (Violle *et al*., 2009). Thus, although identification of effect and response traits is generally accepted and advantageous, it is clear that both cannot be strictly separated.
Figure 1 shows a simplification of the trait approach considering soil fertility as an environmental filter. This conceptual framework articulates the response and effect traits through its components, i.e. the effects of dominant functional traits and the range of trait values present in a community (e.g. functional diversity). The first leads to the mass ratio hypothesis (Grime,

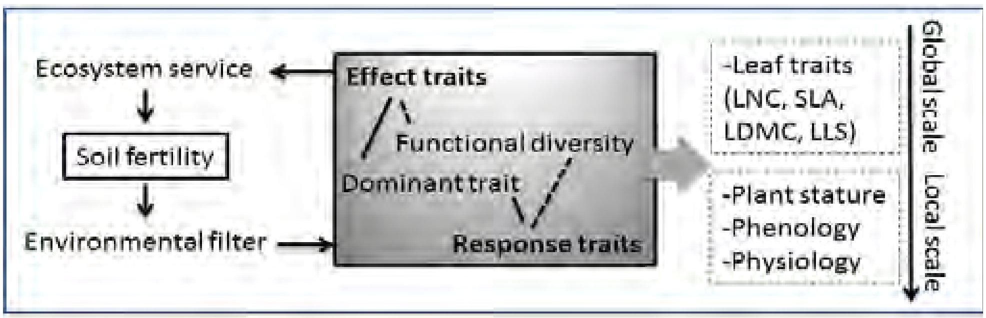

Figure 1. Simplification of the trait approach considering soil fertility as an environmental filter, and its maintenance as an ecosystem service.

1998) which proposes that ecosystem functioning is determined by trait values of the dominant contributors to plant biomass. The latter has been less documented in the literature (De Bello *et al*., 2010) and leads to the niche complementary hypothesis (Tilman *et al*., 1997; Loreau *et al*., 2001). Further, some relevant response and effect traits are given in Figure 1, which often overlap in their response to soil fertility at local and global scale.

The interpretation of occurrence and attributes of individual traits in grassland vegetation is not always straightforward, since plant traits usually co-vary along axes of specialization (Díaz *et al*., 2004; Wright *et al*., 2004), reflecting different trade-offs for plant functioning. So, significant information on the relation between plant form and function can be better derived from a greater set of functional traits that are commonly occurring in a community. If such aggregated traits are found to be related to ecosystem processes (EP) and ecosystem services (ES), it is an important translator of responses and effects (Louault *et al*., 2007; Suding *et al*., 2008; Klumpp and Sousanna, 2009).

The physiological basis of species strategies and related trait attributes is well documented in the literature. Grime's C-S-R model (Grime, 1979) aggregates these strategies and P'yankov *et al*. (2000) supports the evidence of this aggregation by documenting significant differences in assimilate transport and partitioning of contrasting species with strong relation to either C, S or R component. Further, Reich *et al*., (2003) give an excellent overview on the physiological implications of multiple-correlated traits at plant level.

It has often been observed that some species behave similarly in their growth strategy in response to the environment. As these share a similar set of functional traits, the term plant functional type (PFT) has been created. It is defined as a collection of organisms with similar suites of co-occurring functional attributes (De Bello *et al*., 2010), whereby the systematic of plant functional types can be created through regression of their functional traits. The major advantage of defining PFT is that it "bridges the gap between plant physiology and community and ecosystem processes" (Díaz and Cabido, 1997). One can apply PFT to create response functions of vegetation to environment and management, thus enabling us to better understand the ecological constraints of individual species and plant communities on a higher level of abstraction (Semenova and van der Maarel, 2000). PFT most commonly used are grasses, herbs and leguminosae (Díaz *et al*., 2004), which in some studies are further separated according to their trait attributes (e.g. Dyer *et al*., 2001; Gubsch *et al*., 2010). Further, Duru *et al*. (2009) have shown that model simulation of above-ground biomass on grassland can be accomplished by defining characteristics of PFT present in the plant community such as leaf dry matter content, leaf angle, leaf life span, leaf area and radiation-use efficiency. These characteristics are then implemented in the model to create functions for growth and development of the entire vegetation based on percentage contribution of each PFT to total biomass.

It is evident that the interpretation of the response of plants to environment and management based on single traits is limited because always a set of interacting morphological, physiological and phenological traits is involved. However, some traits can act as proxies for other traits and for overall performance of plants such as leaf dry matter content (Duru *et al*., 2010) and plant height (Lavorel *et al*., 2011). In research studies it is preferred to investigate the combination of interacting plant traits (i.e. the traits syndrome) in order to understand the strategy that support individuals in their competitiveness. The co-actions of traits of an individual can empirically be derived from simple correlation of their attributes. The correlation among such hard and soft traits is usually based on sound physiological processes and related functions. For instance, it has earlier been demonstrated that hard and soft traits of leaves are well correlated (Wright *et al*., 2004), such as net photosynthetic rate *vs*. specific leaf area and leaf nitrogen *vs*. leaf life span (Reich *et al*., 2003).

Methodological approaches

Developing widely accepted procedures of functional trait definition and acquisition of its attributes is a prerequisite to a straightforward methodology and successful communication among researchers. Although research questions, experimental design as well statistical evaluation and modeling objectives may dictate the sampling procedure and so vary among studies, research effort should be standardized as far as possible. Cornelissen *et al.* (2003) provide a comprehensive handbook of protocols that is very well fulfilling this task.
For categorical as well as for numerical traits, open access data bases have been created. The common use of the underlying information allows direct comparison of trait-environment interaction derived from field observations at different locations and across scales. Kattge *et al.* (2011) present a list of trait data bases and propose a generic data base structure that is needed to overcome problems of complexity, heterogeneity, compatibility and auxiliary information of trait data. From standardized protocols and communal trait databases at larger scale (e.g., Garnier *et al*., 2007; Kleyer *et al*., 2008; Kattge *et al*., 2011), we should then be able to predict the trait composition of communities by combining knowledge of (i) the regional species pool, (ii) the nature and strength of different filters, (iii) the response traits associated with each filter, and (iv) the rules that shape assembly (Lavorel *et al*., 2007). The choice of traits may focus on those known to be relevant and well understood to each filter (e.g. nutrient gradient). However, within a particular community, different axes of specialization (e.g. related to root N uptake capacities, Maire *et al*., 2009) may determine community structure and hence affect ecosystem functioning, and thus may increase measurements efforts.
Further, advances in statistical procedures on plant functional traits have been made in order to increase our understanding on the predictions of functional structure of communities and ecosystems properties that are directly relevant to ES (Díaz *et al*., 2007; Suding *et al*., 2008). The authors have shown that the testing of hypotheses other than the mass ratio (e.g. functional divergence, Mason *et al*., 2005) may greatly improve our predictive capability (e.g. Klummp and Sousanna, 2009) mainly at larger time scales. Further, within-habitat differentiation for particular traits is accompanied by allometric changes and/or trade-offs with other traits (Westoby *et al*., 2002). So, according to De Bello *et al*., (2009) advanced mathematical tools are needed in order to test if and to what extent trait differentiation occurs at small as compared to large spatial scales.

Trait plasticity

The numerical value of a feature of an individual organism (the trait attribute) naturally varies within certain limits according to environment. That way, plants can compensate for growth-limiting constraints and cope with a wider range of environmental conditions (Schlichting, 1989). Such phenotypic plasticity (Valladares *et al*., 2006) is a prerequisite of competitive ability in plant communities and a key to the success and fitness of species that is strongly linked to their functioning in the ecosystem (Tilman *et al*., 1997). To a certain extent, such variation within one species is determined by genetically fixed variation and fitness consequences (Valladares *et al*., 2006) of individuals. Usually, genetically fixed variation under ambient growing conditions is not known, especially not from species on permanent grassland, and so we fail to separate it from the variation that can solely be attributed to the response to unpredicted management and environment. Further, the fact that even for a given species, numerical trait attributes are not fixed gives space to the debate on the applicability of numerical trait data bases. Numerical trait values from data bases may not be applied without supplementary information on species and environmental conditions under which they have been measured.

Scale dependency of traits

There is no doubt that the application of functional traits in ecology and its interpretation with respect to ecosystem services is possible across larger gradients. For example, from a survey on 247 studies, De Bello *et al*. (2010) revealed a ranking of organisms and systems providing ecosystems services leading to a distribution of trait-service relationship across regions. However, it has also been found that the application of traits along environmental axes may be scale dependent. For instance, differentiation among communities for particular traits can be relatively small compared with processes acting at local scales (De Bello *et al*., 2009). On the one hand, this may make plant functional traits easily comparable among studies and sites, thus supporting the identification of major axes of ecological strategy variation and consistent trait correlations. However, on the other hand, traits exhibiting strong correlations at regional and global scales may be decoupled at a local scale and may contribute to independent axes of ecological differentiation and coexistence. This means that each trait defines an independent axis of functional variation in species strategies, relative to co-occurring species (Ackerly and Cornwell, 2007). In addition, according to spatial scale, different trait associations may be required since niche partitioning among co-existing plant species is affected by a co-ordinated response in numerous traits in order to achieve a balance among different functions (Gubsch *et al*., 2011). The importance of these functions for growth and survival will also depend on ecological conditions (Gross *et al*., 2009). Hence, the choice of relevant key traits (or trade-offs) might be context/scale dependent.

The response and effect plant functional traits along nutrient gradients

It is well documented that biotic and abiotic resources on grassland act on species composition as environmental filters (Keddy, 1992). Soil nutrients stand for such a filter and thus vary the ecological niche dimension and modify the set of species (Harpole and Tilman, 2007). Communities with higher α-diversity are likely to contain higher trait diversity (Loreau *et al*., 2001), and so we can expect a greater variety of species' strategies adapted to exploit different spatial or temporal niche (Díaz and Cabido, 2001). The grassland community can be seen as the result of a hierarchy of filters constraining the persistence of plants and traits (Lavorel and Garnier, 2002). The strategy of a species that is most successful in capturing nutrients in a given environment will also be most successful in out-competing its neighbours. According to competition theory, species may eliminate competitors due to better fitness which leads to a shift in floristic composition but not necessarily to a shift in community trait syndrome. In this context, we define competition as "an interaction between individuals brought about by a shared requirement for a resource in limited supply, and leading to a reduction in the survivorship, growth and/or reproduction of the competing individuals concerned" (Grace, 1990). The success of the plant's strategy to immigrate into an established plant community is largely dependent on the prevailing trait expression and the prospect to give space for additional traits expressing functions not yet occupied, i.e. providing an open ecological niche. Hutchinson (1957) defined the niche as a hyper-volume in which every point corresponds to a state of the environment that would permit the species to exist indefinitely. Quantification and refinement of Hutchinsonian niche is still a matter of research (Holt, 2009). Devictor *et al*. (2010) introduce the ecological niche to the trait concept by defining the Grinnellian niche as one that describes the response of species to a given set of resource variables, whereas the Eltonian niche focuses on the impact of species on the environment rather than on its response to particular resources.

The combination and expression of initial set of functional traits in the community as well as the dimension of the environmental filter decide upon the extent to which trait expression and species composition will be altered. Number and size of the openings in Figure 2 represent number and properties of filters selecting for certain environmental conditions such a soil fertility to which the traits respond, e.g. content of N in soil solution including NH_4^+/NO_3^- ratio, increased litter and organic carbon, and improved availability of other nutrients (Liebig's law). X and Y dimension is related to the number and size of the filter elements, with lower dimension inducing a stronger filter effect (e.g. pH, N nutrition) than higher ones (K content in soil). Thickness of the arrows can be defined as the dominance of the trait in the community before and after transition. For categorical traits, filter effect would not be on trait attribute, i.e. the numerical expression of an existing trait, but on the presence or absence of certain properties of physiological (N_2 fixation), phenological (early flowering) or morphological (with or without rhizomes) nature.

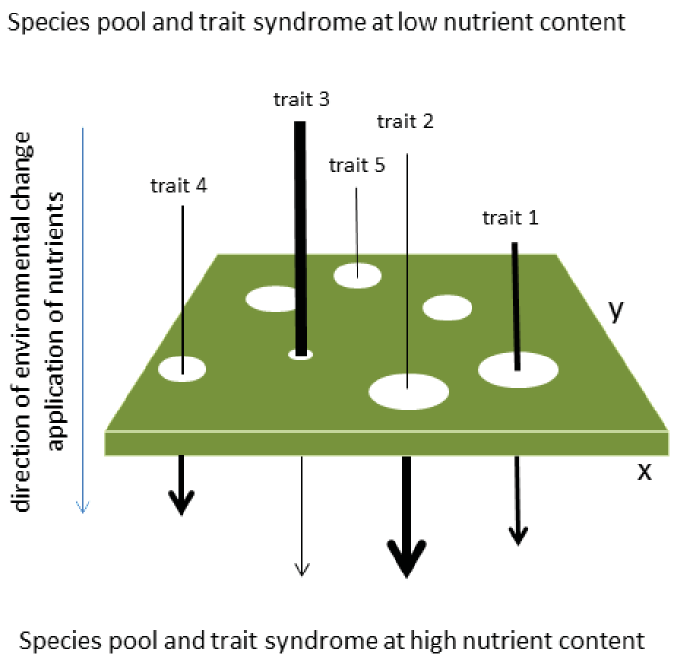

Figure 2. Schematic representation of response of numerical trait attributes to change in soil nutrient content as an environmental filter (see text for explanation).

Figure 3 shows an example of how trait-based approaches can be linked with niche components as proposed by Violle and Jiang (2009). The average of the trait value (derived from standardized databases or measurements in the field) can be used to assess trait expression, and the range of values that a trait can exhibit can be used to indicate trait plasticity. On the second axis, the position of niche on the environmental gradient axis for the species' trait can be displayed together with the range of environmental gradient within which the trait appears, i.e. the niche breadth. In Figure 3, we assumed a non-linear response of plant height to N application. Height values derived from grass monocultures (Pontes *et al*., 2010) were adapted to this curve leading to an estimate of position of the species along the N gradient. We have chosen plant height since it is considered to be a response trait to resource availability (which is N supply in this case). Height also performs best to indicate the plant's capacity for competitive dominance, because it expresses very well the ability to capture light (Duru *et al*., 2010). Plant community mean height of vegetative organs tends to increase with N availability, so community mean traits along environmental gradient provide a good assessment of trait-environment relationships.

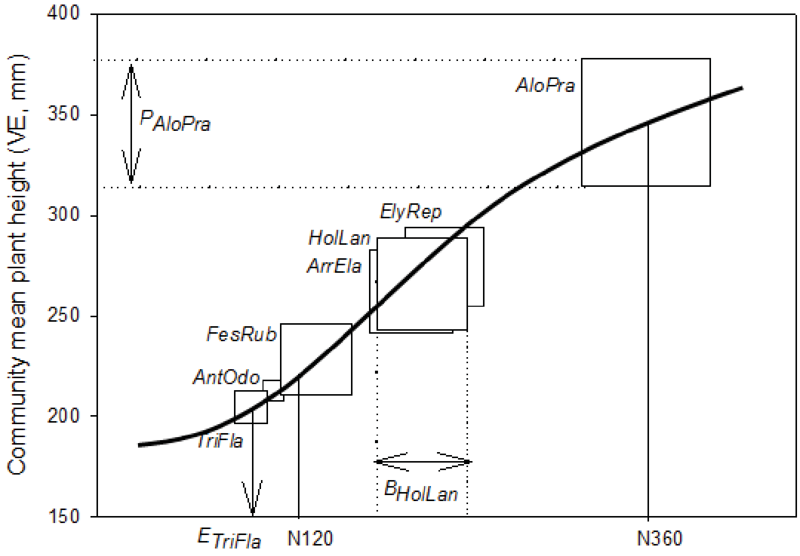

Figure 3. Trait-based quantification of species niche position and breadth along resources gradient (N supply, 120 and 360 kg N ha^{-1} year^{-1}, denoted N120 and N360, respectively). Community mean vegetative height (VE), weighted by species' relative abundance, indicates the position of average height of six grass assemblages. N supply indicates the estimated average of niche position of each species (*AloPra*, *Alopecurus pratensis*; *AntOdo*, *Anthoxanthum odoratum*; *ArrEla*, *Arrhenatherum elatius*; *FesRub*, *Festuca rubra*; *HolLan*, *Holcus lanatus*; *TriFla*, *Trisetum flavescens*) along the gradient and its breadth. As an example, E_{TriFla} indicates the estimated species niche position on the gradient for *TriFla* by positioning its mean trait value derived from monocrops (Pontes et al., 2010) on the distribution of community mean VE values. B_{HolLan} displays an estimate of species niche breadth on the gradient for *DacGlo*. P_{AloPra} indicates the range of trait value (i.e. trait plasticity from monocrops) exhibited by *AloPra* thus reflecting the level of trait adaptation of this species along the N gradient (solid line). Adapted from Violle and Jiang (2009).

The graph also indicates overlapping position and breadth of niches for some species, *Holcus lanatus*, *Elymus repens* and *Arrhenaterum elatius* in this case, whereas *Trisetum flavescens* and *Alopecurus pratensis* differ largely in this respect. As only one environmental gradient is shown here, one may not conclude on the true position of species in the open field where they simultaneously respond to other environmental gradients.

Abiotic filter such as soil fertility leads to a functional convergence hypothesis (Field, 1991) since it reduces within-community trait differentiation, i.e. by selecting species shared ecological tolerances from the regional species pool (De Bello *et al*., 2009). Biotic interactions are supposed to increase within-community trait differentiation, i.e. trait divergence (Silvertown, 2004), by limiting the similarity among co-existing species traits. However, the importance of these biotic interactions will depend of the limiting resource considered. For instance, Gross *et al*. (2009) observed under water limitation that grassland community structure was explained by a shift from competition to facilitation recorded for survival, whereas without water limitation, the community structure was explained by competition estimated with growth alone. So, nutrient gradient in grassland affect both convergence and the importance on divergence patterns determining the functional structure of communities. Recent work on natural grassland in Brazil (Pillar *et al*., 2009) showed that the same trait (e.g. plant inclination and leaf shape) can maximize the expression of convergence and divergence along N gradient. So, depending on traits, convergence and divergence can together be detected within a community.

We have seen earlier, that response and effect traits are often interrelated (Lavorel and Garnier, 2002), since they are both linked to mechanisms that are resource capture related and occurring mostly at the same time. For example, leaf nitrogen content, leaf dry matter content and specific leaf area are response traits to N supply (Al Haj Khaled *et al*., 2005; Pontes *et al*., 2010) and at the same time affecting soil fertility (De Bello *et al*., 2010). This overlap between response and effect traits may facilitate the upscaling from community to ecosystems with changes in soil nutrients (Lavorel *et al*., 2005).

At global scale, these leaf traits have been evidenced in a primary axis of specialization which separates species in relation to their nutrient acquisition or conservation strategies (Wright *et al*., 2004). The conservative plant type is well adapted to resource limitation, may be able to maintain its productivity under severe resource limitation and competes well with soil microbes for mineral nutrients (De Deyn *et al*., 2008). It invests more into structural biomass, exhibits higher specific leaf weight and tissue strength, thus affording higher costs for metabolic energy into growing tissue. Such investment is compensated by longer leaf life span and payback time of invested metabolic energy into growing sinks even at lower assimilation rates. Higher rates of internal C and N partitioning (Craine *et al*., 2001) into vegetative pools including into roots are typical. In contrast, the resource acquisition type (exploitative species) is adapted to high availability of resources, prevails in nutrient-rich habitats and is less cost-conscious. This type competes well through high rates of growth and leaf expansion to the expense of low specific leaf weight. Such fast growing species with rapid resource capture and fast turnover of organs rapidly explore upper canopy levels supporting high rates of light interception and photosynthesis, but size of C and N storage pools in vegetative organs is comparably low.

Traits have often been associated with resource availability, mainly when the effect of plants on its surrounding environment is considered. For example, plant height and root depth are competitive effect traits which also affect resource availability throughout plant growth and development (Violle *et al*., 2009). Further, recent studies (e.g. Klummp and Soussana, 2009) demonstrate that the prediction of ES requires data on different components of functional diversity (i.e. value, range, and relative abundance of plant functional traits in a given ecosystem (Díaz *et al*., 2007; De Bello *et al*., 2010). For instance, a significant effect of the range of trait values (traits plasticity) to predict variations in productivity has been observed, mainly at population level (Pontes *et al*., 2010). Further, syndrome of trait and trait plasticity are involved in the response of species to nutrient availability (Figure 4). This indicates that single processes or services often depend on multiple traits and different components of functional diversity. Interestingly, in Figure 4 we observed different associations between traits to predict variation in productivity in response to changes in N supply at population or community level. Therefore, when including other biotic factors (e.g. interspecific competition) beyond changes in abiotic factors such as N availability, different traits became more relevant leading to an increase in the explained variance of productivity.

Apart from the expression of numerical traits, the usefulness of categorical plant traits to the identification of nutrient gradients on grassland is evident. The identification of such gradients in grassland can be carried out by translating species composition (e.g. weighted species coverage) into a matrix of categorical traits derived from a trait data base. For example, in the Rengen Grassland Experiment (RGE) (Schellberg *et al*., 1999), the percentage coverage of species exhibiting the respective categorical traits was summed up for each fertilizer treatment. This led to a 3-D matrix containing numerical values for each trait, six treatments and four (consecutive) years.

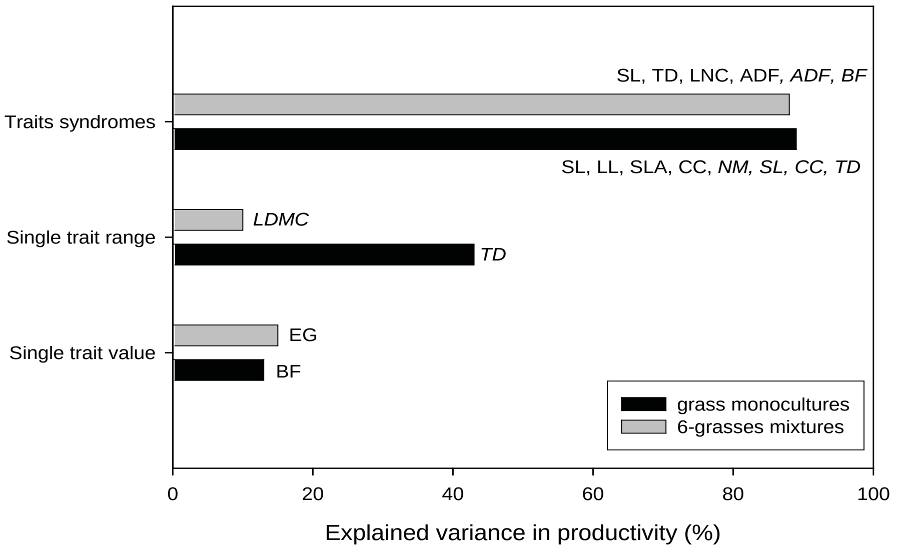

Figure 4. Importance of level of trait organization predicting variations in above-ground productivity in response to changes in N supply. At community level (mixtures of six grasses), aggregated traits (weighted by species' relative abundance) were used. See Pontes et al. (2010) for calculation of variation in productivity and trait plasticity (range, represented by traits in italic), regressions analyses and grass species used in this study.
LDMC, leaf dry matter content; SLA, specific leaf area; LL, leaf length; LNC, leaf N content; NM, number of mature leaves; SL, sheath length; TD, tiller density; BF, beginning of flowering period; EG, earliness of growth; CC, plant cellular content; ADF, plant cellulose and lignin content.

In this experiment, a hierarchical cluster analysis based on categorical functional traits along nutrient gradient from unfertilized to fully fertilized with Ca, N, P and K revealed clear separation of most fertilizer application treatments solely based on categorical traits (Figure 5). At least four collectives could be identified. Without exception, plots without P could be branched out from plots with P fertilizer. Further, control plots created an independent cluster as well as plots receiving either Ca or CaN. In contrast, K treatments could not be separated, indicating that K fertilizer did not create noteworthy segregation of categorical trait expression of plant communities. In conclusion, even if numerical trait values of the vegetation along nutrient gradients are not available, a trait analysis based on categorical traits may provide information that explains the interaction between form and function of species at given soil nutrient levels.
The nutrient enrichment of grassland soils usually occurs when fertilizers are applied. However, with nitrogen a significant enrichment is also possible through long-term presence of N_2 fixing leguminosae. In a recent publication, Gubsch *et al*. (2010) concluded from investigations in the Jena experiment (Roscher *et al*., 2004) that traits related to N acquisition were strongly influenced by presence of legumes, such as leaf N content and ratio of grass module biomass to N content.
Overall, as stated earlier, plant response to environmental factors is usually driven by a combination of traits (Ackerly, 2004; McGill *et al*., 2006; Gross *et al*., 2007). These plant traits co-vary along axes of specialization (Díaz *et al*., 2004; Wright *et al*., 2004), reflecting different trade-offs for plant functioning that ultimately affect plant reproduction, survival and growth (Westoby and Wright, 2006). According to Suding *et al*. (2003), trade-off between traits is a key mechanism to link traits to species abundance, i.e. to link species fundamental niche (response to abiotic factors) to their realized niche (species abundance in the field). Specialization axes

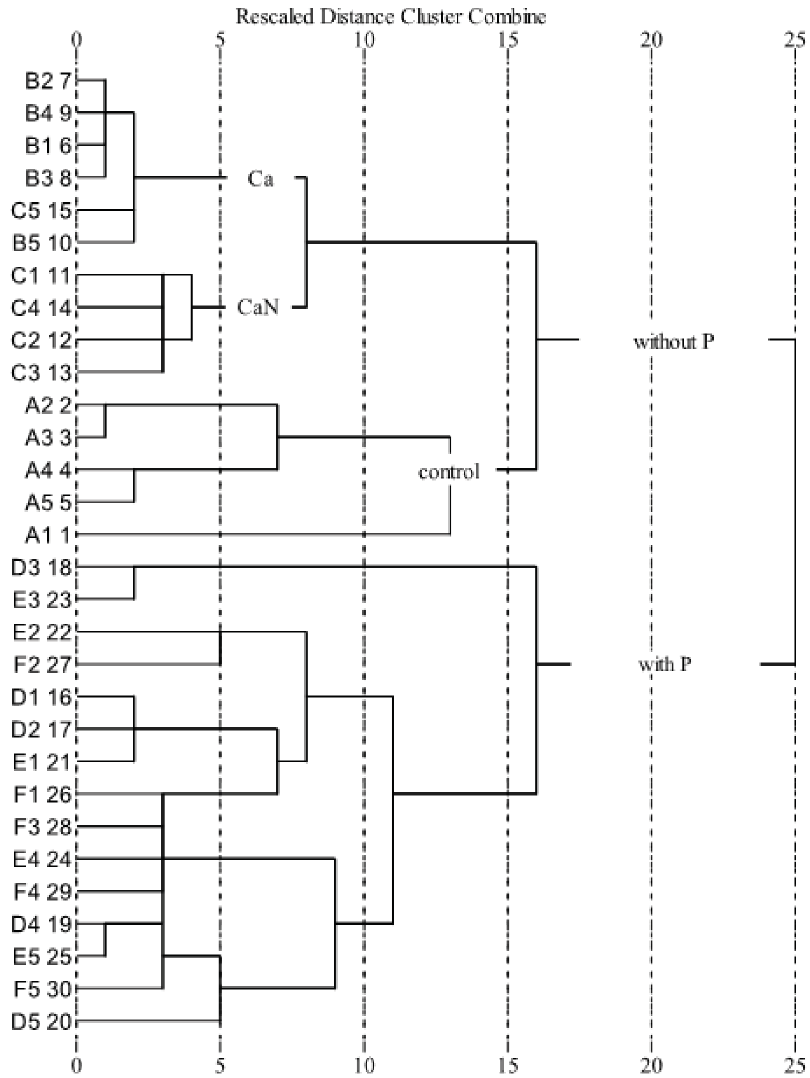

Figure 5. Dendrogram of experimental plots in the Rengen Grassland Experiment (RGE) clustered based on combinations of their categorical plant functional traits (four years average of data, 2005-2008). Indices A, B, C, D, E and F refer to the following treatments: control, Ca, CaN, CaNP, CaNPKCl, $CaNPK_2SO_4$, respectively. Indices are followed by plot numbers (replicates, see Hejcman et al., 2010 for plan of the experiment) and series number of data set.

directly related to nutrient acquisition and use have been well-established, such as the link to leaf economic spectrum contrasting exploitative *vs.* conservative plant types (Wright *et al.*, 2004), and the trade-off between NO_3^-/NH_4^+ uptake capacities, which promote complementarity for N acquisition (Maire *et al.*, 2009). However, in order to capture the response of plants to environmental gradients with multiple limiting resources, further axes of specialization (e.g. plant stature; Ackerly, 2004) may be necessary in order to provide additional information of species coexistence and their consequences for ES. For instance, in a study conducted in central French Alps (Gross *et al.*, 2007), two trade-off axes based on stature traits and leaf traits were required to capture species responses to grassland management factors (fertilization, shade and mowing) compared to acquisition-conservation trade-off alone.

Links across disciplines

The functional trait approach developed during the past two decades has great potential to improve our understanding on the functioning of plants in ecosystems. However, this approach is mostly followed by ecologists and biologists. Most of the scientific papers on functional traits are published in ecological journals and only few in agronomic journals indicating that the trait approach has not yet established in agronomic science. There is evidence that, from an agronomists and grassland scientist's point of view, aspects of productivity and forage quality are most important. However, the need to design sustainable grassland production systems (i.e. multifunctional grassland management) justifies every effort to better understand the link between species composition and its traits as influenced by management on the one hand and its functioning in the ecosystem on the other.

We can expect a significant advance in the science on ecosystem functioning (including that of agro-ecosystems) if we succeed in matching observational, experimental and theoretical studies (Loreau *et al*., 2001). Lemaire *et al*. (2005) state that "…there is a need to provide a stronger basis for genuine inter-disciplinary research with the emphasis on integrated land use programs, effective coordination of production and conservation interests …". Grassland scientists can contribute to concerted actions related to functional ecology by bringing in their long-term experience on field experimentation and deep knowledge on yield performance of plants, their response to nutrients, water and light as well as on the interaction of vegetation with the grazing animal. There are some interfaces between grassland science and other disciplines that can serve as links between research interests. With respect to response and effect of plant functional traits to environmental conditions such as soil fertility, there are many research questions that can be better addressed in joint research activities.

The management of grassland-based production systems has a strong impact on the relationship between plant form and its function. For instance, the application of organic and inorganic fertilizer as an important management factor is indispensible as long as farmers strive for achieving high yields. Related consequences on plant functional traits and resulting functions of vegetation and soil can be important, including its impact on nutrient cycling and loss, thus leading to the question of how much EP and ES is affected. As animals are indispensible on grassland farms, permanent recycling of nutrients with excreta is a strong driver in the relations between species, a topic that would bring together ecologists on the one hand, and animal scientists, grassland scientists and plant nutritionists on the other. Further, the functional relationships between activities of grazers and vegetation are of great interest. Although the influence of plant functional traits on grazing behaviour and intake has been investigated in numerous studies (e.g. Cingolani *et al*., 2005), the question in what way functional traits of animals (e.g. claw size, form of dentition, bite frequency) are directly related to plant functional traits has not been well addressed, but would require experts from grassland and animal science as well as from ecology. Last but not least, farmers strive for achieving high feeding quality and seek for best management options (especially with grazing) that serve this command variable. It is common knowledge that some of the functional traits are strongly influencing analytical value of biomass production and fodder quality, and consequently the feeding behaviour. So, it is worth directly linking these key trait drivers of agronomic value with traits playing a stronger role in others ES (e.g. soil C stock) and search for trade-off and convergence of both, in response to global change in climate and land use.

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Oral presentations

Survey of the biodiversity-productivity relationship in Swiss summer pastures

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Abstract

Centuries of summer pastoralism in the Alps have created grassland habitats which are among the most species-rich in Europe. Summer pastures provide a number of services to farmers and society, for example fodder, biodiversity or openness of the landscape. Our aim was to quantify two primary services: production of fodder for grazing animals and biodiversity in terms of plant species richness. In 2010, we measured biomass production and plant species richness at 54 sites on 6 summer farms in two regions of Switzerland. Sites were selected in order to represent a large range of topographic positions and distances from farm buildings. Vegetation was characterised using the phytosociological classification developed by Dietl for yield estimation and management planning. In addition, a dataset of 382 archival records was classified into Dietl vegetation types. We found an overall hump-shaped relationship between productivity and species richness, in which each summer farm is individually positioned, according to the vegetation groups present. Despite considerable variation in species richness within vegetation groups, the Dietl system has potential to assess ecosystem services other than biomass production, for which it was developed.

Keywords: subalpine grassland, plant diversity, productivity, Swiss Alps

Introduction

Summer pastures provide a multitude of services to farmers and society, including production of forage for ruminants, floristic and faunistic diversity, openness of the landscape, erosion control and carbon sequestration. Whilst provision of additional feed resources in summer has been perceived as the primary service of summer pastures for centuries, other services have recently received much attention. Currently, the Swiss administration is modifying its policy regarding summer pasture management with the aim of more targeted support for additional ecosystem services. This may lead to new optimization criteria for land managers and it is, therefore, important to understand the way in which various ecosystem services are interrelated and to what extent evidence from lowlands can be transferred to summer pastures.

In this paper, we investigate the relationship between two ecosystem services: productivity in terms of annual biomass growth and biodiversity in terms of numbers of plant species on 25 m². In lowland studies, this relationship is shown to be hump-shaped (Grime, 2002; Wassen *et al*. 2005) to monotonically negative (e.g. Harpole and Tilman, 2007); however, research demonstrating this relationship at higher elevations has not yet been well-established. We also assess how the phytosociological classification by Dietl *et al*. (1981) performs in predicting plant species richness in mountain grasslands. Aiming at the assessment of pasture suitability, the classification consists of indicator species for 44 grassland types. These have been extensively used in management planning of summer farms but never been tested on their information content regarding species richness.

Materials and methods

Species composition and biomass production were assessed on 54 sites on 3 summer farms in Obwalden (OW) in the north-central Alps of Switzerland and on 3 summer farms in Engiadina Bassa (EB) in the south-eastern Alps. The sites were selected along the slope gradient at varying distances to the primary farm building.

Biomass dry matter (DM) production was measured using 1 m² grazing exclusion cages. Per site, one cage was placed in the centre of a suitably homogenous sampling area of 25 m², which was used for determination of species richness (SR). Because several exclusion cages were disturbed by grazing animals during the field season, the results of 14 sites had to be dropped from the analysis. A Poisson generalized linear model in the form of SR = $a + b \cdot \log(DM) + c \cdot \log(DM)^2$ was fitted to the data of each farm and a Poisson generalized linear mixed model was used to evaluate effects of topographic factors.

Vegetation types according to Dietl *et al.* (1981) were associated with vegetation relevées by calculating Sørensen distance as $D = 2N_{ij} / N_i + N_j$, where N_{ij} is the number of species shared among relevée and reference, and Ni and Nj are the total number of species in relevée and reference, respectively. Vegetation types were attributed to the vegetation data of the 54 sites surveyed in 2010 as well as to 382 archival records corresponding to the 2010 data with regard to altitude (1500-2500 m asl) and sampling area (20-30 m²). For the sake of simplicity, Dietl vegetation types were aggregated into 6 groups as shown in Table 1.

Table 1. Groups of Dietl vegetation types with characteristics and selected indicator plants

Group	Characteristics	Indicator plants
1	Dry and semi-dry pastures	*Sesleria caerulea*, *Thymus serpyllum*, *Carex firma*
2	Fertile mesic pastures	*Trisetum flavescens*, *Geranium sylvaticum*
3	Fertile humid pastures	*Cynosurus cristatus*, *Alchemilla vulgaris*
4	Nutrient-poor mesic pastures	*Poa violacea*, *Trifolium alpinum*
5	Nutrient-poor humid pastures	*Nardus stricta*, *Carex curvula*, *Calluna vulgaris*
6	Wet pastures and meadows	*Caltha palustris*, *Molinia caerulea*

Results and discussion

Species richness and DM production were negatively correlated at summer farms OW1 and OW2 (Figure 1A). In these cases, even a simple linear model would have captured the relationship. At OW3, EB1 and EB2, species richness has its maximum at intermediate productivity. At EB3, DM production and species richness were weakly positively correlated. Overall, the highest species numbers were found at low to intermediate productivity, in line with investigations from other ecosystems (e.g. Wassen *et al.* 2005).

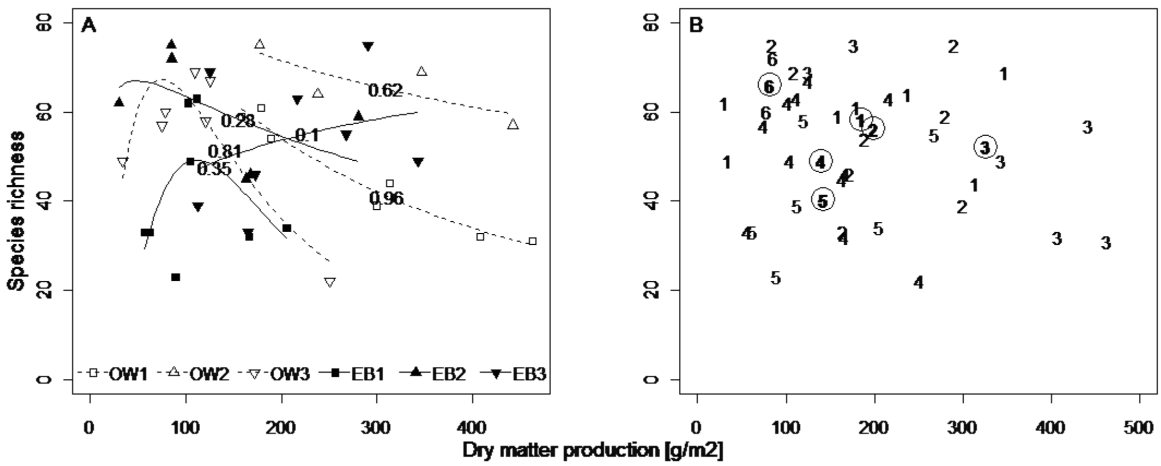

Figure 1. A: Species richness *vs.* dry matter production (retransformed) at 6 summer farms in regions Obwalden (OW) and Engiadina Bassa (EB) with corresponding quadratic regression lines and R²; B: Distribution of Dietl vegetation groups in the same dataset with group numbers as in Table 2. Encircled bold numbers show means of the vegetation groups.

Topographic factors, such as altitude, slope, and distance to buildings, had significant effects on the two investigated ecosystems services. However, none of the two-way interactions between topographic factors and ecosystem services in the mixed models were significant. The relationship between species richness and the DM production was much more closely related to the vegetation types present (Figure 1B). Farms with a negative relationship had a high share of fertile pastures. With increasing productivity, a limited number of productive species dominate the community and species richness decreases. Farms with hump-shaped relationships were dominated by nutrient-poor pastures (mostly *Nardion*). The positive relationship on farm EB3 can be explained by the transition from nutrient-poor *Nardion* to moderately fertile *Cynosurion* pastures.

Figures 2A and 2B indicate considerable variation in DM production and species richness within Dietl vegetation groups. The archival records in Figure 2C generally show lower species numbers than the observation made in 2010 but they confirm the general pattern: Dry and fertile pasture groups 1 to 3 tend to host higher numbers of species than the nutrient-poor groups 4 and 5. However, species numbers are just one aspect of ecological value and groups 4 and 5 could harbour a number of rare specialist species.

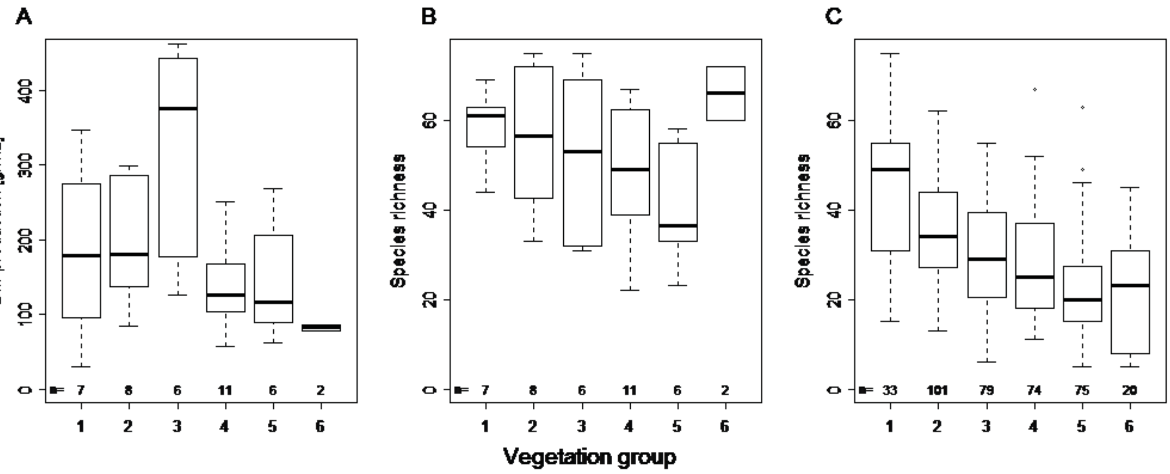

Figure 2. Boxplots of dry matter production (A) and species richness in Dietl vegetation groups on 6 summer farms in two regions of the Swiss Alps (B) and of species richness in 382 comparable archival relevées (C).

Conclusions

Our analysis demonstrates that productivity and biodiversity in grasslands above 1500 m asl generally follows a hump-shaped relationship. However, each summer farm is positioned individually making general guidance on management difficult and complex. Dietl vegetation groups explain the observed productivity-biodiversity relationship relatively well. Bearing in mind that the original aim of the classification was to assess suitability for grazing and to estimate yields, this study demonstrates the system's potential (after modifications) to assess ecosystem services other than biomass production.

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Natural and use value of meadow communities of mountain and lowland regions

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Abstract

The objective was to compare natural and use values of meadow communities of *Arrhenatheretalia* in the mountainous areas of the Kłodzka Valley and of the plain areas of the Wielkopolska Lowland (Poland). The following were determined in the identified plant communities: the number of plants in the phytosociological survey, values of the floristic diversity index, and indices of natural and use values. Meadow communities occurring in mountain areas were characterised by higher natural values, richer species composition and greater species diversity compared with plant communities in lowland regions. In mountain areas there were also more species of medicinal, melliferous and protected plants identified, increasing the natural and use (primarily, non-fodder) values of these regions.

Keywords: *Arrhenatheretalia*, natural and use value, Wielkopolska Lowland, Kłodzka Valley

Introduction

Anthropogenic meadow communities of the *Arrhenatheretalia* order occur both on lowlands and in mountains (Haslgrübler *et al*., 2010). Their development and current floristic composition is affected by site conditions, in particular, moisture content and nutrient availability in the soil (Müller *et al*., 2004). Different climatic conditions found on lowlands and in mountains exert a significant influence on the intensity of utilisation of grass communities (Kryszak and Kryszak, 2007; Waesch and Backer, 2010). These conditions, through their impact on botanical composition, contribute to differences in the natural and fodder value of these communities.

Materials and methods

Investigations included the analysis 400 of surveys representing the most frequently occurring phytocenoses of the *Arrhenatheretalia* order. They were made with the the Braun-Blanquet method in the following two, topographically different, regions. Phytosociological relevés were performed from mid-May to mid-July, from an area of 75-100 m². The structure and natural values of plant communities were analysed on the basis of the following parameters: mean number of species in a phytosociological relevés, Shannon-Wiener floristic diversity index (H/), natural valorisation index (Oświt, 2000) and the occurrence of naturally valuable species (including protected species). The non-fodder use value of the identified communities was assessed on the basis of the occurrence of medicinal and melliferous plant species and the fodder value - with fodder value scores (FVS) according to Filipek (1973).

Results and discussion

The following four communities were evaluated from among the communities of the *Arrhenatheretalia* order found in Wielkopolska Lowland: *Arrhenatheretum* elatioris, com. *Poa pratensis-Festuca rubra*, com. with *Festuca rubra*, *Lolio-Cynosuretum*, whereas in the case of mountainous areas of the Kłodzka Valley, six syntaxons were analysed: *Arrhenatheretum* elatioris, and communities of *Poa pratensis-Festuca rubra*, *Gladiolo-Agrostietum capillaris*, *Meo-Festucetum*, *Phyteumo-Trifolietum* and *Lolio-Cynosuretum*. This structure of the most common communities of this order indicates their greater variability in mountainous regions. Simultaneously, the floristic composition of these communities was characterised by greater floristic diversity (Table 1).

Generally speaking, communities occurring in mountainous areas were characterised by a higher mean number of species in a phytosociological relevé and higher values of Shannon-Wiener floristic diversity indices. These interrelations were further confirmed by values of natural valorisation index which were found higher for communities in the mountains.

Table 1. Comparison of natural and fodder value score (FVS) of plant communities of the *Arrhenatheretalia* order on the examined lowland and in mountainous areas.

	Natural value					Use value		
Phytosociological unit	Share (%)	Number species in relevé	*H‘	Valorisation index**	Protection plants	Medical plants	Melliferous plants	FVS
Wielkopolska Lowland 100-200 m.asl Total annual precipitation: 550-600 mm, length of growing season: 215-220 days								
Arrhenatheretum elatioris	4.1	25.8	1.72	2.5	0	25	6	7.4
Com. *Poa pratensis-Festuca rubra*	16.6	21.4	1.79	1.9	1	41	11	6.8
Com. with *Festuca rubra*	2.7	19.2	1.66	2.6	1	22	3	5.6
Lolio-Cynosuretum	15.2	22.9	1.85	2.2	2	46	13	7.4
Kłodzka Valley 450-600 m. asl Total annual precipitation: 700-800 mm, length of growing season: 190-205 days								
Arrhenatheretum elatioris	1.3	20.0	1.76	3.3	2	22	10	7.1
Com. *Poa pratensis-Festuca rubra*	2.6	18.6	1.78	2.1	2	18	6	5.4
Gladiolo-Agrostietum capillaris	7.9	21.4	1.73	2.6	5	29	11	4.1
Meo-Festucetum	5.4	28.0	1.81	2.9	3	33	10	5.2
Phyteumo-Trifolietum	9.2	19.7	1.85	2.8	2	20	7	6.1
Lolio-Cynosuretum	6.6	15.2	1.88	2.3	2	23	9	6.9

*H’ Shannon-Wiener index ** according to Oświt (2000)

A considerably higher natural value of plant communities from the *Arrhenatheretalia* order growing in the mountainous region was also confirmed by the number and frequency of occurrence of naturally valuable species, which is further corroborated by the results of Żyszkowska (2006). The highest stability of occurrence was observed in the case of *Carlina acaulis* and *Platanthera biforia*, whereas *Colchicum autumnale*, *Veratrum nigrum* and *Lilium martagon* occurred less frequently. The most frequent plant communities found in the Wielkopolska Lowland comprised *Dianthus superbus* and *Helichrysum arenarium* under partial species protection.

Many medicinal and melliferous taxa were identified among the examined meadow communities, which not only enhanced the natural value of the assessed phytocenoses but, in addition, affected the non-fodder use value of the sward. Analysing quantitatively the occurrence of medicinal and melliferous species, they were found more numerous in mountainous communities. Among the most frequently occurring species - both in the mountains and on lowland - the following medicinal and melliferous species, respectively were identified: *Achillea millefolium*, *Daucus carota*, *Plantago lanceolata*, *Rumex acetosa* and *Centaurea jacea*, *Leontodon autumnalis*, *Lotus corniculatus*. Such species as *Taraxacum officinalis* and *Trifolium pratense* exhibit both medicinal and melliferous properties (Table 2).

On the other hand, in comparison with the natural value, the fodder value of the sward communities of the *Arrhenatheretalia* order was shaped quite differently. It was considerably higher in the case of phytocenoses developed on the lowland area. The observed poorer botanical composition of the meadow communities derived from the lowland area was caused by their more intensive utilisation resulting, among others, from a longer vegetation period. The employed utilisation systems frequently required application of higher doses of mineral fertilisers. The use of under-sowing also contributed to sward species simplification. Furthermore, the prevailing weather conditions, especially lower total precipitation on the lowland, limited the occurrence of many plant species.

Conclusions

Climatic conditions and the length of the vegetation period exerted influence on the higher natural and fodder value - in particular, of the non-fodder character, of the mountainous plant communities found in Kłodzka Valley. Higher fodder value was determined in plant communities derived from lowland areas.

Table 2. Medicinal, melliferous and protected plant species occurring most frequently in the identified communities.

Wielkopolska Lowland	Kłodzka Valley
Medicinal plants	
Achillea millefolium	*Achillea millefolium*
Capsella bursa-pastoris	*Alchemilla monicola*
Cardamine pratensis	*Carlina acaulis*
Daucus carota	*Cirsium oleraceum*
Glechoma chederacea	*Crepis biennis*
Plantago lanceolata	*Daucus carota*
Plantago major	*Galium verum*
Potentilla anserina	*Hypericum maculatum*
Rumex acetosa	*Knautia arvensis*
Taraxacum officinale	*Plantago lanceolata*
Thlaspi arvense	*Potentilla erecta*
Trifolium pratense	*Rumex acetosa*
Urtica dioica	*Sanguisorba officinalis*
Viola arvensis	*Taraxacum officinale*
Melliferous plants	
Centaurea jacea	*Centaurea jacea*
Leontodon autumnalis	*Centaurea Montana*
Lotus corniculatus	*Leontodon autumnalis*
Taraxacum officinale	*Lotus corniculatus*
Trifolium pratense	*Taraxacum officinale*
	Trifolium pratense
Protected plant species	
Dianthus superbus	*Carlina acaulis*
Helichrysum arenarium	*Platanthera bifolia*

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Can β-diversity drive dry pastures conservation priorities?

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Abstract

β-diversity is a major determinant of species diversity at the regional scale. Biological, spatial and environmental determinants have been suggested as drivers of composition variation in semi-natural grasslands. The relative importance of such factors is inconsistent among studies also in relation to scale differences. Our aim is to discuss the influence of the scale in determining the relative contribution of spatial and environmental factors to the variation in β-diversity. We used data on central Italian dry grassland (Habitat 6210) and considered two different extents. We built dissimilarity matrices based on species abundances, metric coordinates and environmental factors. We used the former as response in a Multiple Regression on distance matrices to obtain a partition of the variance between the other factors. Furthermore, we used Multivariate Regression Trees to identify the major environmental determinants of grassland composition. Our results strongly suggest that, to conserve most of the diversity in dry grasslands of the habitat, we should take into account differences in rainfall at the broadest scale, and in soil development at a local scale.

Keywords: spatial conservation prioritization, Habitats Directive, Italy, dissimilarity matrices

Introduction

Calcareous grasslands are among the most species-rich habitats in Europe; their decline in extent in the recent decades, mainly due to the abandonment of traditional agricultural practices, has become a major conservation problem (Raatikainen *et al*., 2009).
β-diversity (the difference between sites in terms of species composition and abundance) is a major determinant of species diversity at the regional scale (Anderson *et al*., 2011), and can be used as a basis for prioritizing areas for biodiversity conservation. Spatial patterns are intimately related to environmental conditions and partitioning the variation in β-diversity between environmental and spatial components provides a useful means of testing niche and neutral mechanisms (Legendre *et al*., 2009). Since organisms respond to environmental characteristics at specific scales, discrepancies between studies regarding the major determinants of variation in the composition of semi-natural grasslands (Marini *et al*., 2007; Raatikainen *et al*., 2009; Cingolani *et al*., 2010) may reflect differences among spatial scales (Auestad *et al*., 2008).
The ultimate aim of this study was to identify factors that could be used in conservation plans for dry grasslands referred to the Habitat 6210 (Directive 92/43/EEC). Our goal was to partition the variation in β-diversity between geographic distances and environmental variables at different spatial scales. A further aim was to identify relevé clusters based on species composition and to characterize them in terms of environmental conditions.

Material and methods

We used 207 phytosociological relevés ranging in size from 16 to 100 m², with cover values that follow the Braun-Blanquet scale. The relevés were performed in calcareous mountain ranges in southern Lazio from 80 to 1411 m a.s.l., in the temperate climatic region, from the hilly to the montane belt. The environmental variables were: slope (°), rocks and stones (%), aspect; annual rainfall and minimum temperature (derived from a climatic map; furthermore spatial coordinates were associated to each relevé. In all the sampled communities, grazing caused the main disturbance. The relevés were distributed according to a nested design based on two areas of different extent: i) the Ernici Range (about 520 km², mean distance between relevés ca. 17 km) and ii) the mountain ranges of southern Lazio (about 5,600 km², mean distance between relevés ca. 38 km). To avoid local oversampling, we performed a stratified resampling: 49 relevés for the Ernici Range; 52 for southern Lazio.

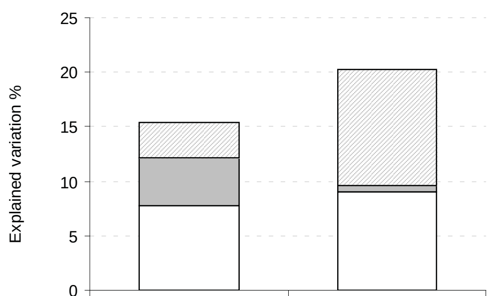
On the basis of the species abundances, we constructed plot-to-plot dissimilarity matrices to be used as dependent variables (Goodman-Kruskall coefficient). For environmental variables and spatial coordinates we created individual plot-to-plot dissimilarity matrices (Euclidean distances).

In order to partition the variance in β-diversity between the geographical distances and environmental variables, we conducted Multiple Regression on distance Matrices (MRM), which is an extension of the Mantel test (Lichstein, 2007), performing three replicate analyses (all the explanatory variables, environmental variables, spatial distances). Diverse species assemblages within the context of the broadest scale dataset were defined through distance-based Multivariate Regression Trees (MRT, De'ath, 2002). We used the same dissimilarity matrix as response and the environmental variables as explanatory. All the calculations were performed using R 2.12.0 (R Development Core Team, 2009), packages ecodist and mvpart.

Results and discussion

The MRM models accounted for 15.4 and 20.3% of the variation from the broadest to the finest scale (Figure 1). At both scales (about 520 and 5,600 km²) all the models were highly significant ($P < 0.01$).

Therefore, both spatial and environmental variables should be considered when selecting areas that need to be prioritized in management plans at these scales. The finest scale was the one at which the environmental variables explained the greatest variance, in accordance with similar studies that found especially topographic variables to be effective drivers of variation in species composition at the local scale (Marini *et al*., 2007; Raatikainen *et al*., 2009). The portion of variance explained by pure spatial distances was maximum at the finest scale; its meaning varies at the different scales: at the subregional scale their effect is related to biogeographical differences in the species pools since the study area is crossed by the boundary between the Eurosiberian and the Mediterranean biogeographical regions (ETC-BD, 2006); at the finest scale spatial autocorrelation is likely to be the main driver of β-diversity spatial pattern.



	Southern Lazio	Ernici range
space	3.32	10.66
shared	4.32	0.64
environment	7.81	8.98

Figure 1. Histogram showing the variation partitioning derived from the Multiple Regression on distance Matrices analyses. Space indicates the variation explained by the geographical distances, environment the one explained by environmental variables, while shared is the portion of variance explained by these two sets of variables jointly.

The portion of shared variation was higher at the broadest scale, at which spatially-structured climatic gradients exert more influence. The unexplained variation yield rather high values, as is usual when using MRM (Goslee, 2010).

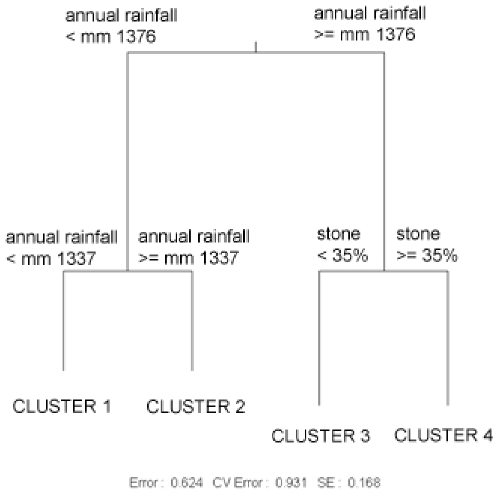


Figure 2. Multivariate Regression Tree built using the dissimilarity matrix based on species abundances in the southern Lazio relevés as response and the environmental variables as explanatory.

It was maximum at the broadest scale, at which differences in the disturbance regime may result in compositional differences; a similar result was found by Auestad *et al*. (2008).

Although the sampled communities all belong to the same subtype of the Habitat 6210 (*), the multivariate regression tree yielded 4 clusters, thus highlighting a certain degree of heterogeneity in our dataset (Figure 2).

The multivariate regression tree identified annual rainfall as the environmental variable most closely related to the main and to the second split, while the percentage of stone determined the split of the more rainy cluster. The latter is a good indicator of soil depth, and determines, together with rainfall, water availability, a factor of crucial importance in grasslands strongly influenced by the Mediterranean climate.

Conclusions

The results indicate that β-diversity patterns may contribute to the selection of sites for management activities aimed at maximizing grassland habitat biodiversity. Our findings demonstrate that conservation plans should take into account: i) the spatial patterns, since spatial distances drive β-diversity patterns; ii) scale issues, since differences were found at different extents; iii) pedologic and climatic variables, as annual rainfall and stoniness proved to be critical factors for the studied grasslands.

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Grassland biodiversity in a mountainous PDO cheese area in France: do organic and cheese production systems provide higher biodiversity?

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Abstract

This work is part of an ongoing research programme on the link between biodiversity and the Protected Denominated Origin (PDO) device in the "Saint Nectaire" PDO cheese area of the Auvergne (France). This study compares grassland biodiversity of organic and conventional dairy farming systems, and of cheese-maker and only-milk producers. Twenty farms were surveyed in order to characterize their forage system and grassland management. A simplified assessment of floristic and faunal (birds, butterflies, orthoptera) diversity was carried out on three pastures for each farm. Results showed significantly higher diversity for the herbaceous vegetation in organic systems, which could be related to some less-intensive agricultural practices. Grassland biodiversity was similar between cheese and milk producers due to the various intensification levels among both systems.

Keywords: grassland biodiversity, organic farming, cheese production, PDO

Introduction

Although wild biodiversity is not yet clearly identified as an objective in the French PDO devices (Bérard and Marchenay, 2006) this argument is often associated with the image of PDO areas, especially for cheese production based on grassland. But many different farming systems occur in such areas and some may be more interesting for biodiversity conservation. Organic farming is well known for its less-intensive practices due to the non-use of chemical inputs and its attention to natural elements. Cheese producers also may be sensitive to grassland biodiversity as they can evaluate the effects of flora diversity and forage practices on cheese quality (Coulon *et al.*, 2003). We tested these hypotheses in the Saint Nectaire PDO area (Auvergne, French Massif central) where cow-milk cheese is mainly produced from permanent grassland (800 to 1800 m elevation) and 45% of the tonnage is home made by farmers. We compared the grassland biodiversity of organic and conventional systems, and of cheese makers and only-milk producers.

Material and methods

This study is part of a research programme combining different analysis scales (territory, farm and plot) in order to identify the links between dairy systems and grassland biodiversity in the Saint Nectaire area. A forage systems typology based on a global survey of 455 dairy farms was performed and its supposed effects on biodiversity were analysed (Gueringer *et al.*, 2010). Grassland management and biodiversity were investigated more precisely on 20 farms (13 conventional and 7 organic; 12 had milk-delivery and 8 had cheese-making systems).

Biodiversity assessment was made in 2008 on three plots for each farm. Two plots had to be typical of the dairy farming system (one only-grazed and one mown) and the third was selected for being the most diversified according to the farmer (grazed or mown pasture). A new method adapted to Auvergne's grasslands was used to evaluate biodiversity (Orth and Balay, 2010). It relied on indicators obtained from field observations of landscape elements and simplified countings of flora and fauna based on a physiognomic approach (size, colour, shapes, etc.) without specialist recognition. The indicators were gathered in assessment grids which define five diversity components (Table 1). Two of them concerned flora and corresponded to the herbaceous vegetation diversity and the additional floristic diversity due to landscape elements, both given at vegetation-facies scale (within a plot). The other three were based on a global landscape mark and countings of individual fauna, which gave the diversity of birds, butterflies and orthoptera at a plot scale. According to the indicators' values, each diversity component received a diversity level ranging from 1 (low level) to 5 (high level) with reference to the regional biodiversity of grassland.

The farming system comparisons were carried out for the five biodiversity components and each of their indicators on 58 plots corresponding to 75 vegetation facies. We distinguished grazed and mown plots as they do not have the same thresholds in their assessment grids. Therefore we had four combinations for each comparison. One-way variance analysis and multiple comparison tests (LSD test) were performed to compare the diversity levels of the four combinations.

Results and discussion

Global results showed high landscape diversity (medium level of 4.5) and a wide range of herbaceous vegetation diversity with an average score of 3.8. Fauna results were around the medium level (mark 3) with a lower mean for butterflies and a higher one for orthoptera. When comparing organic and conventional farming, we found no significant effect on diversity level for landscape elements or orthoptera. The variance analysis was significant for birds and butterflies but the multiple comparison tests showed that differences were between grazed and mown plots, rather than organic and conventional. However, we found a highly significant effect for the herbaceous vegetation diversity, which was due to the farming system: the mean diversity level of organic grazed or mown plots was more than one point higher (Table 1). All the indicators used to obtain the diversity of the herbaceous vegetation (species, colours, flowers) were higher for the organic plots, and five of the seven indicators were significantly different (Table 2). As there was the same proportion of 'most diversified plots' in organic and conventional systems (ca. 40% for mown pastures and 20% for grazed), we conclude that organic farming had a positive impact on the vegetation diversity. The organic farms were mostly in the extensive systems of the forage typology. The two systems, however, used the same total amount of NPK fertilizers, but absence of mineral fertilization in organic systems was probably a determining factor as it induces a later growth of the grass and, therefore, less-intensive pasture utilization. We observed a lower stocking rate on organic grazed plots than on conventional (though the difference was not significant). A higher proportion of mown organic meadows (58%) were harvested later than conventional meadows (35%), which is better for the species' flowering and survival. On the conventional plots there was a significant negative correlation between mineral N amount and vegetation diversity.

When considering the biodiversity results of cheese and milk producers we found only a significant variance analysis for the herbaceous vegetation diversity. However, the LSD test showed that the difference was due to the grasslands' use (higher diversity for mown plots than for grazed) and not to the farming system (Table 3). There is no particular specification in the PDO device concerning the cheese producers' forage practices and we found various degree of intensification among each system. There was the same proportion of organic farming (1/3) for milk and cheese producers, and the latter were divided equally into systems supposed to be positive or negative for biodiversity. Nevertheless, although there were similar means for both systems, we noticed that cheese makers had no poorly diversified herbaceous vegetation (no mark under level 3) for the mown pastures, in contrast to the milk producers. This is perhaps a sign that they pay some more attention to grasslands' floristic composition in relation with the quality or the image of their product.

Table 1. Average diversity level for conventional and organic plots

Biodiversity component	Mown Conventional	Mown Organic	Grazed Conventional	Grazed Organic	*P*-Value
Flora-Landscape elements	4.6^{ab}	4.3^{a}	4.8^{ab}	5.0^{b}	0.20
Flora-Herbaceous vegetation	3.8^{b}	4.7^{c}	2.3^{a}	3.7^{b}	0***
Fauna-Birds	2.6^{a}	2.0^{a}	4.0^{b}	2.8^{ab}	0.03*
Fauna-Butterflies	1.6^{a}	2.3^{ab}	2.5^{b}	2.8^{b}	0.03*
Fauna-Orthopterans	3.7^{a}	3.7^{a}	4.2^{a}	4.2^{a}	0.55

Diversity level from 1 (low level) to 5 (high level), *P*-value of the variance analysis: *** $P < 0.001$, ** $P < 0.01$, * $P < 0.05$, $^{a, b, ab}$ results of the LSD test for each diversity component, a same letter (in a line) means that there is no statistical difference between data

Table 2. Herbaceous vegetation indicators for conventional and organic plots

Herbaceous vegetation indicators	Mown Conventional	Mown Organic	Grazed Conventional	Grazed Organic	*P*-value
Total species number	37.9^{a}	42^{ab}	39.1^{a}	47.3^{b}	0.08
Mean species number	14.2^{a}	17.4^{b}	12.6^{a}	16.7^{b}	0.0001***
Flower shapes number	12.7^{ab}	14.0^{b}	11.5^{a}	14.3^{b}	0.0122*
Total colour number	8.1^{ab}	9.1^{c}	7.3^{a}	8.6^{bc}	0.003**
Mean colour number	4.2^{b}	5.3^{c}	3.3^{a}	4.5^{b}	0.0000****
Pink, blue, violet colours	7.5^{b}	8.9^{b}	5.6^{a}	7.4^{b}	0.0016**
Butterflies types			2.6^{a}	3.0^{a}	0.4697

P-value and $^{a,b, ab}$ see explanations Table 1

Table 3. Average diversity level of the plots for milk and cheese producers

Biodiversity component	Mown Milk	Mown Cheese	Grazed Milk	Grazed Cheese	*P*-Value
Flora-Landscape elements	4.5^{a}	4.4^{a}	4.9^{a}	4.8^{a}	0.397
Flora-Herbaceous vegetation	4.1^{b}	4.2^{b}	2.5^{a}	3.1^{a}	0.0005***
Fauna-Birds	2.2^{a}	2.5^{ab}	4.0^{b}	3.0^{ab}	0.110
Fauna-Butterflies	1.9^{a}	2.5^{ab}	2.6^{ab}	2.7^{b}	0.109
Fauna-Orthopterans	3.7^{a}	3.7^{a}	4.1^{a}	4.3^{a}	0.513

Diversity level, *P*-value and $^{a, b, ab}$ see explanations Table 1

In conclusion, organic farming seems to have more positive impact on grassland biodiversity than cheese production as far as herbaceous vegetation (species numbers, colours, flowers) is concerned. There are, however, few dairy organic producers in the PDO area and this system should be more supported within the PDO organization. New specifications limiting the grasslands intensification for all systems appeared recently in the Saint Nectaire area, which is a first step for biodiversity conservation.

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Restoration of ruderalized secondary grassland in the National park of Western Carpathian Mountains

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Abstract

The aim of our research over the past five years has been the restoration of ruderalized secondary grasslands (monocoenosis *Urtica dioica*). In particular, we studied positions with soil eutrophized by high excrement inputs caused by long-term (daily, over several seasons) overnight lairage of heifers (1240 m a.s.l.). We studied two experimental variants and a control: 1) an originally ruderalized variant treated by introduction of 18 autochtonous species of plants, with 2 mowings per vegetation period; 2) a plain ruderalized variant with 2 mowings per vegetation period without the species introduction treatment; and 3) a control variant of heifer-grazed pasture without ruderalization. The variants were evaluated by analysis of soil, floristic composition and evaluation of grassland quality (E_{GQ}). The main results show a significant reduction of the high K content and reduction of the C:N ratio in soil depths up to 200 mm. Proportion of the *Poaceae* family increased to 53%, which was dominated by *Trisetum flavescens* (16%) and *Phleum pratense* (14%). Similarly, the proportion of the *Fabaceae* family increased to 24% with the dominance of *Trifolium repens* (20%). The overall quality of the treated variant increased by almost twofold in comparison with the control.

Keywords: Western Carpathian Mts., National Park, ruderalized secondary grassland, eutrophic soil, restoration

Introduction

Walachians coming from Wallachia (Romania), as listed by Brătianu (1980), have inhabited the Carpathian Mts. in Slovakia from the 14th to 17th centuries. They deforested mountain pastures (secondary grasslands), which are still maintained currently. They brought with them a typical traditional system of animal breeding, which is still used now. Animals are lairaged for the night in the enclosures near a water source. Above-ground phytomass in such stands is mostly comprised of ruderal vegetation, often with the dominance of *Rumex obtusifolius* and *Urtica dioica* and the soil in such places features a high content of potassium (Novák, 2008). The objectives of our research were, firstly, to restore the pastures that had overmanured soil and ruderal plant species, and subsequently to accelerate their succession, and finally to gradually return them to their original state.

Material and methods

The experimental area Pod Ploskou (1240 m a.s.l.) is situated in the National Park Veľká Fatra. Experimental plots were established in a carefully chosen area of former sheepfold (abandoned ground with monocenoesis *Urtica dioica* L.). The soil in the area is of cambisol type (KMm) and pH is 5.36. Mean annual temperature during the growing season (IV.-X.) is 9°C. Mean annual precipitation is 800-900 mm. Slope inclination of the ground is from 5 to 10 degrees, with south-east exposure. The experiment was set up in 3 variants, with 3 replicates (size of each plot was 15 m²):1) an originally ruderalized variant (*Urtica dioica*) treated by introduction of 18 autochtonous species of plants with 2 mowings per vegetation period; 2)

a plain ruderalized variant treated only with 2 mowings per vegetation period without any other treatment, and finally 3) a control variant of heifer-grazed pasture without ruderalization. In variant 1, an application of herbicide Roundup Bioaktiv (3 l ha^{-1}) was carried out three weeks before sowing, in accordance with approval of Ministry of Environment of the Slovak Republic. The mixture of seeds were sown by hand in the third week of August 2004 (6 species of grass, 3 species of legumes and 9 species of other herbs, sowing total rate was 3.44 g m^{-1} (Table 1). In springs of the following years, before the vegetation and after the last mowing in the autumn, samples of soil were collected by a Kopecký roller from the depths of 0-100 mm and 101-200 mm in three repetitions, to determine: available P and K contents in mg kg^{-1} (by Mehlich III), and C:N ratio.
Floristic composition of the plots was a basis for calculation of 'Evaluation of grassland quality' (E_{GQ}) according to Novák (2004). The values are obtained by the formula $E_{GQ} = \Sigma(D*FV)/8$ (D - dominance - cover of plant species in %, FV - Forage Value) based on the coverage of individual plant species and their forage values. Value of E_{GQ} is on the scale from 0 to 100 points.

Results and discussion

After five years from clearage of Urtica dioica and sowing 18 autochthonous species, the variant 1 had the best representation of high-value species from this family, in particular, *Phleum pratense* (14%), *Festuca pratensis* (4%), *Dactylis glomerata* (3%) and *Trisetum flavenscens* (16%). The *Fabaceae* family increased its percentage proportion to 24%; of that *Trifolium repens* covered 20%. The families of other herbs increased their proportion to 24%. This variant showed the most significant changes: of the other reseeding herbs, the highest recorded presence was for *Achillea millefolium* (3%) and *Plantago lanceolata* (2%). In the control variant, the average total number of recorded plant species for all replicates was 59.
Over five years the proportion of *Urtica dioica* in variant 2 decreased from 100% (2004) to 21% (2008). In the family *Poaceae*, we recorded over five years an increase of *Poa trivialis* to 48%. From the other herb families: *Ranunculus repens* (12%), *Rumex obtusifolius* (8%) and *Taraxacum officinale* (5%). In a similar experiment, Zaller (2006) reported similar results of coverage of families *Poaceae*, *Fabaceae* and other herbs.
Statistically highly significant differences in P and K content in soil was confirmed in all analysed variants and years. The most significant decrease of these elements was reflected in variant 1. The content of P decreased from 0.27 g kg^{-1} to 0.12 g kg^{-1} at depth 0-100 mm and from 0.25 g kg^{-1} to 0.12 g kg^{-1} at depth of 0-200 mm over the years. The most significant changes were recorded in assessing the content of K in the soil. Its content decreased from 0.92 g kg^{-1} to 0.33 g kg^{-1} at depth 0-100 mm and from 0.86 g kg^{-1} to 0.29 g kg^{-1} at depth of 0-200 mm. The content of P and K in the soil at the depths 0-200 mm gradually decreased due to uptake of nutrients from the soil by plants and removal as mowings. Similar results were published by Badia *et al*. (2008).
Content of P and K in the soil was significantly lower at the beginning of the assessment. There were statistically highly significant differences confirmed in assessing the C:N ratio in individual variants over the years. Ratio of C:N decreased at a depth of 0-100 mm from 11.88 to 9.00, and at 0-200 mm from 11.43 to 8.98.
The value of E_{GQ} in the sown variant increased from 12.50 to 79 and was the highest among the examined plots. In the two-times-mown variant its value increased from 12.50 to 31.14 on a scale of 100 points. Semi-natural grazed grassland (control variant) reached the maximum value of E_{GQ} 47. Increase in values of E_{GQ} values in the first and second variant was accompanied by a statistically significant decrease of P and K in the soil - in contrast to the

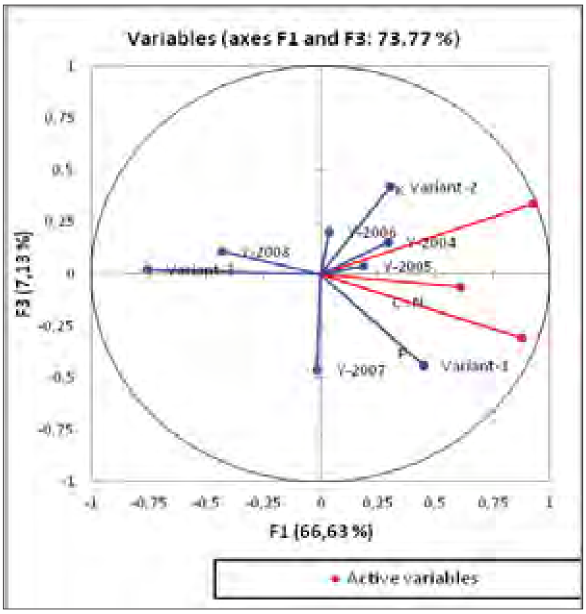

Figure 1. Ordination diagram of impact of variant, the depth of content of K, P and C:N ratio in years (Y) of research.

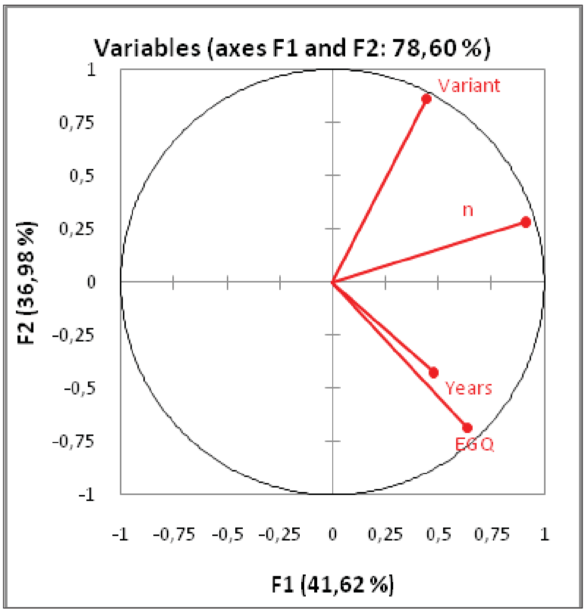

Figure 2. Ordination diagram of impact of variant, species of plants on value of E_{GQ}

control variant, in which we found the lowest value of K, without significant changes during the reporting period.

Conclusion

Introduction of seeds of autochtonous species by sowing and two mowings (variant 1) during the vegetation period 2004-2008 dramatically improved conditions in the soil and above-ground phytomass compared with variant 2 (with only 2-times mowing), where the changes took place much slower. Nutrient ratios improved in the soil as well: P content decreased twofold, K content decreased 2.79 times. Our experiment shows that resowing leads to a rapid restoration of grasslands to their original semi-natural state with high species diversity.

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Poster Presentations

Edible plant species in rangeland ecosystems of Crete, Greece

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Abstract

A large number of plant taxa exists in the rangelands of Greece and most provide feed for livestock and wild life. Many rangeland plants are used for ornamental purposes, in turfgrasses for aesthetic and functional reasons, in medicine, in apiculture, as energy plants and for reclamation of disturbed areas. The native taxa of rangelands have been part of the human diet since prehistoric times. Some species were improved and became crops with agricultural development; others were abandoned over time, while some others are still used in various local cuisines. The increasing interest in the Mediterranean diet will probably raise the demand for edible wild plants that have been a part of this diet. The objective of this study was the investigation and the report of the wild edible plants of rangeland ecosystems in the island of Crete, Greece. Besides the well known *Taraxacum* spp., many other wild edible plants exist in various rangeland types, like *Asparagus acutifolius*, *Asphodelus aestivus*, *Cynara cornigera*, *Sonchus oleraceus* and *Papaver rhoeas*.

Keywords: gastronomy, Mediterranean cuisine, Mediterranean diet

Introduction

The main use of the rangeland plant taxa is forage production for livestock. They also serve as the feeding source for the wild herbivores. Many of these species can be used for ornamental purposes, in lawns as well as for restoration of disturbed places (Koukoura, 2004). In addition, native taxa of rangeland ecosystems have constituted a significant part of the human diet since prehistoric time. Agricultural development 13,000 years ago resulted in the improvement of some of these species as crops. However, this procedure led also to the reduction of the number of species of plants in the human diet. Nowadays, only 3,000 species are cultivated among the 500,000 taxa that exist worldwide (Diamond, 2002). Nevertheless, wild edible plants continue to contribute to human diet in many developing countries, especially in periods of crisis (Balemie and Kebebew, 2006). In the Mediterranean region, wild plants are traditionally used in various local cuisines (Hadjichambis *et al*., 2008). The gastronomic interest in the Mediterranean cuisine has increased as the benefits of the Mediterranean diet have become widely recognised. The conservation of the use of wild edible plants has gained interest in this context. Unfortunately, there is limited information concerning the use of these plants as their systematic report is recent and mainly in ethnobotanical researches.

The objective of this study was the investigation and the report of the wild edible plants of rangeland ecosystems in the island of Crete, Greece.

Materials and methods

Phytosociological data were used for the report of the wild edible plants that existed in rangeland ecosystems of Crete. For the creation of the database published (Barbero and Quézel, 1980; 1989; Gehu *et al*., 1987; Gehu, 1991) and unpublished relevés were used. The data set (443 releves) was classified, through JUICE v. 7.0 (Tichý, 2002) software, using TWINSPAN analysis (Hill, 1979), and rangeland ecosystems were distinguished with the use of diagnostic taxa according to Mucina (1997). A total of 198 native taxa were found. A review of the literature followed in order to investigate the edible uses of these taxa in Crete.

Results and discussion

Among the native taxa which exist solely in the rangeland ecosystems of Crete, twenty are edible (Table 1). Six of them are small woody shrubs (phrygana) and fourteen are annual or perennial herbs. Most belong to Compositae and Labiatae families. Leaves are the main edible parts of plants and are consumed boiled or raw in salads, cooked with olive oil, fried or in pies. *Taraxacum* spp., *Capsella bursa-pastoris*, *Centaurea raphanina* ssp. *raphanina*, *Picris echioides*, *Sanguisorba minor*, *Sonchus oleraceus* and *Tordylium apulum* are species used as leaves (Psilaki and Psilakis, 2004; Alibertis 2006). In addition to its leaf consumption, the flowers of *Cynara cornigera* are used this way too. In some species, like *Asparagus acutifolius* and *A. aphyllus*, the edible parts are the stems that are boiled or usually included in omelettes (Psilaki and Psilakis, 2004). The edible parts of *Asphodelus aestivus* and *Scorzonera cretica* are their roots. They are eaten boiled or cooked with olive oil (Alibertis, 2006). The seeds of *Papaver rhoeas*, flowers of *Carthamus lanatus* as well as the flowered aerial parts of *Origanum vulgare* and *Satureja thymbra* are used as spices (Alibertis, 2006).

Table 1. Wild edible plant species in rangeland ecosystems of Crete, Greece

Species name	Family name	Part Used*	Way of consumption**
Asparagus acutifolius	Liliaceae	St	B, O
Asparagus aphyllus	Liliaceae	St	B, O
Asphodelus aestivus	Liliaceae	R	B, F
Capsella bursa-pastoris	Cruciferae	L	B, C
Carthamus lanatus	Compositae	F	S
Centaurea raphanina ssp. *raphanina*	Compositae	L	B
Coridothymus capitatus	Labiatae	L	B, S
Cynara cornigera	Compositae	L, F	R, B, C
Origanum vulgare	Labiatae	L, F	S
Papaver rhoeas	Papaveraceae	L, S	B, C, P, S
Picris echioides	Compositae	L	B
Prasium majus	Labiatae	St	R, B, C
Salvia fruticosa	Labiatae	L	S, HT
Sanguisorba minor	Rosaceae	L	R, B
Satureja thymbra	Labiatae	L, F	S
Scandix australis	Apiaceae	St, L	HT
Scorzonera cretica	Compositae	R	B, C
Sonchus oleraceus	Compositae	L	B
Taraxacum spp.	Compositae	L	B, F
Tordylium apulum	Apiaceae	L	B, P

* Part used: St = Stem, L = Leaves, F = Flower, S = Seed, R = Root

** Way of consumption: R = Raw, B = Boiled, F = Fried, C = Cooked with olive oil, HT = Herbal tea, S = Spice, O = in omelettes, P = in pies

The consumption of wild edible plant taxa has important benefits to human health. Vardavas *et al*. (2006) have reported that the wild edible plants of the Cretan diet are valuable resources of vitamins, antioxidants, monounsaturated and essential fatty acids, thus contributing to good health. Moreover, it has been reported that some of these species are used in traditional medicine (Vokou *et al*., 1993). The edible uses of many of these species have also been reported for other Mediterranean countries such as Italy (Pieroni *et al*., 2002) and Spain (Tardio *et al*., 2006). Modern lifestyle and urbanization has slowly changed the dietary habits of Mediterranean populations. Many researchers in Greece (Hadjichambis *et al*., 2008), and in other Mediterranean countries (Pieroni *et al*., 2005) reported that only elderly people, mostly farmers, still have the knowledge of the use of wild edible plants. As a consequence, today even fewer of these species are used than in previous decades. However, the significant health benefits of the Mediterranean diet will most probably increase the demand for wild edible plants in the future.

Conclusions

A large number of native wild edible plant taxa exists in the rangelands of Crete. Despite the agricultural development and the modern lifestyle they are still consumed. Further research for the investigation and the report of such species is needed as their use has decreased lately.

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Variation in morphological characters and in rust susceptibility of Northern German *Lolium perenne* ecotypes

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Abstract

Old grassland swards represent a valuable reservoir of genetic variation in forage crops. At eight habitats throughout Schleswig-Holstein, Northern Germany, perennial ryegrass ecotypes were collected and variation in morphology, flowering, and stem-rust susceptibility was quantified. Results of principal component analysis and subsequent multiple comparison tests revealed considerable variation among ecotype populations with respect to dates of ear emergence and flowering, ear length and spikelet number, as well as length and width of flag leaf. Several ecotypes showed resistance to stem rust, yet statistical significant differences among populations could not be verified.

Keywords: perennial ryegrass, ecotypes, morphology, flowering behaviour, rust susceptibility

Introduction

Long-term permanent grassland may provide a valuable source for grass ecotypes adapted to local environmental conditions, showing high variation in phenological development, growth habit and disease resistance. Stem rust (*Puccinia graminis* ssp. *graminicola*) resistance, for instance, is of vital importance in many seed production areas (Pfender, 2009). Studies by Bolaric *et al*. (2005), analysing the molecular genetic diversity of German perennial ryegrass ecotypes and cultivars, were mainly restricted to Southern Germany (Lower Saxony, Hessen, and Bavaria) and they found little variation between ecotypes and cultivars. Information on genetic variation in ecotype populations of Northern Germany is scarce. The objectives of the current study were to quantify the diversity of morphological characteristics, flowering behaviour and susceptibility to stem rust among eight natural populations of perennial ryegrass collected throughout Schleswig-Holstein, Northern Germany.

Materials and methods

Perennial ryegrass populations were collected on eight sites throughout Schleswig-Holstein, which were mostly used as pasture and had not been re-sown for at least 30 years. The collections therefore are regarded as ecotype populations, which have been subjected to natural selection pressure. In early spring 2010, up to 48 plants were taken by hand auger on each site and transferred to pots. Morphological characteristics (ear length [cm], number of spikelets, length of uppermost internode [cm], flag leaf width [cm], flag leaf length [cm]) were measured for the most advanced tiller of a given plant in the first growth. In addition, flowering behaviour (dates of ear emergence and flowering) was recorded. Susceptibility to stem rust was determined by leaf segment tests on leaves of the second regrowth. Mixed spore inocula, collected at 3 sites, were applied to four leaf segments per plant. The inoculated leaves were incubated at 20°C for the first 24 h, and then moved to a growth chamber (22°C, 60% rel. humidity, 16 h light). Disease was visually evaluated according to Beckmann (2010) nine days after inoculation. Principal component analysis (PCA) was conducted on the data of all variables across populations using IBM SPSS Statistics 19. In addition, a Tukey-type test for differences of means of multiple endpoints was conducted using the R statistical package SimComp (Hasler and Hothorn, 2011) by assuming a heterogeneous covariance structure.

Results and discussion

Morphological and phenological characteristics are known to play a major role in determining yield, persistence and forage quality of perennial ryegrass (Hazard and Ghesquière, 1997; Yamada *et al*. 2004; McGrath *et al*., 2010). Average heading date of the ecotype populations varied between 61 and 80 days after April 1st, which may be classified as mid-late to very late with respect to the German cultivar range. Dates of heading and flowering were positively correlated, as expected, with Pearson's r varying from 0.75 to 0.95 among the populations. Additional positive relationships were detected between spikelet number and ear length (0.48 to 0.70), length of flag leaf and ear length (0.39 to 0.76), as well as between length and width of flag leaf (0.48 to 0.82). Flag leaf width was remarkably low, with population averages varying between 0.4 and 0.5 cm. Negative correlations were found for the relations between length of uppermost internode and ear emergence (-0.14 to -0.74), as well as between flag leaf width and ear emergence (-0.01 to -0.77). The ecotype collection thus provided a considerable variation with respect to characteristics influencing reproductive performance (ear length, spikelet number) and forage quality (flowering time, length and width of leaves).
The principal component analysis revealed that three components accounted for 76.2% of the total variability (Comp1: 36.94%, Comp2: 26.8%, Comp3: 12.4%). The distribution of ecotype

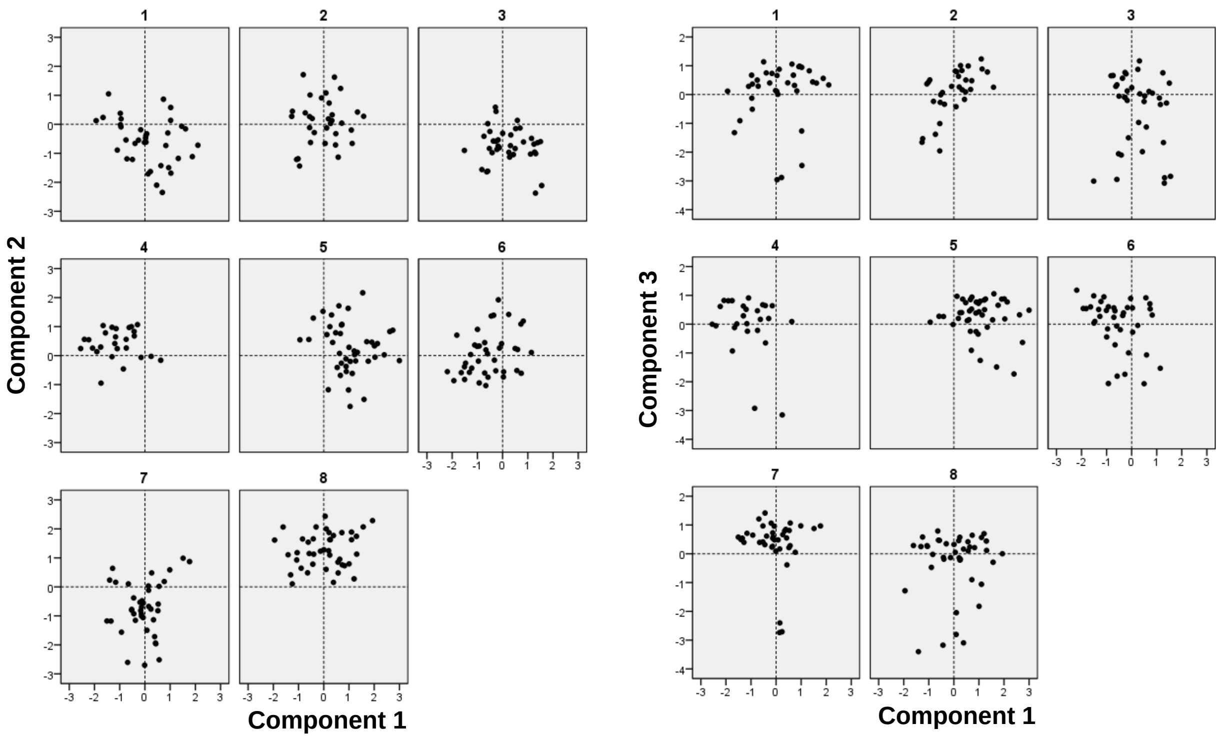

Figure 1. Results of principal component analysis provided as biplots showing separation of the ecotype populations (left) by the first two dimensions, and (right) by dimensions one and three, with the number above the biplots denoting the ecotype populations.

populations in terms of the axes is presented in Figure 1. The main characteristics contributing to Comp1 were morphological characteristics (ear length, spikelet number, length of flag leaf, width of flag leaf, length uppermost internode). With respect to Comp2 the most important variables were the dates of ear emergence and flowering, while susceptibility to stem rust was the main variable contributing to Comp3. When the first dimension was plotted against the second one, a differentiation among the ecotype populations became evident. Populations 4 and 8 were located mainly in the upper part of the biplots, and populations 1, 3, and 7 mainly in the lower part, indicating a different flowering behaviour. Furthermore, population 5 tended towards the right, while populations 4 and 6 were mainly located in the left part, suggesting differences in morphology. When the third dimension was plotted against the first (Figure 1) and second dimension (not shown), differences in the proportion of resistant or less susceptible plants became obvious. Population 3 tended to have a higher share (17.1%) of plants with a susceptibility score ≤ 3.0 on a 1-9 scale compared to the other populations (0-9.5%). The results of the PCA were confirmed by the multiple comparison tests (data not presented). Differences in rust susceptibility among the ecotype populations, however, were not statistically significant.
The results might be confounded with effects of different pre-sampling plant size, plant development and stress reactions with respect to replanting. The within-population genetic variance may be confounded with the environmental variance, which might to some extent limit the validity of the results. Pre-sampling differences in phenology, however, were negligible because of extremely low spring temperature.

Conclusion

The current study revealed a considerable variation in flowering behaviour and morphology among a collection of eight perennial ryegrass ecotype populations. The evaluation will be repeated under field conditions in order to select ecotypes of special interest for future breeding. Ecotypes showing high rust resistance will be subject to molecular analysis.

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Importance and landscape value of legumes on roadsides of the Lublin region

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Abstract

Investigations were designed to determine the legume contribution in roadside verges in respect of their usability for sowing on newly built or modernized roadsides. The studies were conducted at 75 research sites on the sides of provincial, domestic, district and commune roads in the Lublin region. The floristic composition was evaluated by means of the phytosociological method according to Braun-Blanguet. In the roadside verges there were 215 vascular plant species, of which there were 26 legumes. The most frequent legumes were *Trifolium repens*, *Medicago lupulina*, *Trifolium pratense*, *Vicia cracca* and *Vicia sepium* and *Vicia tetrasperma*. The proportion of legumes in roadside verges depended both on the location of the road in the landscape (among cultivated fields, forests or meadows) on the level of soil profile transformation as well as on road traffic intensity.

Keywords: legumes, roadside lawns

Introduction

In the landscape of the Lublin region, the sides of roads (commune, district, provincial and domestic) occupy around 141,560 ha, which accounts to 5.6% of the province area (Statistical Yearbook of the Lublin Province, 2003). They support herbaceous vegetation that tolerates the unfavourable habitat conditions resulting from road use (pollution with combustion gases and heavy metals, petroleum leakage, dust caused by the abrasion of tyres, brake lining and asphalt, occurence of chlorides of sodium and potassium used for combating black ice) as well as fertilizers, herbicides and pesticides (Curzydło, 1995). Furthermore, the soils of roadsides have been seriously transformed in geotechnical, hydrological and geochemical terms. An increased content of many elements in the plants prevents from using this biomass as feed. On the other hand, this vegetation plays numerous beneficial functions in the biocenosis as it protects the roadsides against wind and water erosion, safeguards the water-soil environment of the adjacent areas from pollution caused by road traffic, and it also improves the aesthetical value of the landscape.

The investigations were designed to identify the legume species occurring on the sides of roads in the Lublin region, with a view to assessing their usefulness for sowing on the built or modernized roadsides.

Materials and methods

The investigations were conducted on undeveloped areas in randomly selected research sites on the sides of provincial, national and district roads No. 17, 19, 74, 82, 849 and 835, as well as commune roads in the districts of Lublin, Krasnystaw, Świdnik and Zamość. The roads run through the cultivated fields, forests, meadows and fallows in physiographically diverse

areas (from plains to knolls and hills) distinguished by a rich mosaic of soil types. The traffic density on the commune and district roads (No 849 and 835) did not exceed 200 vehicles per hour, while on roads No 17 and 74 leading to the border crossing points with Ukraine it ranged from 500 to 1000 vehicle per hour. Following the completion of the construction works, the roadsides were not sown with grass seed mixtures. Plant associations occurring on roadsides developed due to the spontaneous appearance of species. The basic source of water for roadside vegetation is provided by precipitation, and the sites are not fertilized. Throughout the growing period the roadside vegetation is cut 2-4 times.
The floristic composition of roadsides was evaluated according to the Braun-Blanquet method in 2004. The ecological indicator values of plants follow Zarzycki *et al*. (2002).

Results and discussion

In the roadside verges 26 legume species were distinguished (Table 1). The following were dominant: *Trifolium repens* (at 28 sites at an amount from + to 10%), *Medicago lupulina* (at 27 sites from + to 10%), *Trifolium pratense* (at 20 sites from + to 10%), *Vicia cracca* (at17 sites from + to 3%), *Vicia sepium* (at 17 sites from + to 5%) and *Vicia tetrasperma* (at 12 sites from + to 15%). The data indicate a considerable tolerance of these plant species to the environmental stress that appears at the roadsides. *Trifolium repens* and *Trifolium pratense* also frequently occurred in the lawns along the streets of Lublin (Harkot *et al*., 1998). These species are resistant to an increased NaCl-content in soil (Zarzycki *et al*., 2002). The following species were recorded in the sward of roadside verges occasionally and in small quantities (< 1%): *Astragalus glycyphyllos*, *Sarothamnus scoparius*, *Vicia angustifolia*, *Vicia dumetorum* and *Vicia pisiformis*.
The highest number of legume species (11-18) occurring at a high proportion (up to 15%) were reported at the rarely modernized roadsides with lower traffic density (roads No 19, 82, 835, 849). All the legume species mentioned above are defined as neutral towards continental conditions (K = 3). Most legume species occurred in the drier habitats (W = 2-3) on mineral-humid soils (H = 2), under mesotrophic and eutrophic conditions (Tr = 3-4) and of neutral and alkaline reaction (R = 4-5). The studies carried out by Jargiełło *et al*. (1996) on the grasslands of the Lublin Upland also proved that soil reaction, as well as P, K, Ca contents in soil affect the occurrence of legume plants.

Conclusions

The investigations showed that the floristic composition of roadside verges was influenced by the location of roads in the landscape (among the cultivated fields, woods or meadows) by the level of soil profile transformation, and by traffic density. The frequent occurrence and high proportion of *Trifolium repens*, *Medicago lupulina*, *Trifolium pratense*, *Vicia cracca*, *Vicia sepium* and *Vicia tetrasperma* in the sward of roadside verges prove the usefulness of these species for the establishment of herbaceous vegetation on roadsides.
The abundance of legume species on the roadsides of the Lublin region, along with the wide range of flower colour, also improves the floristic composition of roadside verges and exerts a beneficial effect on the aesthetic appearance of traffic routes. Furthermore, the occurrence of legume species in roadside verges can contribute to a substantial inhibition of various pollutant contaminations into the soil resulting from road use, and can provide a positive influence on the protection of the environment.

Table 1. Species proportions, climate and edaphic value and numer of releves of legumes species at the roadsides of Lublin region

Legume species	Proportion of the species (range)	Number of releves	Climate value				Edaphic value			
			L	T	K	W	Tr	R	D	H
Astragalus glycyphyllus L.	(+)	1	4	4	3	3	3	4	4	2
Coronilla varia L.	(+)	4	5	4-5	3	2	3	4-5	2-4	2
Chamaecytisus ratisbonensis (SCHAEFF.) ROTHM.	(+)	4	4	4-5	4	2	3	3-5	3-5	2
Lathyrus pratensis L.	(+-2)	5	4	4-3	3	3-4	4	4	4	2
Lathyrus tuberosus L.	(+)	1	5	4-5	3	2-3	3-4	3-5	3-5	2
Lotus corniculatus L.	(+)	5	4	4-2	3	3-4	4-3	3-5	4	2
Lupinus angustifolius L.	(+)	3	5-4	4	3	2-3	3-4	3-4	2-4	2
Medicago falcata L.	(+)	4	5	5-4	3	2-3	3-4	5	2-5	2
Medicago lupulina L.	(+-10)	27	5	4-3	3	2-3	3-4	3-5	2-4	1-2
Medicago sativa L.	(+)	12	5	4-3	3	3	4	3-4	2-4	2
Melilotus officinalis (L.) PALL.	(+)	2	5	4-3	3	2	3	4	3-5	1-2
Sarothamnus scoparius (L.) WIMM.	(+)	1	5	4-3	2	3	3	3	3	2
Trifolium arvense L.	(+)	2	5	5-3	3	2	1-2	3-5	3-1	2
Trifolium dubium SIBTH.	(+-10)	2	4	4-3	3	3	4	4	4	2
Trifolium medium L.	(+-3)	6	4	4-3	3	3-2	3	4	4	2
Trifolium montanum L.	(+-3)	3	4	5-3	3	3-2	3	5-4	4	2
Trifolium pratense L.	(+-10)	20	4	4-2	3	3	4	4	4	2
Trifolium repens L.	(+-10)	28	4	4-2	3	3-4	4	4	4	2
Vicia angustifolia L.	(+)	1	4	4-3	3	3-2	4-3	4-5	4	2
Vicia cracca L.	(+-3)	17	4	4-3	3	3	4	4-5	4	2
Vicia dumetorum L.	(+)	1	3	4	3	3	4	4	4	2
Vicia articulata HORNEM.	(+)	2	4	4-3	3	3-2	4-3	4-5	4	2
Vicia pisiformis L.	(+)	1	3	4	3	2-3	3	5-3	•	•
Vicia sepium L.	(+-5)	17	4-3	4-2	3	3	4	4-5	4	2
Vicia tetrasperma (L.) SCHREB.	(+-15)	12	5	4	3	3	4-3	3-4	2-4	2
Vicia villosa ROTH.	(+)	6	5	4-3	3	3	4-3	4	3-4	2

'+' = proportion of the species in quantity < 1%, 1-2 - means that a species grows within 1-2

L = light value: 1 - deep shade, 2 - moderate shade, 3 - half-shade, 4 - moderate light, 5 - full light

T = temperature value: 1 - coldest regions in the country, 2 - moderately cold areas, 3 - moderately cool climatic conditions, 4 - moderately warm climatic conditions, 5 - warmest regions and microhabitats

K = continentality value: 1 - Atlantic species, 2 - Sub-atlantic species, 3 - species with no continentality preference, 4 - sub-continental species, 5 - continental species

W = soil moisture value: 1 - very dry, 2 - dry, 3 - fresh, 4 - moist, 5 - wet, 6 - aquatic

Tr = trophy value: 1 - soil extremely poor (extremely oligotrophic), 2 - soil poor (oligotrophic), 3 - soil moderately poor (mesotrophic), 4 - soil rich (eutrophic), 5 - soil very rich (extremely fertile)

R = soil (water) acidity (pH) value: 1 - highly acidic soils (pH < 4), 2 - acidic soils (pH 4-5), 3 - moderately acidic soils (pH 5-6), 4 - neutral soils (pH 6-7), 5 - alkaline soils, (pH > 7)

D = soil granulometric value: 1 - rocks and rock crevices, 2 - rock debris, scree, gravel, 3 - sand, 4 - argillaceous clay and dusty deposits, 5 - heavy clay and loam

H = organic matter content value: 1 - soil poor in humus, organic matter, 2 - mineral-humid soil, 3 - soil rich in organic matter.

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Barren fallows as small areas with potential for increasing grassland biodiversity

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Abstract

Artificially established barren sites in the Podyjí National Park (Czech Republic) are studied as a sustainable ways to increase biodiversity in grasslands. Permanent plots in a) periodically disturbed barren site, b) plot with spontaneous succession and c) neighbouring managed meadow were established. We confirmed that barren sites help many plant species to reproduce from the soil seed bank and finish their life-cycles. The results of analyses of phytosociological relevés show differences in both the species composition and the number of species between nutrient-poor and nutrient-rich sites. Significant differences were also found among plots in different successional stages. From the point of view of nature conservation, no massive occurrence of invasive and expansive species was found. Species commonly found in cultivated landscapes, field margins and ridges prevailed, but we found also plant species that had been missing in the national park for many years.

Keywords: grasslands, barrens, succession, vegetation, diversity, management

Introduction

During the last century natural grasslands in Europe have faced a loss of area and increased isolation of their remaining fragments, which is linked to cessation of proper management and an increased load of nutrients (Pärtel *et al*. 2005). Strong decrease of biodiversity in semi-natural grasslands, hedges, hollows and steppe plots is connected with intensification of agriculture and abandonment of traditional management. Habitat fragmentation leads to the loss of connectivity, having a strong impact on decrease in the species richness, changes in soil nutrient availability, and increased in litter deposition and reduced light availability at the community level (Soons, 2003). It leads to a decrease in seed production and viability and to the low availability of pollinators as a result of genetic erosion inside small populations. Age, management history and isolation of grasslands from human influence play a crucial role in the recent state of species richness both above (in the vegetation) and below ground (in the soil seed bank). The spreading of some extensive agricultural species into the biotopes of barren sites and fallows has been observed. Only a few works related to these problems have been published (Chytrý *et al*., 2001; Hofmann and Isselstein, 2004).

Materials and methods

The Podyjí National Park, located in the southern part of the Czech Republic, was chosen as the study site. Ten experimental sites of barren areas in different vegetation types - dry grasslands (*Koelerio-Phleion phleoidis* Korneck 1974) and mesic ones (*Arrhenatherion elatioris* Koch 1926) - were chosen. Three treatments were tested in 2009 and 2010: (A) ploughing every year, (B) ploughing once and following spontaneous succession; (C) control plot (meadow). In each treatment 5 permanent plots of 4 m×4 m were chosen to record the actual vegetation. Twice a year in 2010 (May and August) phytosociological relevés using Braun-Blanquet scale were collected and recorded into TURBOVEG database (Hennekens and Schaminee 2001). Spring and summer sets were created and compared. In CANOCO software (Ter Braak and Šmilauer, 2002) canonical correspondent analysis was used: locality was selected as covariable, environmental variables were ABC treatments mentioned above. 499 permutations under reduced model were chosen. The nomenclature of plant names follows Kubát *et al*. (2002).

Results and discussion

The spring and summer CCA ordination plots (Figure 1 and 2) show significant diversity in the obtained data. Differences between the spring and summer relevés were also observed. Ploughing plots (Treatment A) were characterised by species like *Raphanus raphanistrum*, *Thlaspi arvense*, *Sinapis arvensis*, *Lamium amplexicaule*, *Chenopodium album* agg., etc. In summer more species occurred: *Echinochloa crus-gallii*, *Persicaria lapathifolia*, *Setaria viridis*, *Polygonum aviculare* agg., etc. Spontaneous succession (Treatment B) was characterised by *Rumex acetosa*, *Stellaria graminea*, *Convolvulus arvensis*. In summer *Rumex obtusifolius*, *Lamium album*, *Agrostis gigantea*, *Potentilla argentea*, *Elytrigia repens* were found. Meadow plots (treatment C) were differentiated by: *Avenula pubescens*, *Festuca ovina*, *Ranunculus acris*, *Lotus corniculatus*, *Plantago media*, *Trifolium pratense*, *Poa pratensis*, *Calamagrostis epigejos*, *Trisetum flavescens*, *Dactylis glomerata*, *Hieracium sabaudum*, *Veronica chamaedrys* agg., etc..

Rapid development of a herb layer was observed: in May the coverage of herb layer reached 60%, in August it was up to 95%. A significant difference was found in the number of species (16-45 per plot) and their coverage (May 30-70%, August 60-100%) between nutrient-poor and nutrient-rich sites. No massive occurrence of invasive and expansive species was recorded. Species commonly found in cultivated landscape, field margins and ridges prevailed. Barren sites and especially fallows helped many ephemeral plant species to reproduce from the soil seed bank. After the ploughing of meadows some rare and endangered species, which had survived in the soil seed bank, appeared again: *Thymelaea passerina*, *Adonis flammea*, *Bupleurum rotundifolium*, *Valerianella rimosa*, *Tordy-*

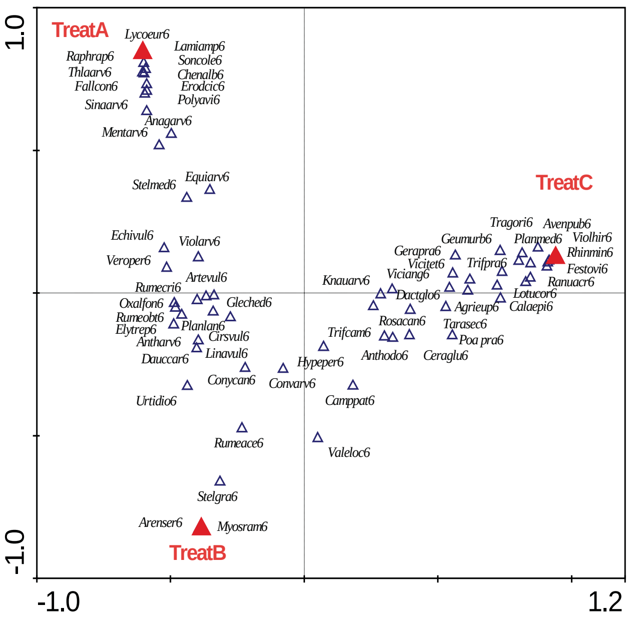

Figure 1. CCA analysis of spring relevés (*P*-value 0.0020 F-ratio = 9.48)

Axes		1	2	3	4	Total inertia
Eigenvalues		0.566	0.146	0.507	0.462	8.632
Species-environment correlations		0.980	0.843	0.000	0.000	
Cumulative % variance of species data		6.8	8.5	14.6	20.2	
of species-environment relation		79.5	100.0	0.0	0.0	
Sum of all	eigenvalues					8.339
Sum of all canonical	eigenvalues					0.712

Axes	1	2	3	4	Total inertia
Eigenvalues	0.561	0.092	0.497	0.440	8.526
Species-environment correlations	0.975	0.709	0.000	0.000	
Cumulative % variance of species data	6.8	7.9	14.0	19.3	
of species-environment relation	85.9	100.0	0.0	0.0	
Sum of all eigenvalues					8.216
Sum of all canonical eigenvalues					0.652

lium maximum, *Filago lutescens*, *Alcea biennis*, *Ajuga chamaepitys*, *Hyoscyamus niger*, etc. The species *Pseudognaphalium luteoalbum* was found (germinating from the cultivated soil sample) as a new species for Podyjí NP. When we compare the number of species per plot, we find significant differences, favouring disturbed plots, especially in summer. Many characteristic species (mentioned above) were observed. It supports the idea that barren areas have a positive effect on biodiversity.

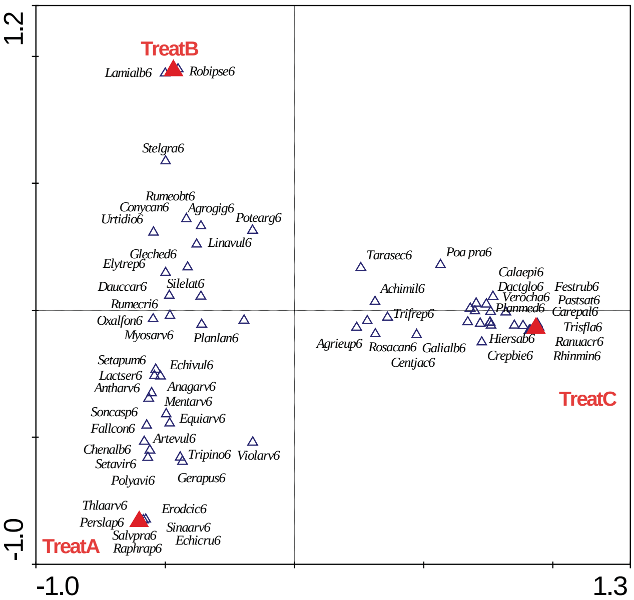

Figure 2. CCA analysis of summer relevés (*P*-value 0.0020 F-ratio = 9.55)

Conclusions

Barren sites enable ephemeral plant species to reproduce from the soil seed bank. The rapid development of a herb layer was observed, depending on climatic conditions during the seasons. Significant differences were recorded in the number of species and their coverage between each treatment, especially in summer. Species commonly found in cultivated landscape, field margins and ridges prevailed, while invasive or expansive plants were suppressed.

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Combustion of grassland biomass: Effects of species richness and functional groups on energy parameters

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Abstract

The generation of energy from semi-natural grasslands can be an alternative to the practice of reseeding for fodder production and is a measure for protecting unique plant communities. A possible path of generating energy from such grasslands can be the combustion of hay. Little is known about the linkages between increasing plant diversity or the presence of functional groups on energy parameters relevant for combustion. In this study, changes in higher heating value (HHV), two fuel-quality parameters and gross energy yield (GE) along a well-defined diversity gradient (1-60 species) were investigated. Furthermore, the effects of functional-group presence on these parameters were tested. It was found that increasing diversity did not affect HHV or ash content, while GE increased by 108% from a one-species plot to a high-diversity 16-species plot. Nitrogen (N) content decreased with increasing species richness. The presence of legumes had a positive effect on both HHV and GE. N concentrations exceed recommended thresholds and need to be considered before combustion.

Keywords: ash, combustion, energy, fuel quality, species richness, functional groups

Introduction

Semi-natural grasslands, originally used for animal nutrition, have many ecosystem functions and are known to be hotspots of biodiversity in rural areas. However, their species diversity is expected to decline. Causes for this loss are the changes in land use, either through intensification or abandonment. In developed countries, fodder quality of mown herbage from semi-natural grassland is becoming less suitable for animals with high milk and meat performance, leaving the farmer with the options to either intensify the grassland management, or to retreat from it. For some regions in central Europe it has been estimated that up to one quarter of permanent grassland will be abandoned in the near future as part of that change. This leads to a surplus of permanent grassland that requires management of at least one cut per year if its richness in flora and fauna is to be protected. As the biomass is not suitable for animal nutrition it is available for energy production. Combustion of extensive grassland biomass was considered a promising conversion technique both in terms of greenhouse gas emissions and maintaining biodiversity. The focus of this study is on the linkages between diversity parameters (species richness, functional group presence) and energy parameters (HHV, GE) as well as fuel quality parameters (ash and N content).

Materials and methods

In May 2002 a semi-natural mesophilic grassland was established in the floodplain of the River Saale (near Jena, Germany, 130 m a.s.l.). 60 plant species were used to create a gradient in plant species richness (1, 2, 4, 8, 16, 60) and in functional-group richness (1, 2, 3, 4). Functional groups were grasses, small herbs, tall herbs and legumes. 82 plots were established on four blocks, the blocks accounting for the differences in soil texture. 16 possible combinations of species richness and functional-group richness were realized and replicated over the four blocks. The location of the mixtures within each block was fully randomized. Management of the site was two cuts per year (late May and late August) and no application of fertilizer. Plots were weeded twice a year. The experimental setup is described in full detail in Roscher *et al*. (2004). Above-ground biomass was harvested twice in the years 2008 and 2009 just before the first and second cut. Carbon (C), hydrogen (H) and N content of the biomass was analysed using an elemental analyser. The HHV was calculated based on C, H and N concentrations with the empiric equation for biofuels from Friedl *et al*. (2005). GE was calculated as the product of HHV and biomass. Statistical analyses were conducted by analysis of variance with sequential sum of squares (Schmid *et al*., 2007), in which effects of variables can be identified independent of what was fitted before. Thus, block is fitted first to account for the variation due to management and differences in soil so that the later fitted terms are independent of the block effects. The 60-species plots were used as a point of reference for highest possible diversity but were not included in the statistical analysis. Two plots (both SR = 1) had to be omitted.

Results and discussion

The HHV is the amount of heat released during combustion. The range of HHV measured in this study was between 16.3 and 19.2 MJ kg^{-1} DM with an overall mean of 18.13 MJ kg^{-1} DM. The mean value is slightly lower than that of Miscanthus (19.1 MJ kg^{-1} DM) (Hartmann, 2009). The statistical analyses (Table 1) show that increased species richness did not affect HHV, while the presence of legumes had a significantly positive effect. The presence of legumes also had a significantly positive effect on C content (data not shown) which affects HHV directly (Friedl *et al*., 2005). Furthermore, legumes may have a positive effect on HHV due to their increased lignin content (data not shown). Lignin is known to have a carbon content of 640, as compared to cellulose with 420 g kg^{-1} DM.

As there was no effect of SR on HHV, the strong positive correlation between SR and GE (Table 2) is due to increasing biomass. Furthermore, legumes had a significantly positive effect on biomass (data not shown) and thereby GE. The positive effect of legumes on biomass and GE is related to their ability to fix atmospheric N via symbiotic root bacteria which are released into the soil as part of their decomposition The increase in GE from a one-species plot (56 GJ ha^{-1} yr^{-1}) to a high-diversity 16-species plot (116 GJ ha^{-1} yr^{-1}) was on average at 108%, and up to 172% from a one- to a 60-species plot (152 GJ ha^{-1} yr^{-1}).

Ash is the physical remnant after combustion and is negatively correlated with HHV (Hartmann, 2009). The ash content amongst the species mixtures was not affected by SR (Table 1) and had a wide range of 53 to 220 g kg^{-1} DM across the two years with an overall mean of 94 g kg^{-1} DM. Ash content was positively affected by the presence of herbs. This is in line with the findings of Tonn *et al*. (2010). Other substrates used for energy production, e.g. biomass from grass verges, can have ash contents of up to 231 g kg^{-1} DM (Hartmann, 2009). High ash contents are problematic for the combustion process. Common problems with ashes from grassland biomass are, e.g., slagging in the furnace and corrosion of metal parts, which can reduce the plant's lifespan (Obernberger *et al*., 2006).

N contained in vegetation has a major role during combustion as it is the source of undesired NO_x emissions. N concentrations ranged from 9 to 38 g kg^{-1} DM (overall mean of 19 g kg^{-1} DM), compared 7.3 g N kg^{-1} DM for Miscanthus (Hartmann, 2009). N concentrations were significantly affected by SR (Table 1) and declined, from the lowest to the highest species mixture, by 14% in the first cut and 18% in the second cut. However, N concentrations were above the critical level of 6 g kg^{-1} DM as suggested by Obernberger *et al*. (2006).

Table 1. Analysis of Variance of higher heating value (HHV), ash and nitrogen (N) content as function of species richness (SR) and presence/absence of individual functional groups. First and second cut were analyzed separately. Arrows indicate increase (↑) or decrease (↓) with presence of respective functional group or with increasing species richness.

			HHV (MJ kg^{-1} DM)			Ash (g kg^{-1} DM)			N (g kg^{-1} DM)		
	Factor	DF	SS	F	P	SS	F	P	SS	F	P
1st cut	Block	3	0.7	5	0.003	573	3	0.038	81	2	0.182
	Log (SR)	1	0.1	1	0.261	205	3	0.079	51	3	0.082↓
	Legumes	1	0.7	15	<0.001↑	<1	<1	0.997	218	13	<0.001↑
	Grasses	1	0.5	12	0.001↓	821	13	0.001↓	396	24	<0.001↓
	Tall herbs	1	0.1	3	0.090	489	8	0.008↑	13	1	0.367
	Small herbs	1	0.1	2	0.202	857	13	0.001↑	9	1	0.453
	Residuals	67	3.0			4321			1087		
2nd cut	Block	3	0.6	2	0.157	3845	5	0.005	56	2	0.149
	Log (SR)	1	<0.1	<1	0.598	972	4	0.064	116	11	0.001↓
	Legumes	1	2.4	22	<0.001↑	1749	6	0.014↓	804	79	<0.001↑
	Grasses	1	0.1	<1	0.493	266	1	0.328	76	7	0.008↓
	Tall herbs	1	0.2	2	0.221	1542	6	0.020↑	14	1	0.246
	Small herbs	1	0.6	6	0.022↓	786	3	0.095	99	10	0.003↓
	Residuals	67	7.3			18317			678		

		GE (GJ ha^{-1} yr^{-1})		
Factor	DF	SS	*F*	*P*
Block	3	3883	2	0.155
Log (SR)	1	28443	40	<0.001↑
Legumes	1	11160	16	<0.001↑
Grasses	1	285	0	0.531
Residuals	69	49615		

Table 2 (left). Analysis of Variance of gross energy yield (GE) as function of species richness (SR) and presence/absence of legumes and grasses. Arrows indicate increase (↑) or decrease (↓) with presence of respective functional group or with increasing species richness.

Conclusions

Species richness has a positive effect on GE and positive effect on fuel quality by decreasing N content. Legumes play an important role for increasing HHV and GE. High ash and N values require treatment of the fuel to improve fuel quality and enhance the combustion process.

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Validation and promotion of biodiversity in Alpine pastures

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Abstract

Switzerland and the international community have a high responsibility to save biodiversity in Alpine regions. Current changes in the Alpine economy have negative consequences for biodiversity. The mission of federal authorities is to preserve and promote biodiversity through agricultural practices. While in lower regions some tools exist for the preservation and promotion of biodiversity in grassland, as yet no suitable tools have been developed for Alpine pastures. With regard to a future funding scheme, a practical pilot concept should be developed: how can biodiversity be assessed, measured and controlled in a simple, but sufficiently differentiated way? Using a combination of scientific principles and the broad expertise of professionals from Alpine economy, grassland management, vegetation mapping and nature conservation, a pilot concept was developed based on existing tools. The pilot concept was applied and tested on different Alpine pastures. Key elements include assessment of plant communities and the quantity and quality of landscape features. The exact procedure with the criteria will be refined during the period until the planned launch in 2014.

Keywords: ecology, biodiversity, landscape, Alpine pastures, funding scheme

Introduction

Preservation and promotion of biodiversity by the means of agricultural practices is one of the missions of the Swiss federal authorities. As the prevailing view was, until recently, that biodiversity is mainly under pressure in the lower region, while being in an excellent state in the higher region, Switzerland has focused the initial development of a funding scheme for different habitats, including grasslands, on the lower region. However, the current changes in Alpine economy - less labour, centralisation of buildings, intensification of nearby pastures and, at the same time, undergrazing or abandonment of distant and steep pastures - also have negative consequences for biodiversity in higher regions. At the same time these processes also lead to landscape changes with negative consequences for tourism.
Based on these trends the Swiss authorities decided to develop a funding scheme for Alpine pastures, too. As a first step AGRIDEA was charged to conduct a feasibility study (Schiess *et al*., 2008), addressing the question: Which criteria and which method can be used for assessing, measuring and controlling the ecological and landscape value of Alpine pastures? The proposed concept should be based on existing criteria and the methods should be simple to apply in large areas as well as easy to understand by farmers.

Methodology

Plausible criteria and methods for a funding scheme for Alpine pastures were elaborated, based on existing tools for the preservation and promotion of biodiversity in lower regions, the expertise of professionals in Alpine management, agricultural extension and nature conservation, as well as scientific principles. The resulting pilot concept was adapted and further developed in an iterative process by:

- Consulting representatives of Alpine economy, grassland management, vegetation mapping, nature conservation and government officials.
- Applying the method in 9 regions in the Alps differing in size between 32 ha and 1100 ha, in species of grazing animals (cows, cattle and sheep) and in altitude (1300 m to 2580 m a.s.l) including the assessment of the so-called natural value of Alpine pastures with a point-based system.
- Discussing the results of the test with several stakeholders in agricultural extension, inspection and implementing organizations and adapting the pilot concept.

The aim of this continuous and participatory process involving different views was to ensure a tool which is broadly accepted, realizable and suitable.

For preparation and implementation of the tests in the 9 Alpine regions the following documents were necessary: Orthophotos, aerial photographs, assessment forms and if available management plans or inventories of habitats. Further maps with different scales are necessary in order to mark the surfaces of natural value. The assessment of one region took about one day and was made between the beginning of July and end of August.

Results and discussion

The criteria for entering into the planned funding scheme for the preservation and promotion of biodiversity and landscape in Alpine regions was the fulfilment of the ordinance of Alpine pasture. It provides direct payments, regulates nutrient import, as well as number and species of animals. Apart from that, participation in the funding scheme should be voluntary. The developed practical pilot concept included assessment of single surfaces and landscape value of the whole alp. As the landscape topic is now pursued in a separate programme throughout Switzerland, it is not presented here. The natural value of a single surface considered three criteria: (1) vegetation, (2) structures, and (3) difficulty in management.

For criteria 1 a simple system based on 3 classes of vegetation quality was introduced and tested, as a precise mapping of plant communities (Dietl *et al*., 1981) and it proved to be unsuitable and too time consuming:

Quality class 1 included the inventoried and protected natural areas (moor, dry nutrient-poor meadows and pastures etc.) and highly species-rich, nutrient-poor pastures. These surfaces were valued with three points.

Quality class 2 comprised species rich, nutrient-poor pastures and highly species-rich, nutrient-rich pastures. They were valued with two points.

Quality class 3 comprised species-poor, nutrient-poor pastures and species-rich, nutrient-rich pastures. They were valued with one point.

All pastures above the tree line (Welten and Sutter, 1982) were counted with one point because the risk of deterioration of vegetation is very small.

Surfaces covered with shrubs, screes and weeds (so called foreign vegetation) were deducted; however, only if the coverage by dwarf shrubs or screes was higher than 20%, by green alders (*Alnus viridis*), Mountain pines (*Pinus mugo* ssp. *mugo*) or highly nutrient-rich surfaces with cover of weeds higher than 10%.

The assessment of the vegetation value during the tests showed the following results: the proportion of high quality vegetation reached 10-20% in 3 alps, 40-70% in 5 alps and accounted for 90% in 1 alp. If only the two best classes were taken into account and the surfaces above the tree line were excluded, 6 alps reported 0-20% and only 3 alps 40-50% of high quality vegetation. In the final concept, simplifications to this system were necessary because the

value of class 3 vegetation was not estimated to be high enough for entering into the funding scheme. At last, only the first two classes were retained and assessed.
The criteria 2, which considered the structures, included shrubs, trees, running water and rocks. If their proportion constituted 5-30%, the surface was valued with one point; if the proportion was 30-50% the surface was valued with half a point. The application of the method in the test areas showed that in all the alps the influence of the structure value on to the overall assessment of the natural value was quite small. But the definition of rocks must clearly be distinguishable from screes, because they are considered as foreign vegetation and give deductions.
The evaluation of the difficulty in management (criteria 3) included the access to the alp, the access to the surface, the potential of mechanization and the danger from natural hazards. The result was a factor (1, 1.5 or 2 depending on the rate of difficulty) that was multiplied with the points from the criteria (1) vegetation and (2) structures. The tests showed that in this methodology the difficulty of management has a big effect on the assessment of the natural value. Under difficult conditions, it can lead to a doubling of the value of the vegetation plus structures. The strong impact of this criterion to the overall assessment of the natural value needs to be reconsidered and the factors might need to be corrected.
In a next step the criteria and the method of assessment will be refined and then tested with designated controlling persons. Launching is planned for 2014.

The pilot concept and adaptations due to the test results

Criteria	Pilot concept	Change of the pilot concept due to the tests
Access to the funding scheme	Compliance of the ordinance of Alpine pasture Voluntary participation	Retained
Vegetation	Mapping of the vegetation Differentiation of the quality (3 levels differing in number of points) Deduction for foreign vegetation	Mapping skipped Levels of quality reduced to 2 Foreign vegetation retained
Structures	Shrubs, trees, running water and rocks	Delimitation of rocks and screes (rock count positively; screes result in a deduction)
Difficulty in management	Access to the alp Access to the surface Potential of mechanization Danger from natural hazards	Access to the alp skipped, less emphasis on this criteria
Landscape	Various criteria	Skipped and pursued in a separate programme

Conclusions

The participatory process and the involvement of the stakeholders and experts had proved to be highly successful. When applying this tool, the assessment of biodiversity in the Alpine pastures is feasible with a modest effort. Classifying vegetation into different levels of quality must be easy; mapping is impossible.
The assessment of the difficulty in management must be reviewed.

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Germination capacity of threshed material from an *Arrhenatherion* meadow

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Abstract

In the last few decades there has been a significant decrease of biodiversity in Europe. To counter this trend, harvested-seed mixtures from potential donor sites can be used to establish semi-natural grassland. It is important to guarantee a certain level of seed quality and successful germination as well as the regional provenance of the harvested seed mixtures. In this study, seed material was harvested via on-site threshing from an *Arrhenatherion* meadow, stored under room temperature, and 400 randomly selected seeds of harvested mixtures were tested in two germination trials in a climate chamber for four weeks. In the first trial, three substrates (potting soil, sand and filter paper) were tested. Germinated seedlings were counted as monocots and dicots. Potting soil showed the highest germination rate. In the second trial, the germination capacity of the seed mixture was tested on potting soil with and without pre-chilling after addition of potassium nitrate (KNO_3), addition of gibberellin acid (GA_3), and without addition of chemicals. In general, the germination capacity of the pre-chilled variants was lower. Variants with KNO_3 developed a higher rate of monocots, and variants with GA_3 showed a slight increase in dicotyledonous seedlings. The germination capacity of treated variants was lower than the variant without pre-chilling or chemical treatment.

Keywords: germination, pre-chilling, gibberellin acid, potassium nitrate, biodiversity, restoration, semi-natural grassland

Introduction

Site-specific restoration is a successful way to combat the increasing loss of biodiversity, and many examples exist in Europe (Kirmer and Tischew, 2006). It is important to choose the right harvesting method according to the target vegetation and site-specific conditions (e.g. protection against erosion, development of semi-natural and low maintenance vegetation). There is little common knowledge about the quality control of harvested material. This paper, therefore, deals with possible quality-criteria for on-site threshing (OST) material from an Arrhenatherion community. There is no existing normative regulation for this kind of revegetation material. The OST material was tested in two trials to assess its germination capacity. In the first germination trial the substrate was tested, and in the second different dormancy-breaking treatments were examined.

Material and methods

The *Arrhenatherion* donor site of Welser Heide is situated in Upper Austria (48°18‘N, 14°03‘E). Until the end of the 1980s, 30% of the area was still under agricultural use. Since 1998 the whole area has received no fertilization and is mown once a year at the end of June. Within two years it had changed from a nutrient-rich and species-poor meadow to a species-rich *Arrhenatherion* community. Red-list and rare species appeared (e.g. *Dianthus carthusianorum*, *Numenius arquata*) which were already extinct or were no longer found in Upper Austria (Plasser *et al*., 2006). During 1971-2000 the mean annual precipitation was 753.8 mm with a yearly average temperature of 8.8°C. The tested material (OST) was threshed with an appropriately adapted combine harvester (Wintersteiger classic thresher) on 1 July 2009 at a time of optimum seed maturity. The threshed material was subsequently dried and stored at room temperature (20-22°C) under dry conditions. Before the germination trial started, the purity and the thousand-seed weight (TSW) of the seed mixture was determined. Existing literature for previous successfully applied germination treatments was studied (ISTA, 2009; Godefroid *et al*., 2010) but information was available only for some individual species. To test the germination capacity of our seed mixtures, we used a combination of different treatments. The germination trials were monitored for four weeks and all experiments were carried out with four replicates.

In the first germination trial, three different types of substrate were tested: potting soil, quartz sand and filter paper. Quartz sand (ME 0.5-2.0, Quarzwerke) is a natural resource, washed, hydro-classified, sieved, and free of carbon and organic waste. Potting soil (Torboflor® EASY) is nutrient-rich for the first four weeks. The added biocatalyst Zeolith is highly resistant, absorbs pollutants, saves important nutrients and the bioactive clay stabilises the water-storage capacity. The filter paper (Lactan) is classified according to ISTA (2009). 4×100 randomly selected seeds were sown in white cups (15.5 cm×11 cm), after adding the respective substrates. The results of the first germination trial were used to select the substrate for the second germination trial.

In the second germination trial different dormancy breaking treatments (KNO_3 0.2%, GA_3 0.05%, without additives, and all variants in combination with/without pre-chilling) were tested. The pre-chilled variants were stored for one week covered in the cooling chamber under controlled temperature of 3-4°C. The germination trial was done in a climate chamber (KBWF 720, Binder) (Table 1). The seedlings were counted once a week and divided into monocots and dicots. One-way ANOVA was used to compare germination rates of different substrates. A generalised linear model (GLM) was used to test results of the second germinations trial and if the pre-chilling treatment significantly influences the germination rate of the seed mixture. All tests were calculated with Statgraphics 15.1.

Table 1. Climate chamber conditions for the assessment of the germination capacity

1st germination trial: substrate	2nd germination trail: dormancy breaking treatment
Day light (14.200 lux) / Night: 8h/16h	Day light (14.200 lux) / Night: 12h/12h
Humidity: 85% ± ≤ 2.5	Humidity: 85% ± ≤ 2.5
Temperature: 20°C/30°C ± 0.1-0.5°C	Temperature: 20°C/30°C ± 0.1-0.5°C
Duration: 6 April - 26 April, 2010	Duration: 19 August - 16 September, 2010
	Pre-chilling: 12 August - 19 August, 2010 (3-4°C)

Results

The OST material had an average purity of 60% pure seeds with an average TSW of 1.04 g. In the first germination trial, we found no statistically significant differences between substrate groups (Table 2). All variants in the first germination trial 'substrate' reached a total germination capacity of between 58% and 68%. The results of the germination trial show that the substrate potting soil had the highest and most homogenous germination rate. Therefore, this substrate was selected for the second germination trial.

Table 2. Germination capacity of threshed material from an Arrhenatherion grassland sown on different substrates, and results of one-way ANOVA.

substrate	Mean total	SD	F	Sig.
Quartz sand	59.50	± 10.08	3.033	0.098
Potting soil	68.25	± 3.59		
Filter paper	58.00	± 2.58		

In the second germination trial, the results revealed significant differences between all variants ($F = 3.060$, $P = 0.036$). The GLM showed significant differences between the treatments (OST, KNO_3 and GA_3) and the pre-chill variants. The interaction between pre-chill and treatment was not significant (Table 3). The mean total values show that all variants reached a germination capacity of between 41% and 56% (Table 4). Best results were obtained by the variants without any dormancy breaking treatment (OST). Pre-chilling had, in general, a decreasing effect on germination. The variants treated with GA_3 showed a slightly higher percentage of dicots but the total germination capacity was slightly lower. In the variants treated with KNO_3 there was a higher percentage of monocots.

Table 3. Germination capacity of threshed material from an *Arrhenatherion* grassland; results of the GLM

GLM	treatment *	prechill **	prechill*treatment
F	4.65	5.62	0.19
Sig.	0.0235	0.0291	0.8323

Table 4. Germination capacity means of threshed material from an *Arrhenatherion* meadow with different treatments, devided into monocot and dicot species.

Variant	OST	OST - prechill	KNO_3	KNO_3 - prechill	GA_3	GA_3 - prechill
Monocotyledons	26.5	26	31.75	28.5	24	18
SD	± 2.08	± 5.35	± 6.99	± 5.74	± 3.16	± 9.76
Dicotyledons	29.75	24	23.25	22.5	24.75	23
SD	± 5.12	± 8.21	± 6.18	± 4.43	± 5.85	± 10.36
Mean total	56.25 *	50 **	55 *	51 **	48.75 *	41 **
SD	± 3.10	± 3.92	± 11.69	± 5.89	± 5.25	± 2.55

Discussion

The results confirm that on-site threshing of material from potential donor sites is an effective way to harvest seed mixtures for use in restoration of semi-natural grasslands. The harvested material contained 60% of pure seeds and these reached a germination capacity of 68% in the first trial and 56% in the second trial after four weeks, which can be considered high in comparison with the assessments of Heilinger and Florineth (2003). Variants treated with GA_3 showed a slightly higher germination of dicotyledonous seedlings. GA_3 is known to break seed dormancy in dicot seeds, whereas KNO_3 is used to break dormancy of monocots (ISTA, 2009), resulting in more monocotyledonous seedlings in KNO_3 treatments.

In our germination trial most of the seeds germinated within the first two weeks, allowing the conclusion that a 4-week observation period was sufficient. No quality standards for harvested seed mixtures from semi-natural grassland are yet defined. To guarantee a fast vegetation development on receptor sites and protection against erosion, a minimum germination capacity of 50% should be used as a quality criterion for directly harvested seed mixtures.

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SALVERE - Semi natural grassland as a source of biodiversity improvement - a Central Europe Project

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Abstract

The 1992 Rio de Janeiro Convention on Biological diversity and the recent EU regulations promote the protection of biodiversity and seek to reverse the trend of biodiversity decrease in Europe. To implement this aim, the availability of site-specific native seed and plant material is needed. In the case of grasslands, this requirement is not sufficiently met in Central Europe, where seed of herbaceous native ecotypes is seldom available in large amounts. Extensively managed semi-natural grassland (the most important type of High Nature Value Farmland - HNVF) can be regarded as a seed source useful to establish new HNV areas. Indeed, they are normally rich in species of native provenance and for this reason they can be harvested to obtain valuable propagation material. State-of-the-art techniques to create forage meadows or to restore degraded areas using commercial seed mixtures are not appropriate techniques for achieving the target of ecological restoration done with propagation material from semi-natural grassland. Therefore a large number of different harvesting methods and application techniques have been developed for exploitation and application of site-specific seed or plant material.

Keywords: High nature value farmland, native seed and plant material, harvesting methods, biodiversity, restoration

General aims of the project

The Project SALVERE is implemented through the CENTRAL EUROPE Programme and co-financed by the European Regional Development Funds (European Territorial Cooperation). Until the end of the project in December 2011, eight project partners from six countries work together. The general aim of the project is to stop the rapid decline of biodiversity and to contribute to protect biodiversity present in semi-natural grassland. The propagules of such potential donor sites can be used to restore new HNV areas or species-rich grassland on former arable land, road embankments, ski slopes, areas of opencast mining and for compensation sites (Kirmer and Tischew, 2006; Krautzer and Hacker, 2006). Semi-natural grassland is the only existing source to provide ecological restoration of grassland with appropriate seed and plant material (Krautzer and Pötsch, 2009). Another important point is the quantification of the seed potential on donor sites, best-practice methods for harvest and re-vegetation and the analysis of harvested seed material in terms of species composition and seed germination. Knowledge transfer into practice will be promoted via five workshops, one final conference, several field trips with interested stakeholders and other public relations events.

Material and methods

In the summer 2009 the project partners implemented 17 trials with different target plant communities and continued studies on five already existing trials (Scotton 2010). Table 1 lists the implemented trials and the methods used.

Table 1. Number of implemented trials, involved plant communities and used methods to establish semi-natural grassland

target plant communities	
Arrhenatherion	8 partners (15 trials)
Bromion (*Mesobromion*)	4 partners (4 trials)
Molinion	2 partners (2 trials)
Deschampsion (*Cnidion*)	1 partner (1 trial)
used methods to establish semi-natural grasslands	
Green hay	8 partners
Dry hay	2 partners
On-site threshing	7 partners
Seed stripping	4 partners
Seed mixtures of local origin from seed propagation	3 partners

Material from available donor areas can be harvested for either direct use in restoration or for the further propagation of suitable material (Krautzer and Pötsch, 2009). Most of the different harvesting methods for site-specific restoration have been developed in English- and German-speaking countries in recent decades. The following harvesting methods for restoration were used for the introduction of target species and implementation of the demonstrations and experimental trials.

Green Hay (GH): A 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. The ratio of donor site to restoration site depends on biomass, seed content and plant community of the donor site and it varies between 3:1 and 1:2.

Dry Hay (DH): Comparable to the green-hay method but the material was dried on the donor site before harvesting. This method requires increased manipulation expenditure, whereby a large part of the diaspore material gets lost (ratio varies between 3:1and 1:2).

On-site-threshing (OST): Threshing takes place with an appropriately adapted combine harvester at the optimum time of seed maturity. Through harvesting of parts of several areas, a wide spectrum of species can be received at the right moment and stored for at least 1-3 years. The harvested pure-seed yield depends on seed content and the technique used and it varies between 40 and 150 kg ha^{-1} pure seeds. The application rate of on-site-threshing is 1-5 g m^{-2}.

Seed stripping (SS): 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. The harvested yield of pure seeds varies between 20 and 80 kg ha^{-1} and the applications rate is 1-5 g m^{-2}.

Seed mixtures of local origin (S): Seeds for propagation were collected from suitable donor sites and cultivated for seed propagation. The recommended seed density is 1-5 g m^{-2}. This method was used in combination with GH and OST.

Results and discussion

The SALVERE Project is still running and the results are not yet all available. By now our results clearly show that harvesting of semi-natural grassland with different harvesting methods is an effective way to obtain regional seed mixtures for restoration. The composition of the harvested seed material varies depending on the harvesting method. On-site threshing and green hay are suitable harvesting methods and the material is rich in number and seeds of target species. The species richness of donor sites increases the restoration success of receptor sites (Kiehl *et al.*, 2009; Kirmer, 2010). Green hay is easier to harvest (with a tractor and self-loading forage wagon), but in a normal case just one cut is possible. The material from on-site threshing is bulk reduced and can be stored more easily after drying, and it is possible to thresh a meadow in several parts to harvest the early and the late-maturing species. Harvesting of Arrhenatherion meadows in June enhances the transfer of grasses, whereas harvesting in July promotes the herbaceous species.

In Europe ecological restoration has made enormous progress in recent years (Krautzer and Wittmann, 2006). Twenty-years ago, near-natural restoration was considered impossible. A large number of methods for obtaining, reproducing and using this material have been developed. All over Europe there are numerous excellent examples of ecological restoration, from wetlands to opencast mining areas up to high zones. The only available resource of seed- and plant material, which can fulfil the demands of nature conservation, regional aspects and site-specificity, is semi-natural grassland. To guarantee the regional availability of site-specific seed and plant material a register of potential donor sites should be developed. The donor site register will give information about site conditions, plant communities, exploitation methods and limitations. A draft for implementation in the single partner countries will be worked out within the SALVERE project. A potential problem in the use of site-specific native plant material for nature conservation improvement of existing grassland areas is given by the limitations of the national seed laws as an EU skeleton law. Until now, it has not been permitted to bring threshed material for the restoration of grassland on the seed market. To solve this conflict between the nature conservation law and the seed law, the SALVERE team is working on a European guideline that is in context with the EU directive 2010/60 (EU 2010) that provides for certain derogations for marketing of fodder plant seed mixtures intended for use in the preservation of the natural environment. In summary, the restoration of semi natural grassland is an important way to enhance the biodiversity loss.

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Specific biodiversity and forage value of pasture as affected by the expansion of two wood types in the Venetian Prealps

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Abstract

During the past 50 years extensive livestock farming has declined in mountainous Italian regions and it has now become more common to stable the stock year-round. This has led to a sub-utilization or abandonment of many mountainous grassland areas, and they have naturally evolved into woodland. With the aim to evaluate some consequences of these land changes, a study was carried out in the Venetian Prealps on a pasture overgrown by *Fraxinus ornus* and *Ostrya carpinifolia* on one side, and *Fagus sylvatica* on the other side. In 2006, 46 botanical surveys (23 per each wood expanding zone) were performed on sampling areas of 100 m², with an arboreal coverage ranging from 0% to 100% and a cover of shrubby species ranging from 0% to 93%. Specific biodiversity and forage value were measured and used as main criteria to estimate the influence of wood expansion on the pasture. The highest number of species was found at 40% cover values of both *Fagus sylvatica* and *Fraxinus ornus - Ostrya carpinifolia*. Under the influence of both types of wood, a strong linear negative relationship was observed between forage value and the shrubby and arboreal coverage.

Keywords: mountain pasture, specific biodiversity, forage value, wood expansion

Introduction

Mountain pastures play an important social and economic role in the mountainous regions of northern Italy. However, agro-pastoral activities have declined considerably during the last century, leading to a decrease of about 800,000 hectares of grasslands due to the expansion of the forest (Chemini and Gianelle, 1999). The process of forest re-colonization which follows the abandonment of agricultural land has been largely underestimated, in terms of both quantity and potential impacts. In these areas most of the grasslands have replaced natural forests after the removal of the trees; therefore there is an artificial equilibrium between human activity and forest re-growth, perhaps a lack of management would lead to reversionto forests (Spatz and Papachristou, 1999). When pasture management stops, wood expansion causes considerable changes to the pastoral vegetation, such as a change in biodiversity and a shift in botanical composition (Sabatini *et al*., 2000). The aim of this study was to evaluate the main effects of forest expansion of two different types of wood on the same pasture.

Materials and methods

The work was realized at the Cimo summer Farm (Campolongo sul Brenta, NE Italy), situated in the Venetian Prealps (45°49’08’’ N, 11°40’31’’ E). Annual average temperature for this zone is 12.6°C, and the mean annual rainfall is 1,350 mm. The study area covers 36 ha (about 1,200 by 300 m) and is characterized by carbonate substrate; the grazing area has been subjected to a process of natural forest re-colonization by two wood types starting on the long edges of the area: *Fagus sylvatica* in one side (F area; 1,000-1,130 m a.s.l.) and *Fraxinus ornus - Ostrya carpinifolia* in the other side (O area; 850-950 m a.s.l.). In each side, 23 botanical surveys were performed on sampling areas (100 m²) choosing typical sites with an arboreal coverage ranging from 0 to 100%. The cover estimation of vascular plants was performed between June and September 2006 following the Braun-Blanquet approach (Westhoff and Van der Maarel, 1978). Percentages of arboreal and shrubby cover were estimated using a 0-100 scale for each of the two layers, and were subsequently cumulated to form wood cover values. Number of all herbaceous species and their abundance (% cover) were recorded in order to describe the specific biodiversity of pastoral vegetation. A scatter plot of number of species versus wood coverage suggested a non-linear relationship between the two variables and the best association was identified according to Motulsky and Christopoulos (2003). Forage values were calculated on the basis of Stahlin (1970) and Klapp (1971) forage indices and regressed against the wood coverage using SAS Proc Linear (version 9.2; SAS Institute, Cary, NC). Within the surveys presenting 0% of coverage (10 in F area and 8 in O area), difference in forage value between O area and F area were also tested by one-way analysis of variance.

Results and discussion

In the F area, the edge of the forest was clear, with high *Fagus sylvatica* trees. *Fagus sylvatica* forest was accompanied by shrubs which grew on the pasture and anticipated forest re-colonization. Some of the shrubby species growing on the grazing area were *Corylus avellana* (coverage > 10% in four plots), *Berberis vulgaris*, *Rosa canina*, and *Rubus* spp. In the O area, the forest was principally composed by *Ostrya carpinifolia* and other arboreal species: *Fraxinus ornus*, *F. excelsior*, *Acer pseudoplatanus*, *Fagus sylvatica*, and *Tilia cordata*. In the shrubby layer, the most abundant growing species were *Corylus avellana* (coverage > 10% in ten plots), *Viburnum lantana*, *V. opulus*, *Laburnum alpinum*, and *Rubus* spp.

The analysis of botanical surveys performed under 0% wood coverage indicated that the average floral composition involved a large number of species belonging to the mountain form (group of *Alchemilla vulgaris*) of the association of *Festuco-cynosuretum* in both F and O areas. These areas were characterized by poor pasture, with the presence of basophilic species, such as *Primula veris*, *Medicago lupulina*, *Koeleria pyramidata*, and *Anthyllis vulneraria*, and also acidophilic species, such as *Festuca nigrescens*, *Hypericum maculatum*, *Agrostis tenuis*, and *Peucedanum oreoselium*. Even though there was a large similarity between the botanical composition of the two areas, a greater forage quality was found in the F area (P = 0.007) (Table 1).

A second order polynomial correlation was found between specific biodiversity of herbaceous species and wood coverage in both F and O areas. No differences occurred between the two fitted curves (P = 0.748); therefore data were pooled (Figure 1). Under the influence of both wood types, number of pastoral species first increased as wood coverage progressed from 0% to about 40%, and then decreased as wood coverage reached maximum values.

Progressing from 0% to maximum wood coverage, a strong linear decrease of forage quality was observed in both areas (Figure 1 and Table 1). Regression analyses revealed that the two fitted linear regressions had different intercepts (P < 0.001) but no different slopes (P = 0.138). Results indicated that, regardless of the forage values present at 0% coverage, the forest expansion resulted in a similar depletion of pasture quality for both the wood types (Figure 1).

Conclusions

The expansion of *Fagus sylvatica* and *Fraxinus ornus* - *Ostrya carpinifolia*, whose forest re-colonization has been anticipated by *Corylus avellana*, had similar effects on specific biodiversity and forage quality of the pasture. A strong decline of pasture quality and negative effects on biodiversity were observed as the forest re-growth progressed.

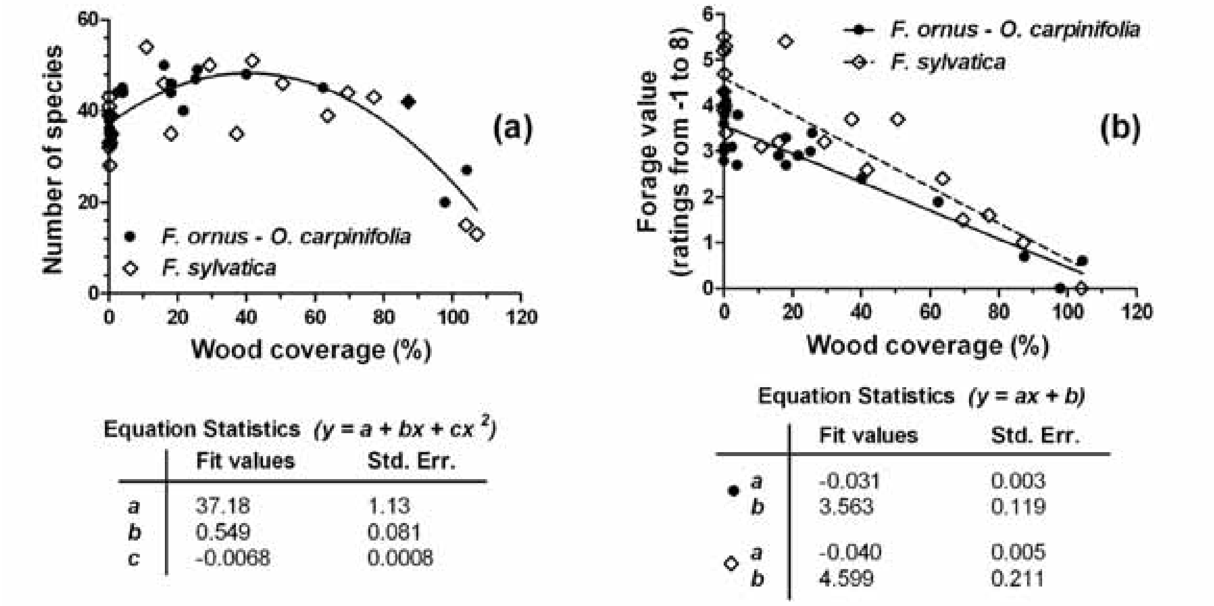

Figure 1. Relationships (a) between wood coverage and number of herbaceous species, and (b) between wood coverage and weighted average forage value of the herbaceous species (weighted by % coverage) in a pasture dominated by *Fraxinus ornus* and *Ostrya carpinifolia* or by *Fagus sylvatica*.

Table 1. Forage value measurements at different wood cover values in a pasture dominated by *Fraxinus ornus* and *Ostrya carpinifolia* or by *Fagus sylvatica*.

	F. ornus - O. carpinifolia			*Fagus sylvatica*		
Forage value*	0-35%	35-70%	70% - max cover	0-35%	35-70%	70% - max cover
			Total coverage in the herbaceous layer (%)			
< 3	27	28	33	20	18	16
≥ 3	62	50	11	73	68	32
≥ 5	49	41	8	62	55	16
			Number of herbaceous species (%)			
< 3	36	27	24	32	28	26
≥ 3	50	44	20	54	52	22
≥ 5	36	30	14	39	38	17

* Ratings according to Stahlin (1970) and Klapp (1971)

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Use of selected herb species for increasing biodiversity of grasslands

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Abstract

In small-plot field trials conducted between 2006 and 2010, the presence and dominance of selected herb species in newly established grasslands were evaluated. Two seed mixtures with different proportions of herb species were sown on plots on arable land and in 90 cm wide strips on non-sown land (fallow). The best establishment results were shown for *Leucanthemum vulgare*, *Galium verum*, *Jacea pratensis* and *Plantago lanceolata*. High establishment rates were observed for *Hypericum perforatum*, *Leontodon hispidus*, *Ranunculus acris* and *Silene vulgaris*. In the spontaneous fallow only *L. vulgare* and *P. lanceolata* spread. Proportions of herbs in mixtures had no effect on actual herb presence or dominance, except *L. vulgare* and *Cirsium pannonicum* (positive effect of higher ratio) and *L. hispidus*, *Tragopogon orientalis* and *Trifolium rubens* (negative effect).

Keywords: herb, grassland, biodiversity

Introduction

Grasslands are among the most species-rich plant communities in the world. Permanent and semi-natural grasslands are very important not only as source of fodder but also for their significant role for the environment (Stypiński *et al*, 2009). However, in the past fifty years a large amount of grasslands, often with high ratio of herbs, were ploughed and transformed to arable land in the Czech Republic. This land is now restored to grassland. Some fields were left as untreated fallows and their botanical composition was created by spontaneous succession; others were sown using grass and legume cultivars of non-regional origin. Nevertheless, for restoration of species-rich grasslands, site-specific seed mixtures of regional origin should be used (Ševčíková and Šrámek, 1998). However, few newly established grasslands contain a successful ratio of herbs due to the high cost of herb seeds and little information about their possibilities for increasing grassland biodiversity. This paper deals with the possibilities of individual herb species for increasing grassland biodiversity.

Material and methods

Small-plot trials were established in July 2006 with different mixtures of grasses, legumes and herbs on arable land at Zubří (altitude 360 m a.s.l., average annual temperature 7.6°C, average annual precipitation 864 mm). Six trial variants were used. Trial plots were arranged in randomized blocks with 3 replicates. Three types of mixtures and unsown fallow were laid out in plots, each 6 m×4 m. Species-rich regional mixtures were sown into whole plots and/or in 90-cm wide strips into spontaneous fallow. Composition of the mixtures is shown in Table 1. The sowing rate of each mixture was 30 kg ha^{-1}. The site was mown twice a year, in mid-July and at end of September. Before all cuts the presence and dominance of all species according were evaluated (Braun-Blanquet). Statistical analyses (Normal regression analysis - species dominance in all the observation years) were made using STATISTICA 9.1.

Results and discussion

Only a few herb species covered more than 2% of ground cover. *Leucanthemum vulgare* showed good dominance in the first three years but in the fourth year this species rapidly disappeared from the sward. Conversely, *Galium verum* and *Jacea pratensis* increased their dominance as the sward aged. Good results were also shown for *Plantago lanceolata*, *Silene vulgaris*, *Ranunculus acris* and *Hypericum perforatum* (Table 2). These results support findings of Jongepierová and Mitchley (2009). However, from sown strips into spontaneous fallow only *L. vulgare* and *P. lanceolata* were spread (unpubl. data).

Table 1. Evaluation of presence and dominance of sown plant species on whole plot-variants (Reg = regional mixture)

Mixture	Reg 1					Reg 2				
Species	used share*)	2007	2008	2009	2010	used share*)	2007	2008	2009	2010
Grasses	60.0					85.0				
Agrostis tenuis	2.0	+	+	r	+	-	-	-	-	-
Anthoxanthum odoratum	10.0	+	+	+	1	10.0	+	r	+	r
Briza media	5.0	r	r	r	+	10.0	+	+	1	r
Cynosurus cristatus	8.0	+	1	1	1	-	-	-	-	-
Festuca rupicola	15.0	2	1	1	1	15.0	1	1	1	r
Koeleria pyramidata	5.0	r	+	+	r	10.0	1	1	1	r
Poa angustifolia	10.0	r	+	+	+	15.0	+	+	r	r
Bromus erectus	5.0	x	x	x	x	25.0	x	x	x	x
Legumes	10.0					5.0				
Anthyllis vulneraria	3.0	+	r	r	r	2.0	r	r	r	r
Lotus corniculatus	3.0	2	2	2	2	1.0	r	r	r	r
Trifolium montanum	2.0	r	+	+	1	1.0	r	r	r	r
Trifolium rubens	2.0	r	r	+	r	1.0	2	2	2	r
Herbs	30.0					10.0				
Betonica officinalis	1.5	r	r	r	r	0.5	x	x	x	x
Campanula glomerata	0.6	r	r	r	r	0.2	x	x	x	x
Centaurea scabiosa	0.8	x	x	x	x	0.5	x	x	x	x
Cirsium pannonicum	1.5	r	r	r	r	0.5	x	x	x	x
Dianthus carthusianorum	0.6	r	r	+	+	0.3	x	r	r	r
Galium verum	1.5	+	+	1	2	0.5	r	r	r	r
Helianthemum nummularium	0.9	x	x	x	x	0.3	x	x	x	x
Hypericum perforatum	0.8	r	+	+	1	0.2	+	1	2	r
Jacea pratensis	2.4	+	+	1	2	0.8	r	r	r	r
Knautia kitaibelii	1.5	r	r	r	r	0.5	x	x	x	x
Leontodon hispidus	1.5	+	+	+	r	0.5	+	1	2	r
Leucanthemum corymbosum	0.2	r	r	r	r	0.1	r	r	r	r
Leucanthemum vulgare	3.0	1	2	2	r	0.9	+	+	r	r
Lychnis flos-cuculi	0.8	r	r	r	+	0.2	x	x	r	r
Plantago lanceolata	3.0	1	+	1	1	0.9	2	2	r	r
Prunella laciniata	1.5	r	r	r	r	0.5	r	r	+	r
Ranunculus acris	1.5	r	r	+	r	0.5	+	1	1	r
Salvia verticilata	1.5	r	r	r	r	0.5	x	x	x	r
Sanguisorba minor	1.5	+	+	+	+	0.5	r	+	r	r
Silene vulgaris	0.6	+	r	+	1	0.2	r	r	r	r
Tragopogon orientalis	2.8	r	r	r	r	1.0	+	+	+	r

Legend: x = no presence, r = 1%, + = 2%, 1 = < 5%, 2 = 5-25%, 3 = 25-50%, 4 = 50-75%, 5 = 75-100%
*) proportion of species in sown mixture

Changes in abundance of single species were observed in all years. The greatest increases in cover for all the observation years were shown for the following: *Jacea pratensis*, *Lotus corniculatus* and *Galium verum*. Moderate increase in dominance was observed for *Trifolium montanum* and *Anthoxantum odoratum*. Conversely, dominance of some species (*Festuca rupicola*, *Leucanthemum vulgare*) was decreasing (Table 3). However, the low levels of coefficient of determination (R^2) do not meet statistical significance and lead us to the opinion that presence and dominance of single species is affected by weather condition in different years rather by than age of sward.

Table 2. Regressions of dominance on crop year and coefficients of determination

species	regression	R^2	species	regression	R^2
Agrostis tenuis	y = 0.042x + 1	*0.00*	*Galium verum*	y = 3.892x + -4.59	*0.31*
Anthoxanthum odoratum	y = 1.575x + 0.63	*0.09*	*Hypericum perforatum*	y = 0.534x + 0.59	*0.12*
Briza media	y = 0.001x + 1.21	*0.00*	*Jacea pratensis*	y = 5.05x + -6	*0.23*
Cynosurus cristatus	y = 0.25x + 0.8	*0.02*	*Knautia kitaibelii*	y = 0.034x + -0.05	*0.04*
Festuca rupicola	y = -0.625x + 9.63	*0.01*	*Leontodon hispidus*	y = 0.017x + 1.92	*0.00*
Koeleria pyramidata	y = -0.017x + 1.3	*0.00*	*Leucanth. corymbosum*	y = 0.117x + -0.05	*0.05*
Poa angustifolia	y = -0.1x + 1.46	*0.01*	*Leucanthemum vulgare*	y = -0.642x + 7.3	*0.01*
Anthyllis vulneraria	y = -0.159x + 1.3	*0.05*	*Lychnis flos-cuculi*	y = 0.159x + -0.13	*0.09*
Lotus corniculatus	y = 3.842x + 12.46	*0.06*	*Plantago lanceolata*	y = -0.367x + 4.17	*0.03*
Trifolium montanum	y = 1.575x + -0.59	*0.09*	*Prunella laciniata*	y = 0.159x + 0.75	*0.04*
Trifolium rubens	y = 0.15x + 1.84	*0.01*	*Ranunculus acris*	y = 0.217x + 1.13	*0.09*
Betonica officinalis	y = -0.001x + 0.09	*0.00*	*Salvia verticilata*	y = 0.059x + 0.09	*0.02*
Campanula glomerata	y = 0.1x + 0.05	*0.04*	*Sanguisorba minor*	y = -0.017x + 1.92	*0.00*
Cirsium pannonicum	y = -0.001x + 0.09	*0.00*	*Silene vulgaris*	y = 0.4x + 1.3	*0.07*
Dianthus carthusianorum	y = 0.292x + 0.3	*0.18*	*Tragopogon orientalis*	y = -0.159x + 1.3	*0.05*

Legend: y = dominance (%), x = crop year (first year after sowing = 1)

However, seed share of selected plant in used mixtures had either no effect or a very small effect on their actual presence or dominance with the exceptions of *Leucanthemum vulgare* and *Lotus corniculatus* (positive effect of higher share) or *Leontodon hispidus*, *Tragopogon orientalis* and *Trifolium rubens* (positive effect of low share).

Conclusion

In small-plot field trials conducted between 2006 and 2010 the best results were achieved with *Leucanthemum vulgare*, *Galium verum*, *Jacea pratensis* and *Plantago lanceolata*. Also, for some other species e.g. *Hypericum perforatum*, *Leontodon hispidus*, *Ranunculus acris* and *Silene vulgaris*, a good presence was observed. However, into spontaneous fallow only *L. vulgare* and *P. lanceolata* were spread. Only a few herbs had positive effect on the actual herb presence or dominance at sward, relative to their share in the seed mixture .

Acknowledgements

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Productivity and interspecific relations in the meadows with *Arnica montana* in Gârda, Romania during 2006

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Abstract

Arnica montana, a mountain plant species with medicinal properties, is protected all over in Europe. In Romania, in the area of Apuseni Mountain, there are some of the most important areas of grassland with this species in Europe. Grasslands with *Arnica montana* that are situated on limestone have, in general, a high floristic diversity. The coverage level of each species was quantified using the metric frame. The studies made regarding the vegetation during 2006 on Garda area (Apuseni Mountain) pointed out several inter-specific relations between the species. The biomass of the samples showed relatively low productivity. Due to their low productivity, the habitats of *Arnica montana* may be greatly endangered in the future.

Keywords: mountain grassland, *Arnica montana*, medicinal plant productivity, Transylvania

Introduction

Arnica montana is a valuable medicinal plant in the mountain area. Romania is one of the main source countries of dried *Arnica montana* flower heads processed in Central Europe (Kathe *et al*., 2004). Untill now, this species could be seen frequently in the meadows with a traditional management in the Garda de Sus region (Apuseni Mountains). However, currently these habitats are threatened by changing the mode of use. Species-rich habitats with *Nardus stricta* and *Arnica montana* are listed under the code - Code 6230 - in the EU-FFH- directive (92/43) and the species *Arnica montana* is listed in Annex V (92/43) (Michler *et al*., 2005). It occurs both on siliceous and on calcareous substrates. We included in our study only grasslands with *Arnica montana* on the limestone plateau in the Apuseni National Park.

Material and method

Randomized selection for the plots on which the vegetation samples were taken was made with the golden numbers method. These were identified with the help of integrated mapping of the meadow surfaces on which the medicinal species *Arnica montana* was identified, that was achieved in Garda de Sus, within the research project called ‚*Arnica montana*'. In 2006 in Garda de Sus we established 17 sample plots for the northern calcareous plateau. On these plots we analysed one vegetation sample for each. The plots were identified on the field with the help of satellite images and topographical maps and confirmed with the help of GPS system. The vegetation samples were made with the help of a metric frame. All the vascular plant species were identified on a surface of 1 m² and their level of coverage was quantified with high accuracy, especially for the species with a low coverage value.

For each vegetation sample, the biomass was harvested from the whole surface of the metric frame (1 m²), from a height of 5 cm above the soil. The lichen and bryophyte layers were not harvested. The weight of the dry matter was obtained by drying the material in oven at a temperature of 100ºC for three hours.

The obtained data were statistically processed with the help of CANOCO for Windows (version 4.0) by redundancy analysis (RDA) followed by Monte Carlo permutation test.

Results and discussions

Of the vegetation samples taken, we identified 96 vascular plant species. The measured dry matter was between 0.54 t/ha and 2.23 t/ha (on average 1.62 t/ha). Applying RDA analyses, the quantity of dry matter explains 13% of the total variance of the floristic composition (P = 0.03). Low productivity can be seen especially in the case of the samples dominated by *Nardus stricta*, *Deschampsia flexuosa*, *Potentilla erecta, Hieracium pilosella* etc. Regarding the interspecific relationships, these oligotrophic species can be identified in the right of the RDA ordination (Figure 1). In this group there can be seen the protected medicinal species *Arnica montana* which appears in all habitats taken into study, but shows a higher coverage value in the habitats dominated by the above-mentioned species. Blueberry (*Vaccinium myrtillus*) can produce an important increase in the dry matter production, but being a chamaephyte, it is represented especially by lignified branches, with no fodder value (Figure 1).

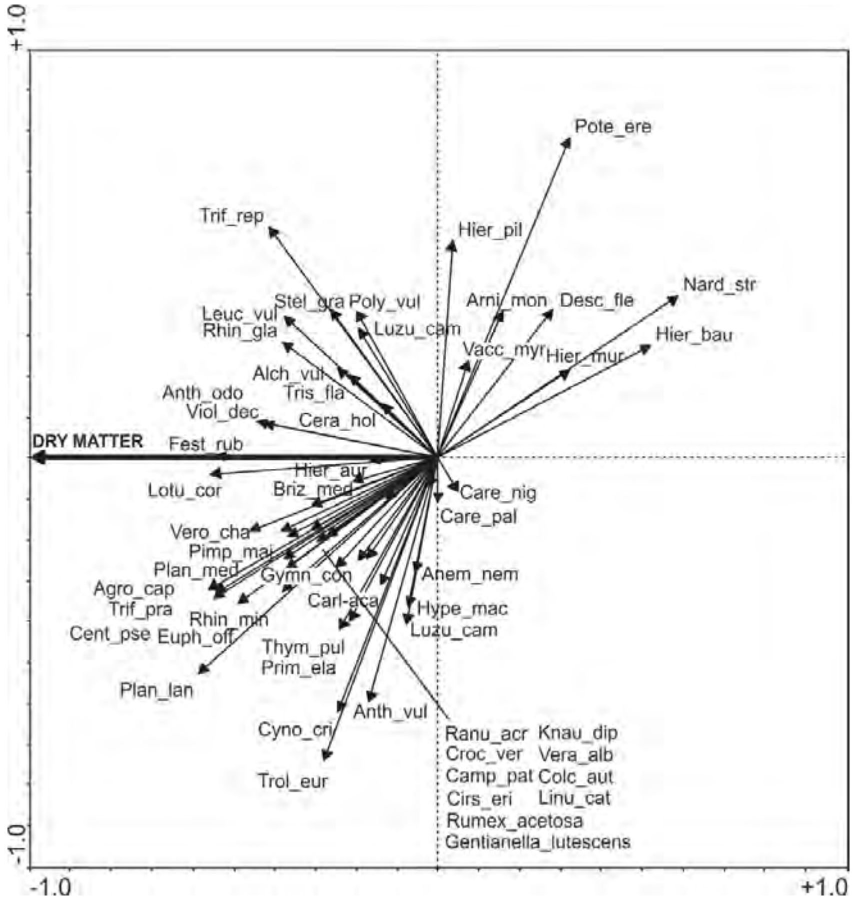

Figure 1. Ordination diagram of species and dry matter yield from *Arnica montana* habitats in the floristic space defined by RDA, based on species coverage values. (The first four letters represent the shortage of the genus and the last three the shortage of the species)

Frequent species, important in terms of fodder value, are to be seen in the left part of RDA ordination, contributing not only to the improvement of the productivity but also to the increased quality of the hay (e.g. *Festuca rubra*, *Agrostis capillaris*, *Anthoxanthum odoratum*, *Trifolium pratense*, *Trifolium repens*, *Lotus corniculatus*). The important fodder species *Trisetum flavescens* presents a high dominancy in the eutrophic meadows with a higher productivity in the area taken into study (Brinkmann, 2006) and it is seldom met and with low coverage level in the habitats for *Arnica montana*. In the left group there are also the species belonging to *Orchidaceae* botanical family, the most frequent of them is *Gymnadenia conopsea*. These species represent also a high conservative value.

The grasslands analysed are presently used as meadows, the main harvest being represented by the mowing of hay once a year. Due to the low productivity, in context of EU grasslands, the profitability of these meadows, and maintaining them with the floristic composition and interspecific relationships as presented in this study, remain uncertain in the future. Changing the way they are used brings important changes in the floristic composition. A frequent phenomenon observed in the mountain meadows in Romania is the lack of usage followed by the succession towards a woody vegetation of shrubs and forest. Another possibility is represented by the transformation from meadows in extensively or intensively grazed pastures, which leads to important changes in the floristic composition (Ludvikova *et al*., 2009; Seither *et al*., 2010). A third possibility is the intensification and continuous fertilization that determines important decrease in floristic diversity of the mountain meadows (Stybnarova *et al*., 2009; Rotar *et al*., 2010).

Conclusion

The biomass of the samples showed relatively low productivity. Due to their low productivity, the habitats of *Arnica montana* may be greatly endangered in the future, depending on the intensity of the changes in the mode of use imposed by their low profitability. Increasing the biomass productivity, the abundance of the vascular plant species and their interspecific relationships are also endangered because of their linkage with the dry matter production. Some of these species (e.g. the orchids) are also of high conservation value.

Acknowledgements

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Plant species diversity in the Bavarian alpine grasslands

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Abstract

Due to the combination of a small scale habitat diversity and low management intensity, mountainous grasslands are very species rich. In Bavaria these grasslands were traditionally used as pastures. To conserve the laborious management alpine farmers are subsidized by agri-environment schemes. To evaluate the current state of agricultural grasslands in Bavaria with regard to plant species richness and composition, the Bavarian State Research Center for Agriculture started a grassland vegetation survey in 2002. All plant species, their percentage of total yield, elevation a. s. l. and management type on more than 6000 plots were recorded. The analysis of survey data showed an outstanding species richness in mountainous grasslands. Whereas the mean species number per plot all over Bavaria was 19, plots in the agricultural region Alps showed in the average 25 and those on alpine pastures 33 species. Species numbers within the Alps were mainly influenced by the altitude and the grassland value.

Keywords: alpine pastures, species richness, grassland value, management intensity

Introduction

In Bavaria permanent grassland covers 35% of the agricultural land and is an important source of animal feed. Large habitat gradients within the Bavarian landscape effectuate considerable regional differences in grassland species composition. While the Bavarian lowland grassland is predominated by meadows, the main cultivation of the southernmost part of Bavaria are alpine pastures grazed during the summer (600-2400 m a. s. l.). Alpine pastures are a complex of intensive and oligotrophic grasslands, waste and fallow land, wetlands and alpine forests, thus, represent a high degree of biodiversity. They present about 43% of all European plant species (Ringler, 2009). Former studies identified site conditions as slope and remoteness, management type and agri-environment schemes (AES) to affect their species richness (Kampmann *et al*., 2008; Pötsch and Blaschka, 2003). Based on more than 6000 vegetation relevés of the Bavarian grassland monitoring (BGM) this study analyses interactions of species diversity of lowland and mountain grassland in Bavaria with site and management conditions.

Materials and methods

The study was conducted in the federal state of Bavaria in the South of Germany. From 2002 to 2008, 6108 permanent grassland plots of 25 m² were surveyed. A species list, the percentage biomass per species and the elevation of the plots were recorded. Additional information on livestock units per hectare (LU/ha), management type and grassland value (valuation number for grassland sites considering soil, climate and relief) were obtained from the agricultural administration (Kuhn *et al*., 2011). LU/ha was used as a surrogate for management intensity. To analyze the interrelation of species richness, site conditions and management, plots were grouped into 12 agricultural regions (AGR), elevation classes and the main management types. Mean species numbers per group were calculated. The effect (adjusted r^2) of management and site conditions on species richness was determined with SAS 9.1 by general linear models (GLM).

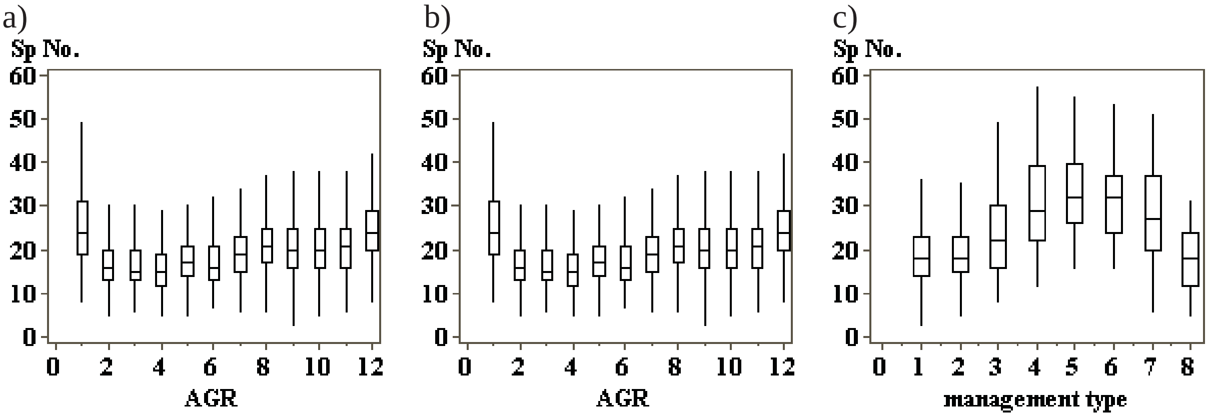

Figure 1. mean species number per plot a) in the 12 AGRs (numbers increase from South to North) b) on different levels of elevation (1: 100-200 m a.s.l.;…; 10: >1000 m a.s.l.) and c) at different management types (1: meadow; 2: mowing pasture; 3: pasture; 4: rough grazing; 5: alpine pasture; 6: migratory herding; 7: litter meadow; 8: fallow land) in Bavaria.

Table 1. Site conditions influencing species number in the Bavarian and alpine grassland; parameter estimates of general linear model (GLM, type III SS); AGR1 = region Alps

		Bavaria: adjusted $r^2 = 0.196$, $F = 104.30$, $P < 0.0001$				AGR1: adjusted $r^2 = 0.355$, $F = 94.47$, $P < 0.0001$			
	level	Beta	SE	t	*P*	Beta	SE	t	*P*
intercept		27.90	0.67	41.45	<.0001	26.04	2.14	12.17	<.0001
elevation m a.s.l.		0.00	0.00	4.32	<.0001	0.01	0.00	4.89	<.0001
grassland value		-0.12	0.01	-14.92	<.0001	-0.25	0.03	-9.60	<.0001
AGR	1	-1.87	0.71	-2.65	0.0082				
AGR	2	-7.97	0.61	-13.01	<.0001				
AGR	3	-8.15	0.59	-13.88	<.0001				
AGR	4	-8.26	0.55	-15.12	<.0001				
AGR	5	-6.79	0.54	-12.51	<.0001				
AGR	6	-5.93	0.73	-8.12	<.0001				
AGR	7	-6.75	0.59	-11.44	<.0001				
AGR	8	-4.89	0.58	-8.40	<.0001				
AGR	9	-4.37	0.55	-7.92	<.0001				
AGR	10	-3.96	0.51	-7.74	<.0001				
AGR	11	-3.13	0.57	-5.52	<.0001				
AGR	12	0	.	.	.				

Results and discussion

In 6108 vegetation relevés all over Bavaria we found 777 plant species (mean 19 species per plot). The 377 plots within the agricultural region Alps presented 423 species with a mean value of 25 species per plot. The Alps (AGR 1) account only for 10% of the Bavarian grassland, but they host 55% of the Bavarian grassland species, thus, were the most species-rich region in Bavaria (Figure 1a, Table 1). Referring to the management type the alpine pastures presented most species per plot (Figure 1c, Table 2) and, referring to elevation, the higher situated plots were most species-rich (Figure 1b, Table 1). Within the region Alps the grazed grassland and the litter meadows - that is the low intensity grassland - and the high elevated plots were most species-rich. Thus, high elevated, alpine pastures in the region Alps were most diverse in Bavaria. In Austria Krautzer *et al*. (2007) found on alpine grassland on average 39 to 53 species per plot. In accordance with our results their study showed an increase of species number with increasing elevation (see also Kampmann *et al*., 2008; Sobotik *et al*., 1998). As Kampmann *et al*. (2008) observed a positive correlation between elevation and the frequency of AES-grassland (low intensity grassland) the elevation effect may actually be an effect of low intensity management. Referring to the management type Pötsch and Blaschka (2003) in Austria also stated alpine grassland and pastures - particularly rough grazing - as being notably species-rich. Kampmann *et al*. (2008) detected no significant difference in diversity between AES-meadows and conventional pastures, but diversity was lower on conventional meadows. As grazing is more heterogeneous than mowing both in biomass removal and in nutrient return plant species find more diverse niches (Bakker *et al*., 2003). In the Bavarian Alps management intensity did not significantly influence species number (Table 2). Müller (2002) arrived at the same conclusion on Swiss alpine pastures. In Austria Pötsch and Blaschka (2003) found both the cutting frequency and the stocking rate to be negatively correlated with species number in accordance with the whole Bavarian grassland (Table 2). Another factor influencing species richness in the Bavarian Alps was the grassland value (Tables 1, 2). This means the more fertile the soil and the better climatic conditions the lower the species number.

Table 2. Effect of management and site conditions for whole Bavaria and the region Alps; gl No. = grassland value

	Bavaria: adjusted $r^2 = 0.268$, $F = 93.36$, $P < 0.0001$					AGR1: adjusted $r^2 = 0.458$, $F = 33.84$, $P < 0.0001$				
	DF	SS	MS	F	*P*	DF	SS	MS	F	*P*
management:										
LU/ha	1	11823.36	11823.36	356.84	<.0001	1	55.70	55.70	1.34	0.2482
mt	7	5213.50	744.79	22.48	<.0001	5	1981.94	396.39	9.52	<.0001
site conditions:										
elevation										
m a.s.l.	1	330.47	330.47	9.97	0.0016	1	1400.51	1400.51	33.64	<.0001
gl No.	1	2049.74	2049.74	61.86	<.0001	1	699.85	699.85	16.81	<.0001
AGR	11	8719.55	792.69	23.92	<.0001					
Error	5368	177859.47	33.13			320	13320.68	41.63		

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Effects of grazing intensity and sward structure on grasshopper (Orthoptera) diversity and abundance

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Abstract

Grazing management is an important factor influencing grassland flora as well as fauna. In a long term grazing experiment on a moderately species-rich permanent pasture, the effect of cattle grazing intensity on grasshoppers (Orthoptera) was investigated. Swards were grazed either with a moderate or a lenient intensity in a continuous grazing system. Grasshopper species richness and abundance were measured in 2002-2004 and again in 2010. Results show that the higher grazing intensity reduced grasshopper species richness and abundance. Findings are discussed in relation to sward structure and plant species richness. We conclude that an intermediate grazing intensity (here resulting in an average compressed sward height of about 12 cm) has a high potential for the restoration of diverse grasshopper assemblages.

Keywords: Grazing intensity, grasshoppers, sward height, sward height heterogeneity

Introduction

Extensive grazing with beef cattle offers opportunities for the restoration of biodiversity in formerly intensively used grasslands (Isselstein *et al*., 2007). Cattle grazing at low stocking rates is known to create more heterogeneous and taller swards with more ecological niches and plant biomass, which is beneficial for herbivorous insects like grasshoppers (Kruess and Tscharntke, 2002; Wallis de Vries *et al*., 2007; Dumont *et al*., 2009). In this study, the influence of grazing intensity, sward height heterogeneity, plant species richness and grass cover on grasshopper species richness and abundance was examined.

Materials and methods

The experiment was carried out on a mesophile grassland in the Solling uplands, Germany (for productivity and forage quality details see Isselstein *et al*., 2007) and consisted of nine 1.0 ha paddocks grazed continuously by Simmental cattle at two (2002-2004) and three (2010) grazing intensities managed in a put-and-take system for target compressed sward heights (CSH), which were measured at least biweekly on each paddock throughout the grazing season using a rising-plate meter (target CSH - moderate: 6 cm, lenient: 12 cm, both in place since 2002, very lenient: 18 cm, in place since 2005). Treatments were replicated three times in a randomized block design. Grasshopper (Orthoptera) species richness and abundance were recorded on three parallel 50 m transects per plot on three occasions each year as described in Wallis de Vries *et al*. (2007). Botanical species richness and grass cover (%) were assessed on ten permanent subplots (1 m^2) per paddock twice a year, for further details see Wrage *et al*. (2011). Small scale sward height was recorded once at the end of August along the middle transect line of each paddock at every 0.5 m using a sward stick.
Data were analysed using a mixed model with grazing intensity, year and the interaction of main effects as fixed factors; year was treated as a repeated measure. Prior to statistical analysis, grasshopper data were pooled over transects within one paddock. Plant species richness and

grass cover were pooled over subplots and averaged over both occasions per year. One-way ANOVA was used to compare the treatments in 2010. For the same year, grasshopper abundance and species richness were analyzed in two separate models using multiple linear regressions with sward height (sward stick), sward height range (sward stick) as a measure of horizontal sward heterogeneity, average plant species richness and grass cover as independent variables.

Results and discussion

In total, nine grasshopper species were found on the site. Species richness (Figure 1a) was significantly larger in the lenient grazing treatment compared to moderate grazing ($P < 0.05$), but there was no year effect. For 2010, more species occurred on the very lenient grazing treatment than on moderate grazing ($P < 0.05$), but not in comparison to the lenient grazing. The effect of the higher grazing intensity on species richness is consistent with results of Wallis de Vries *et al*. (2007) and Dumont *et al*. (2009).

More individuals (Figure 1b) were found on lenient than on moderate grazing ($P < 0.001$) and in 2010 compared to the previous observation years ($P < 0.01$). As for species richness, there was no difference between very lenient and lenient grazing intensity in 2010, but very lenient grazing showed more individuals than the moderate treatment ($P < 0.05$). These results again show that the lenient and very lenient grazing intensity treatments resulted in increased grasshopper abundance and richness compared to the moderate treatment and could possibly be explained by a preferred sward height of 10-20 cm of *Chorthippus albomarginatus*, the most dominant species on the site, and *C. parallelus* (Gardiner *et al*., 2002).

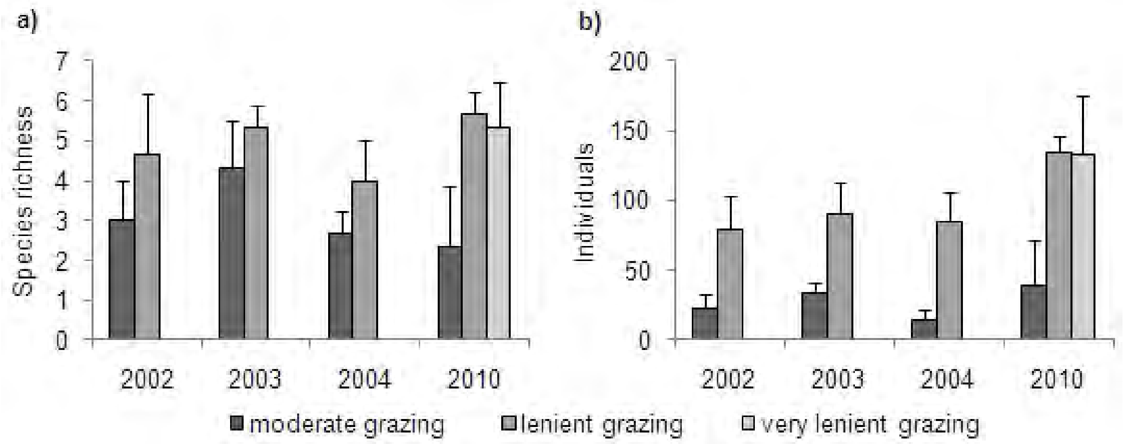

Figure 1. a) Species richness (number of species) and b) abundance (counts of individuals) of grasshoppers at different grazing intensities. Moderate and lenient grazing have been in place since 2002, very lenient grazing since 2005. Error bars show standard deviation. Statistical differences as described in the text.

Species richness in 2010 could not be explained by the measured variables (Table 1). In contrast, small-scale sward height had a significant effect on abundance ($P < 0.01$). The importance of sward height was also emphasized by Batary *et al*. (2007) and is obviously dependent on grazing intensity (correlation with grazing intensity treatments: $P < 0.05$). Neither the range of sward height as a measure of horizontal heterogeneity nor plant species richness and grass cover had an effect on grasshopper abundance (Table 1).

Table 1. Influence of sward height and its range, plant species richness and grass cover on grasshopper species richness and abundance. Multiple regression statistics displayed are the ANOVA fit of the regression line, F; the coefficient of variation, R^2 and the regression coefficients for each variable with statistical significances.

	Species richness	*P*	Abundance	*P*
F	1.574	0.336	8.97	0.028
R^2	0.22		0.80	
Sward height	0.36	0.116	10.68	0.005
Range of sward height	- 0.09	0.388	- 0.69	0.926
Plant species richness	1.20	0.392	21.52	0.178
Grass cover	0.08	0.547	0.96	0.620

Conclusions

Reducing grazing intensity appears to be an adequate management practice to create and maintain swards appropriate for diverse grasshopper assemblages, but it can be concluded from this study that it is not necessary to aim at a target compressed sward height of more than 12 cm. Furthermore, average small-scale sward height seems to be a better predictor of grasshopper abundance than sward height heterogeneity, plant species richness or grass cover.

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Influence of stocking density on plant species richness and diversity in permanent grassland

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Abstract

Extensive grazing has often been suggested to be a useful management tool for the protection and recreation of species-rich grassland. We investigated influences of stocking density on plant species richness and diversity in a permanent pasture experiment established in 2002 in the Solling uplands, Germany. Paddocks were managed in a put-and-take system with German Simmental cattle to target compressed sward heights of 6, 12 and (starting in 2005) 18 cm, respectively. Phytodiversity was measured in ten permanent quadrats per paddock. From 2007 onwards, the vegetation height in the quadrats was determined with a rising-plate meter at the time of botanical investigations. Grazing treatments did not lead to differences in mean species number or Shannon diversity. However, the local height of the vegetation at the vegetation relevés had a significant influence on mean species number independent of the grazing treatment. Thus, the conditions at the small scale seem to have been more important for vegetation diversity than the larger-scale management during the first nine years after a change in grazing management.

Keywords: grazing intensity, sward height, patch, scale, Shannon index

Introduction

As grazing animals increase the heterogeneity of a sward, extensive grazing has often been suggested as a tool for the recreation of species-rich grassland (Hart, 2001; Krahulec *et al*., 2001; Pykälä, 2005; Pavlu *et al*., 2007). The animals influence sward phytodiversity by selective grazing, nutrient redistribution and treading (Rook *et al*., 2004), thus creating a patchy sward structure. So far, investigations of the interaction between grazing intensity and phytodiversity have measured grazing intensity mainly as the number of animals per unit area, or the average sward height (e.g. Hart, 2001; Hickman *et al*., 2004; Pavlu *et al*., 2007) without taking sward patchiness into account. Here, we report the results of a nine-year study where swards were managed for different sward heights, but where we also measured sward height at the sites of vegetation relevés. We hypothesized that the sward height at the patch is more important for phytodiversity than the average height of the sward.

Material and Methods

The experiment was carried out on a moderately species-rich mesotrophic hill grassland, vegetation type *Lolio-Cynosuretum*, in the Solling uplands in Relliehausen, Germany (Isselstein *et al*., 2007; Sahin Demirbag *et al*., 2009). In 2002, grazing intensity treatments were established with Simmental cattle in a randomized block design in triplicate (plot size 1 ha): moderate stocking (MC) with a target compressed sward height (CSH) of 6 cm, lenient stocking (LC) with a target CSH of 12 cm, and - starting in 2005 - very lenient stocking (VLC) with a target CSH of 18 cm. The latter treatment was grazed before 2005 to a target CSH of

12 cm by German Angus cattle. CSH was measured (bi-) weekly according to the method of Castle (1976) and animal numbers adjusted in a put-and-take system.

The vegetation was analysed in May each year in ten permanent quadrats (1 m² each) per paddock, where the botanical composition and percentage cover of species was determined. The average number of species per m² and Shannon diversity index were calculated (Magurran, 2004). From 2007 onwards, the CSH of the quadrats (five measurements per m²) was also recorded at the times of botanical surveys.

Statistics were calculated with Statistica 9.0. Differences between treatments ($\alpha = 0.05$) were analysed with repeated measures ANOVA (year as repeated measure, block and treatment or vegetation height class as factors; Kolmogorov-Smirnov test for normality, Levene's test for homogeneity of variances).

Results

Analysed over all years, there were no significant differences among treatments in the average number of species per m² ($P = 0.400$) or in the Shannon index ($P = 0.382$). Table 1 shows, as examples, the results obtained for 2002, 2006 and 2010. At a taller local sward-height class, the number of species was decreased (Figure 1, $P < 0.001$), independent of the grazing intensity.

Table 1. Average number of species per m² and Shannon diversity index for paddocks differing in grazing intensity (MC: moderate grazing, LC: lenient grazing, VLC: very lenient grazing). Shown are means and standard deviations. For further information, see text.

	2002	2006	2010
Mean number of species [m²]			
MC	12 ± 1	12 ± 2	11 ± 2
LC	12 ± 1	11 ± 3	10 ± 4
VLC	12 ± 1	12 ± 3	10 ± 4
Shannon diversity index			
MC	1.94 ± 0.20	1.80 ± 0.33	1.78 ± 0.23
LC	1.92 ± 0.24	1.80 ± 0.28	1.63 ± 0.40
VLC	1.78 ± 0.27	1.80 ± 0.27	1.69 ± 0.49

Discussion

In this investigation of influences of grazing intensity on phytodiversity, we did not find treatment effects on mean species number or Shannon diversity index nine years after the start of the experiment. However, species numbers varied among patches differing in local sward height. The sward height of the patches stayed relatively stable with time. Thus, patches with tall vegetation in spring typically still had tall vegetation in autumn and in spring of the next year, which is in line with the literature (e.g. Hofmann and Tallowin, 2003). Nutrient conditions (mineral N, P, K) could not explain differences in botanical diversity between patches (data not shown). Probably, light was an important factor influencing phytodiversity in this mesotrophic grassland grazed at moderate to very lenient intensity.

Conclusions

Local vegetation height was a better predictor of botanical diversity at the patch scale than stocking density *per se*. Less competition for light probably led to a quicker diversification in the short patches. As patches remain relatively stable over time, a patch-specific species turnover is likely to take place in the longer term. Tall grass patches that cover a larger area

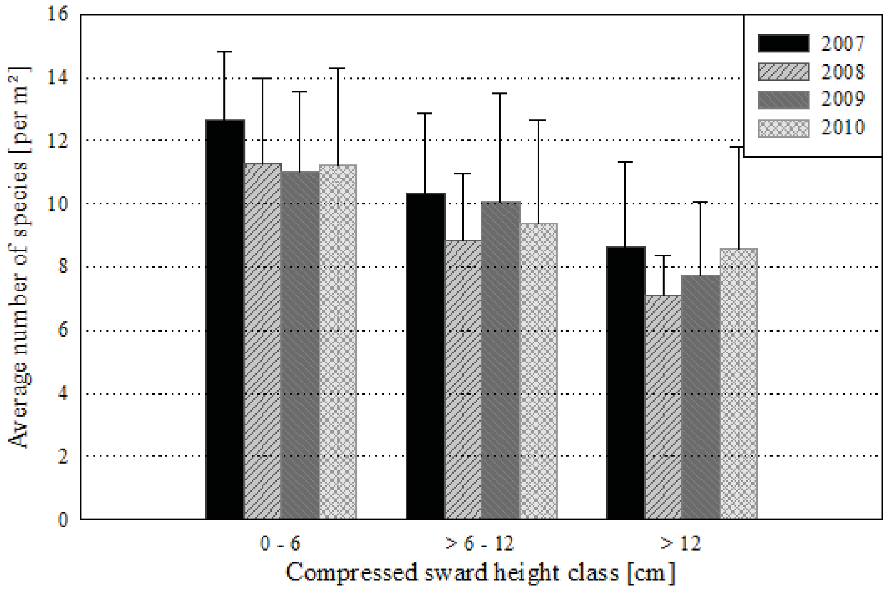

Figure 1. Number of species per compressed sward height class, averaged over all treatments, for the years 2007 to 2010.

under extensive grazing enable plants to develop seeds, which will further affect population structure and botanical composition. Thus, the mosaic of short and tall patches developing under lenient grazing intensity should lead to increased phytodiversity in the long term.

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Change of plant species composition in mountainous meadows against the background of climate change and altered management

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Abstract

Analysis of regional climate data along a transect from the 'Salzkammergut' in the north through the Styrian Enns valley to the 'Niedere Tauern' mountains in the south indicate a constant increase of temperature from 1970 to 2000 and a widened growing season mainly manifested between 1987 and 1994. Encouraged by above facts and aiming at high energy forage some farmers responded since 1997 by more frequent cutting and by setting the first cut ten days earlier. Vegetation change was detected by comparing species composition of differently managed grassland between 1997 and 2010. The relevés varied by cutting frequency (2, 3, 4 times) and type of fertiliser (slurry, solid manure). Changes in floristic composition correlated significantly with increasing cutting frequency and partly with changes in manuring. Control relevés with unchanged low cutting frequency showed a weaker response, except for meadows fertilised by slurry. Changes of mean Ellenberg indicator values were not significantly correlated with climate variables. Generally, several short-lived species were lost and formerly widespread dicots with nice flowers (typically for meadows cut twice) decreased. This may be related to more dense swards resulting from reseeding of more productive forage species and sophisticated timing of cuts and manuring.

Keywords: global change, grassland, diversity, manuring, mowing

Introduction

During the last decades management practice of meadows was intensified with respect to timing and frequency of cutting, and type of fertilisation throughout Europe. Possible drivers for compositional changes of meadow vegetation are mainly earlier cutting dates and, probably, climate change. This study aimed at detecting changes in species composition of meadows in the mountainous region of the Styrian Enns-valley between 1997 and 2010, and at searching for correlations of diversity shifts with changes of management practices of farmers and of climate variables (Green, 2006; Marini *et al*., 2008; Vittoz *et al*., 2009).

Materials and methods

The study was carried out along a 24 km NE-SW gradient from Tauplitz to Oppenberg in the eastern Alps. Meadow fields north of the Enns-valley are located on neutral to basic soils, whereas fields situated south of the Enns valley show nutrient-poor and acidic soils. Altitude reaches 640 m in the Enns-valley and 1200 m in the mountains to the north and south. High precipitation rates (1000-1300 mm/yr) facilitate grassland farming. Mean annual temperature ranges from 4.9 to 6.7°C. Mean annual temperature at the station Admont (next to the investigation area) increased by 1°C between 1970 and 2010. Such warming was accompanied by an increase of the growing season by 3 weeks between 1987 and 1994 at the stations Bad Mitterndorf, Gumpenstein and Aigen, all within the investigation area. Length of the growing

season was calculated as the time between 'daily mean temperature (Tday) > 5°C for > 5 d and Tday < 5°C for > 5 d' (Frich *et al*., 2002).
Nowadays, meadows are cut three to four times a year in the Enns-valley and two to three times in the mountainous regions. Application of organic fertiliser is common on most fields. We interviewed farmers owning meadow fields that were documented in a regional vegetation survey in 1997 with regard to changes in cutting frequency, fertiliser application and sowing of meadows. Finally, we found 49 fields with the following eight treatments: two cuts + manure, no change; two cuts + slurry, no change; two cuts + manure to slurry; two to three cuts, manure; two to three cuts, slurry; three cuts + manure, no change; three cuts + slurry, no change; three to four cuts + manure to slurry. Those fields were revisited in 2010 producing phytosociological relevés.
Pairs of relevés from 1997 and 2010 were analysed with respect to dissimilarity (weighted Soerensen-Index), change of total species numbers and species specific dynamics. Average Ellenberg indicator values were used to identify temporal changes in site conditions. Differences of means were tested with pairwise t-tests at significance level $\alpha = 0.05$.

Results and discussion

Some farmers acted after 1997 by cutting their meadows more frequently. In 1997 none of the studied fields on the Enns-valley floor were cut four times a year; in 2010 there were five of them. In the mountains cutting frequency was augmented on five out of ten fields that were cut two times before. This intensification might not be induced exclusively by the farmer's awareness of climate change but nowadays farmers generally tend to mow earlier aiming at high energy forage. This fact is often accompanied by deploying slurry instead of solid manure. 20% of farmers changed to a stable system with slurry production.
From 1997 to 2010, the mean number of species per relevé decreased from 44 to 37. Soerensen dissimilarity indices of relevé pairs 1997/2010 range from 0.25 to 0.35. Relevé pairs with unchanged two-cut system have the lowest values indicating, that there are minor changes in species composition. High values in relevé pairs with increased cutting frequency (two to three, three to four) suggest serious shifts in vegetation (Figure 1). Annuals and other species demanding light were less frequent in 2010. There is also a decline of species typically for meadows cut twice and light manuring. In contrast, the cover of *Trifolium repens* and *Poa*

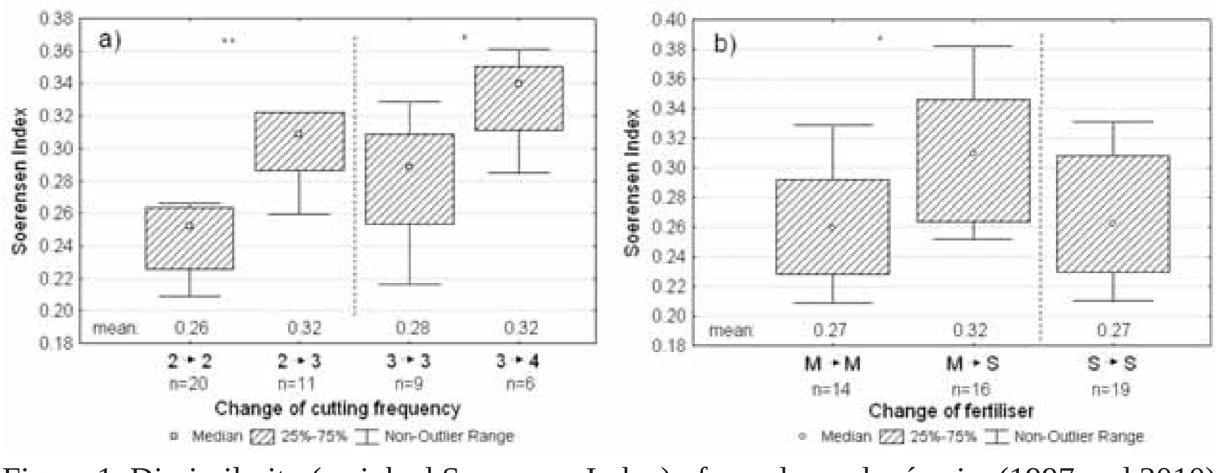

Figure 1. Dissimilarity (weighed Soerensen Index) of meadow relevé pairs (1997 and 2010) in the Enns-valley region with regard to a) change of cutting frequency, b) change of fertiliser; (S = slurry; M = solid manure)

trivialis increased in the same period. Both species are CR-strategists (according to Grime); they profit from vegetation gaps due to their ability to spread quickly by vegetative growth. Loss of species and increasing dissimilarity of vegetation is positively and partially significantly correlated with cutting frequency. Change from solid manure to slurry causes significant higher vegetation dissimilarity than in relevé pairs with unchanged manure application (Figure 1). Additionally, there is a (not significant) trend to species loss in relevés with solid manure before. Several species that indicate cold climatic conditions decreased in abundance, only *Ranunculus montanus* remained constant and *Poa supina* occurred more frequently. *Lolium*×*boucheanum* is the only indicator for warm climate conditions within the dataset. It became more frequent by sowing, which was reported by the farmers. Thus it is inappropriate to indicate climate change. Mean Ellenberg indicator values for temperature increased on fields at lower altitudes simply because of the higher frequency of *Lolium*×*boucheanum*. At higher altitudes the mean indicator values for temperature slightly decreased, even though some indicators for cold climate decreased. At the same time those species indicate poor manuring. Thus we consider that the decline is due to intensification.

Conclusion

Vegetation shift in natural vegetation of mountain peaks is observed and related to climate change (Pauli *et al*., 2007). Our data show that compositional changes and diversity loss in mountainous grasslands are directly correlated to management intensifications such as increased cutting frequency and change to slurry fertilisation. An unambiguous interference of vegetation change and warmer climate conditions could not be verified within the last 13 years. Other authors (e.g. Vittoz *et al*., 2009) also argued that in managed grassland the influence of global warming is overruled by management practices. The warming in the last decades of the 20th century had no directly measurable influence on conservational aspects (biodiversity, aesthetics) of meadows but the earlier start of the vegetation period induced farmers besides other economic constraints to intensify management. Such resulted in floristic biodiversity loss and shift of plant species composition, i.e. the increase of undesired species like *Poa trivialis*.

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Assessment of productivity of semi-natural grasslands under different fertilisation and cutting treatments

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Abstract

Extensively managed grasslands are strongholds of biodiversity and habitats for many endangered plant and animal species. Therefore these habitats are under special protection according to the European Union's directive on the conservation of natural habitats and of wild fauna and flora. The optimal management regime for these areas often includes a late seasonal harvest. This leads to high amounts of lignin and cellulose in the biomass, thus reducing its suitability for animal nutrition and leading to a low degradability in common biogas plants. Combustion of these materials has proved to be problematic because of the high content of minerals detrimental to combustion. Within the European-wide PROGRASS project, the use of semi-natural grassland for energy production, solid fuel and biogas, is investigated. Effects of fertilisation and mulching on productivity were examined by six representative sites within or bordering nature conservation areas in the Vogelsberg region, Germany. Results showed that the IFBB (Integrated Generation of Solid Fuel and Biogas from biomass) system preserved the productivity ranging from 2.90 to 9.49 t DM ha^{-1} yr^{-1}.

Keywords: biodiversity, productivity, semi-natural grasslands, IFBB, fertilisation

Introduction

Semi-natural grasslands are protected by European law (Anonymous, 2007) because they harbour a wide range of plant and animal species dependent on these types of habitats. Ostermann (1998) pointed out that a considerable share of the European protected habitat types are semi-natural grasslands in need of an extensive cutting and fertilisation regime. Under German conditions, nature conservation agencies propose a late-cut regime with no fertilisation. These conditions lead to a low nutritive value of the harvested biomass making it impossible to use the material as forage for highly bred dairy cows. There is no convincing process available to use this material for bioenergy production, because of the problems the material causes, e.g. ash melting, corrosion and emissions in combustion (Obernberger *et al*., 2006) and low methane yields in anaerobic digestion (Richter *et al*., 2009). Therefore the University of Kassel has developed a system to use this kind of material, the IFBB process (Wachendorf *et al*., 2009). The effect of extensive management on six semi-natural grasslands in the Vogelsberg has been investigated. The aim was to investigate the influence of a late-cut system with and without fertilisation and a mulching system on productivity and biodiversity of these grasslands.

Material and methods

Six sites in the Vogelsberg were investigated in 2009 and 2010, being representative for semi- natural grasslands in rural and mountainous areas in Germany. For each site, seven plots of 100 m² each were established, three replicates of fertilised (FC) and three replicates of unfertilised plots (UC) with a cutting treatment and one unfertilised plot with a mulching treatment (UM). The sites were managed extensively, with one or two cuts per year (Table 1).

Table 1. Dates of cutting, mulching, fertilisation and botanical inventory of study sites

Area Number	Natura 2000 Habitat Code	Cutting / mulching dates 2009	2010	Fertiliser application 2010	Botanical inventory 2009
I	6510	14.07. / 11.09.	07.07. / 09.09.	05.05.	14.06.
II	6510	13.07. / 09.09.	05.07. / 10.09.	05.05.	23.06.
III	6520	13.07. /11.09.	06.07. / 09.09.	05.05.	01.07.
IV	6230	13.07.	08.07.	05.05.	07.07.
V	6410	21.07. / 18.09	20.07. / 10.09.	05.05.	16.07.
VI	6431	08.09.	07.09.	05.05.	30.08.

The UC and FC plots were harvested with a finger bar mower. Harvested material was collected and removed from the site. The UM plots were managed similarly to the UC plots, with one or two mulching cuts with a rotary mower; harvested material remained on the mulching plot. Dry matter (DM) yield was measured by cutting 5 m² of each plot and weighing the material. A sample was taken to determine DM content in a drying oven for 48 h at 105°C. Dry matter yield was statistically investigated by using a univariate ANOVA with treatment (UC, FC, UM) as the independent factor. Level of significance was set at $P = 0.05$. The plots were fertilised on 5 May 2010 with a separated digestate from a biogas plant with a DM content of 32.6 g kg^{-1} fresh matter (FM) and a content of P_2O_5 and K_2O of 0.82 and 3.76 g kg^{-1} FM respectively. The content of K_2O was 3.76 g kg^{-1} FM. The separated digestate was analysed and applied to each FC plot. The amount of N applied to the plots ranged between 23.3 and 54.6 kg ha^{-1} yr^{-1} and was calculated to match 50% of the N exported in harvested biomass. The amount of P_2O_5 and K_2O applied ranged between 4.9 and 11.5 kg ha^{-1} yr^{-1} for P_2O_5, 22.3 and 52.6 kg ha^{-1} yr^{-1} for K_2O. Within every plot, one permanent study area of 5×5 m for monitoring of biodiversity has been marked with a magnet in each corner. Vegetation cover for each plant species present and total plant cover were estimated. The botanical inventory will be observed until end of the project 2013 at yearly intervals. First assessment of biodiversity at the beginning of the project in 2009 showed a high number of vascular plant species on five of six sites, ranging between 54 and 77 species, with the exception of Area VI where only 18 vascular plant species could be found (Table 2). The number of rare and endangered plant species from the German red list (Korneck *et al.*,1996) was between 2 for Area VI and 13 (Area III and V). Biodiversity monitoring will be continued with emphasis on the highly endangered plant species present.

Table 2. Results of botanical census in 2009 at the beginning of the experiment.

Area	Vegetation type	Total No. of Species	No. of Grasses	No. of Sedges / Rushes	No. of Forbs	No. of Red List Species
I	Lowland hay meadow	54	16	0	38	7
II	Lowland hay meadow	61	16	1	44	8
III	Mountain hay meadow	77	18	6	53	13
IV	Species-rich Nardus grasslands	61	17	6	38	12
V	Molinia meadow	68	16	8	44	13
VI	Humid tall herb fringes of watercourses and woodlands	18	2	5	11	2

Results and discussion

In 2010 there was a difference in productivity between FC and UC plots and mulched plots *vs.* cut plots (Figure 1). Statistics revealed that for means across sites the difference between UC plots and UM plots was significant. With the exception of Area III the productivity was highest for the UM plot, second highest for FC plots and lowest for UC plots. The DM yields ranged between 2.79 and 6.87 t DM ha^{-1} a^{-1} for UC plots, 3.87 and 7.86 t DM ha^{-1} a^{-1} for FC plots and 4.35 to 8.66 t DM ha^{-1} a^{-1} for UM plots. The values for productivity are in the typical range for semi-natural grasslands in Europe (Tonn *et al*., 2010; Wachendorf *et al*., 2009).

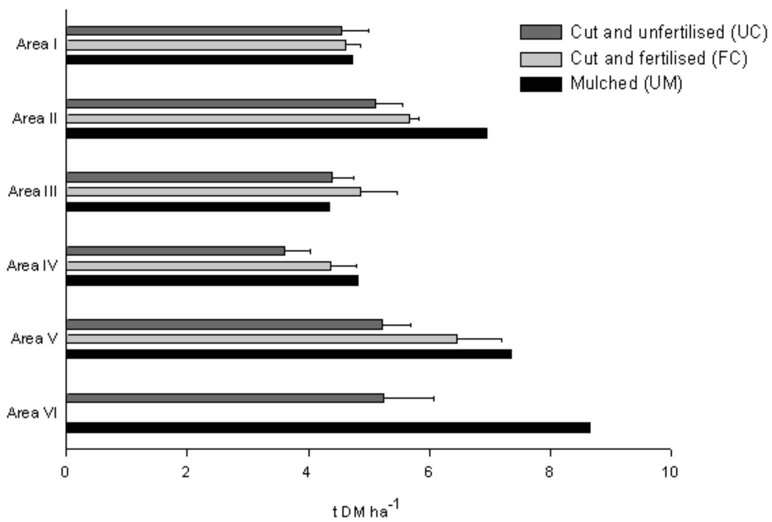

Figure 1. Mean values (with s.e. of mean) of productivity of six semi-natural grassland areas in 2010 under different cutting and fertilisation treatments

Conclusions

This study showed that nutrient replacement had an increasing effect on productivity of semi-natural grasslands. Fertilised plots had a higher productivity, even if only small amounts of nutrients were applied. Because no nutrients were removed, mulching resulted in a higher productivity than the cutting variants. Productivity of these areas is crucial for their economic benefit for bioenergy systems; therefore a certain level of productivity has to be achieved and maintained. Thus, re-application of minerals which are detracted through harvest for energetic use has to be considered in order to maintain the productivity of these sites. The effects of applying low levels of fertiliser and adapting an extensive cutting regime compared to a mulching regime will be monitored in future years. Further research is needed to find the optimal management regime for using semi-natural grassland biomass for energy production and, at the same time, conserve the high biodiversity of these habitats.

Acknowledgements

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Variation in beetle (Coleoptera: Carabidae, Scarabaeidae) assemblages at a local scale in mountain grasslands of central Greece

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Abstract

The effects of environmental factors and management of grasslands on the beetle assemblage composition and species richness was studied in Antichasia Mountains (central Greece) using pitfall traps. We recorded (i) the seasonal species composition in terms of mean abundance per trap, species richness, Shannon - Weiner diversity index, Fisher's a, Evenness index, and (ii) landscape variables (altitude, slope, soil depth, erosion) for both management systems (grazed *vs*. non-grazed). Species composition was analysed using Canonical Correspondence Analysis (CCA). Throughout the experimental season, a total of 4,722 beetles were collected belonging to 25 species. Altitude, season and management were significant predictors of species composition. Ground beetle assemblages were correlated positively to the management of grasslands and altitude, while dung beetle species were represented by little dependence on variables. In order to conserve Scarabaeidae assemblages in such grasslands, grazing is suggested.

Keywords: diversity indices, management, season, predictors, CCA analysis

Introduction

At a local scale, microenvironmental and biotic interactions are the most important factors explaining species distribution patterns (Whittaker *et al*., 2001). Dung beetles are an excellent indicator taxon as they are an integral part of any grazing ecosystem (Nichols *et al*., 2008). Aims of this study were the biodiversity evaluation of Mediterranean grasslands using beetles as bioindicators of sustainable grassland management and the assessment of impacts of the environmental factors and management system on their assemblages.

Materials and methods

The study area was approximately 950 ha. The fourteen randomly selected grassland plots were non-irrigated and located at altitudes between 780 and 830 m above sea level and at distances of at least 2 km from each other. The climate of the area is sub-Mediterranean with average annual precipitation ≈ 700 mm. Landscape variables characterizing the plots were obtained from digitized geological and soil maps and a processed digital elevation model (DEM) using ArcGIS 9.3. Management included grazing intensity determined on the basis of the traces of livestock excreta (24 grazed *vs* 18 non-grazed). For beetle sampling, we used 42 pitfall traps (9 cm in diameter and 13 cm in depth) filled with water and traces of household vinegar (5% acetic acid) to preserve insects and placed in a single transect separated by a distance of 10 m (three traps per plot). Traps were set at the surveyed sites from May 2006 until January 2007, and were active in only 48 h during a one-week period per month. Overall, five beetle diversity estimates were analysed: average abundance per trap; species richness; alpha diversity indices: Shannon-Wiener and Fisher's alpha; and the evenness index Pielou

J (Magurran, 1988) using the test developed by Solow (1993) (Henderson and Seaby, 2002). Beetle assemblage composition was analysed using CCA. The species abundances were log transformed, and the species abundance was used as a dependent variable. The management system and season were transformed into two dummy variables in the CCA, while forward manual selection was used with Monte Carlo Permutation Procedure (999 permutations) of all variables using Canoco for Windows 4.02 (ter Braak and Smilauer, 1998).

Results and discussion

A total of 4,722 beetles belonging to 25 species were collected in the 14 grasslands. The Carabidae family was more diverse (Figure 1), but the most common species were *Onthophagus ovatus* and *O. coenobita*, accounting for 74% and 13% of all individuals trapped respectively. The Shannon diversity index for Carabidae family was significantly more diverse than that for Scarabaeidae (*delta* = 0.99, $P < 0.05$). Pielou J index resulted in similar findings (delta = 0.309, $P < 0.05$) (Table 1).

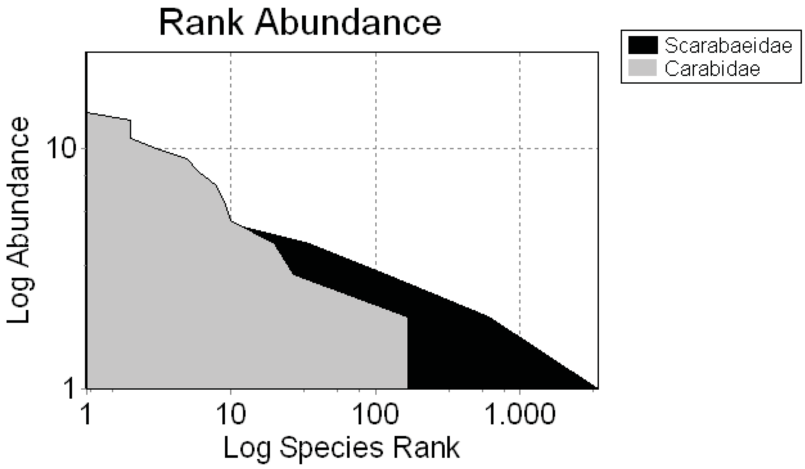

Figure 1. Species rank-abundance plot for the grasslands.

Table 1. Per trap mean (± SE) abundance, species richness, diversity and evenness indices of Carabidae and Scarabaeidae in 42 traps.

	Carabidae	Scarabaeidae	Total
Abundance (individuals)	437	4,285	4,722
Species richness (± SE)	19 (± 3.27)	6 (± 0.97)	25 (± 3.68)
Mean (± SE)	0.55 (± 0.44)	17 (± 26.93)	2.68 (± 4.99)
Shannon - Weiner (± SE)	1.59 (± 0.13)	0.59 (± 0.13)	0.99 (± 0.15)
Fisher´s a (± SE)	4.05 (± 0.91)	0.69 (± 0.18)	3.38 (± 0.65)
Pielou (± SE)	0.54 (± 0.04)	0.33 (± 0.07)	0.31 (± 0.05)

In the analysis of the relationships between beetle community structure, environmental factors and management, axis one of the CCA ordination plots explained 37% of the species-environment relationship, and together with axis 2, explained 69.7% of the relationship (Figure 2). The first axis was strongly related to the management ($F = 2.26$, $P = 0.005$) and diversity ($F = 1.45$, $P = 0.04$), while the second one was strongly related to the spring season ($F = 2.12$, $P = 0.01$). Multivariate analysis showed that soil depth and erosion were not important for the beetle diversity.

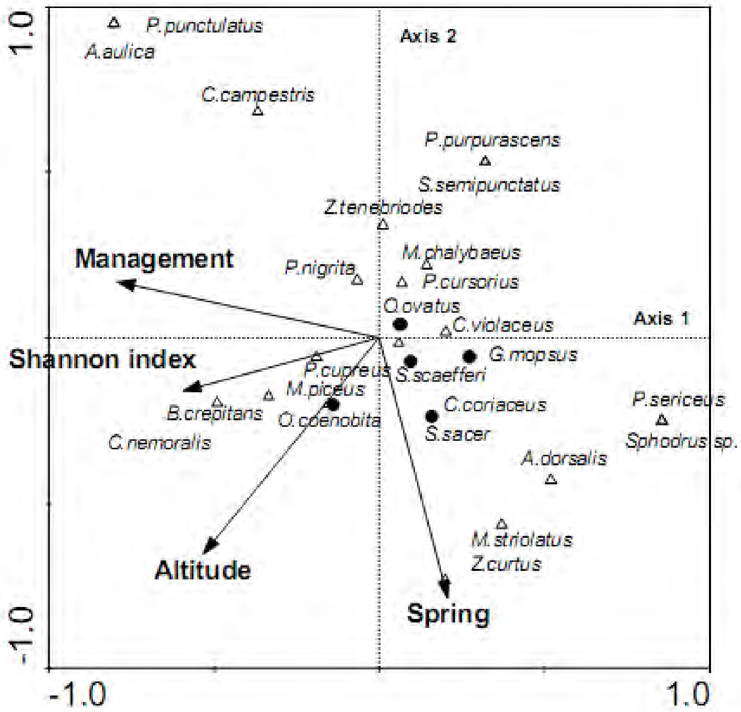

Figure 2. Biplot of beetle abundances and the most important environmental variables from CCA. Arrows represent environmental variables. Filled circles represent Scarabaeidae species, while triangles represent Carabidae species.

The history of livestock grazing of cattle, sheep and goats began in early Holocene and has been a common and traditional practice in the Mediterranean region ever since (Papanastasis, 1998). In our study area, properly managed grazing intensity, mainly occurring during the summer period, apparently because grasslands are situated at altitudes above 750 m, affected positively beetle diversity and therefore can be considered as a solution for protection of marginal mountainous areas.

Conclusion

This study illustrated that beetle abundance differed significantly among seasons. In addition, Scarabaeidae species occurred near the origin of the axes represented little dependence on management and other variables. Our results highlighted the fact that mountain grasslands threatened by abandonment need to be maintained as they exhibit high local beetle diversity.

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Multifunctionality of karst grassland to ensure an optimal provision of public goods

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Abstract

Multifunctionality of grassland is shown in this paper as a set of public goods provided by an organic farm located in a low mountainous area of North East Italy. The 98 ha of open landscape with typical karst grassland vegetation (*Scorzoneretalia villosae*) are grazed by suckler cows, sheep, goats and donkeys. Apart of organic products the farm provides a wide range of public goods, some of which are highly appreciated by visitors as well as others which are equally important for ecosystem functioning but currently are not known to the wider public. Agricultural products are sold directly or served to tourists who may also stay in confortable rooms or in a camping site. In this farm non-agricultural activities give three times more income than traditional farming.

Keywords: farm income, karst grassland, multifunctionality, organic products, public goods

Introduction

Grassland ecosystems represent the most important part of biodiversity in mountainous areas. They offer ideal conditions for diversity of habitats and species, and are very important for birds and invertebrates. Grasslands are also the source of a wide range of public goods and services, ranging from meat and dairy products to recreational and tourism opportunities. They act also as carbon sinks to reduce greenhouse gas emission levels in the atmosphere. In mountainous areas grasslands are disappearing and are among Europe's most threatened ecosystems. In 2006, the EC adopted an Action Plan that defines priority actions to halt biodiversity loss, i.a. the conservation and wise use of grasslands. The Habitats and Birds directives are the main pieces of legislation ensuring the protection of Europe's grasslands. EU agri-environmental measures also have a direct impact on the conservation of grasslands, particularly through the maintenance of extensive systems. In addition to species conservation and habitat protection, grassland biodiversity can contribute to enhanced value of traditional agricultural products and to non-commodity outputs, agro-tourism, ecosystem functions and resilience to environmental perturbation (Hopkins and Holz, 2006). Karst grasslands are among the richest grassland ecosystems in Europe but many extensively grazed areas were abandoned in the last few decades and turned into shrubland. The low level of phosphourus, high acidity and summer drought determine the karst swards' low productivity.

Materials and methods

The ‚Alture di Polazzo' farm (www.parcorurale.it) is located near the village of Fogliano di Redipuglia (GO) (114 m a.s.l., 45°52'16"N, 13°29'84"E) in the karst plateau, a limestone borderline region in southwestern Slovenia extending into northeastern Italy. The area is sorrowfully famous because it was the theatre of bloody battles during the First World War. The grassland belongs to the order *Scorzoneretalia villosae*, a xeric grassland type (Poldini, 1980) with an important presence of shrubs i.a. smoke tree (*Cotinus coggirya*). The farm has a size of 98 ha of grassland restored from shrubland. It is managed according to the general principles of low input farming systems (Biala *et al*., 2007) and is located in a Nature 2000 area and profits from EU subsidies. Farming practices are associated with high biodiversity values and the area may be defined as a High Nature Value (HNV) farmland (EEA, 2010). The grassland is grazed by 18 Italian Simmenthal suckler cows, 110 sheep of the domestic authoctonous breed ‚Carsolina‘ (=Istrian Pramenka), 10 goats and 16 donkeys for recreational use. The average stocking rate is 0.5 LU ha^{-1}. The area is divided into 7 paddocks, of which six are grazed in sequence, each use being followed by a rest period of 30-40 days, and one is left for hay making to feed animals during the winter period. The rotational grazing cycle is of 365 days, i.e. during the non-vegetation period (about 100 days) animals are grazing on senescent or dead material.

In the past grassland received mineral fertization and was submitted to direct drilling with legumes (*Lotus corniculatus*, *Trifolium repens, Trifolium pratense, Trifolium subterraneum*) to improve the yield and the herbage intake.

Experiments were carried out to determine grass yield, its chemical composition i.e. CP (crude protein), neutral detergent fibre (NDF), and the grass intake of suckler cows by measuring *in vitro* organic matter digestibility (IVOMD) and Cr in faeces. Results have been published in Parente *et al*., 2000.

Since 1997 the farm has been managed according to the European Organic rules. The farm has got an environmentally labelling logo reported on products, i.e. a way for marketing agricultural sustainability (Biala, 2008). Agricultural products are sold directly to customers or served at the farm restaurant.

Until 1998 the farm was breeding dairy cows but milk production in this area was unprofitable because of low prices and logistical problems in delivering the milk to the dairy plants. Therefore the dairy barn was transformed in a guest-house with eight comfortable apartments and a camping site for 20 caravans or campers was arranged. Didactic activities are carried out in a large well equiped conference hall. The owner is living with his wife, two married sons and their three young children. All the adults work on the farm.

Results and discussion

Vegetation and animal breeding. The production of grass sward has been calculated to be 2.7 t DM ha^{-1} but it is possible to double the yield with PK fertilizers plus legumes drilling (Parente *et al*. 2000).

Sheep are shown to be well adapted to the environmental conditions and the integration of cows in the optimal utilization of the biomass has been demonstrated (Rook *et al*., 2003). Carsolina sheep possess unusual characteristics, i.e. the distinct long-stepping walk and the ability to graze in rocky terrain, even on dry old grass, being also skillful at finding fresh grass between rocks. Their fertility is quite good for the local environmental conditions and the organic production standards, i.e. the lambing rate is 90%.

Dunkeys selectively graze immature and less stemmy species and contribute to reducing shrub cover. This role is fulfilled by goats in order to limit the encroachment of shrubs and also to preserve this distinctive landscape element. Extensive grazing with different animals also guarantees a high level of grassland biodiversity.

Animal life. There is a high diversity of birds, expecially birds of prey such as hawks (*Accipiter gentilis*), buzzards (*Buteo buteo*) and sparrowhawks (*Accipiter nisus*). The reintroduction of grazing also resulted in the increase of invertebrates i.a. grassland butterflies.

Agritourism. To ensure a good income, since 1999 the owner has been organizing various events targeted at farmers (e.g. livestock shows), schoolchildren (farm tours, birthday parties, petting zoos) and the general public (e.g. adoption of animals and trees). After the creation of a small guest-house, a restaurant and a camp site, the number of visitors increased exponentially. Direct sale and in farm served products (e.g. meat, vegetables, fruits, cheese, honey) are the main sources of farm income.

In 2010, people spent 1937 nights in the apartments and 2090 nights in the camping. All farm products were sold to visitors or served to 1200 people at the farm restaurant. About 2500 guests visited the farm and 10 youth camps, each for 30 participans, were organized during the summer period.The owner declares that his gross income is presently three times higher than the income possible with traditional farming.

Conclusion

The favourable location and the open grassland landscape serve as a big magnet for tourists. However, the maintenance of the open landscape can only be achieved through grazing as an efficient tool to limit the expansion of shrubs. Extensive pasture practices require financial aid and greater social and political support. The CAP policy gives an important support to farmers but the present situation of mountainous areas is such that agriculture on its own can hardly support the farm economy. The complementarity is of extreme importance but it requires more versatility and involvement of farmers.

This farm runs farmland that is of high nature value. It provides, apart from organic products, a wide range of public goods, some of which are highly appreciated by visitors (e.g. agricultural landscape or farmland biodiversity) as well as others which are equally important for ecosystem functioning but currently not known to the wider public (i.a. soil functionality, carbon storage, air quality, resilience to fire, food security, rural vitality, farm welfare and health). In this farm non-agricultural activities provide three times more income than traditional farming. Nevertheless, this example is not the panacea for all farmers living in mountainous areas. The ‘Alture di Polazzo’ farm is located in a very favourable area, easily reachable by a good road network and near to three towns (Trieste, Udine, Gorizia). Its size is relatively large and is located in a zone of high historical importance. Most farms in mountainous areas are in unfavourable conditions and can be hardly managed like this organic farm. Nevertheless, multifunctionality of agriculture is the only way to make possible the survival of many farms in mountainous areas.

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Utilisation of species-rich *Bromion* grasslands as donor sites for regional seed mixtures

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Abstract

The utilisation of species-rich grasslands as donor sites for regional seed mixtures was tested in a *Bromion* meadow located in the White Carpathian Mts. (Czech Republic). The seed was harvested with a brush harvester in two methods: a) once only (H1) and b) three times per site (H3). Seed number and weight were assessed from seed samples. In H3, the number of seeds per 1 m² of grassland was significantly higher in the first harvest (164.8) than in the second (36.3) and third (22.4) harvests. The high number of seeds found in method H1 (162.6) was not significantly higher than in the early harvest of method H3. In terms of weight, the greatest amount of seed was harvested on the first date of method H3 (0.327 g), when the mixture contained 78% grasses. On all other dates the amount of seed was significantly lower, and forbs (including legumes) were the predominant fraction in the samples, i.e. 74% (H1), 62% (H3 - 2nd harvest) and 91% (H3 - 3rd). The number of plant species identified in the seed samples was 27 (H1), 24 (H3 - 1st), 26 (H3 - 2nd), 23 (H3 - 3rd), and 34 (H3 - total). 12 plant species were common to all harvests.

Keywords: semi-natural dry grassland, brush harvester, seed production, restoration

Introduction

In the White Carpathian Mts. (Czech Republic), 4,000 ha of species-rich meadows (*Bromion*) have survived in the landscape despite decades of intensive agricultural management (Jongepierová, 2008). Such grassland is the only existing source of diaspores for ecological recreation of grassland with appropriate seed and plant material (Krautzer and Pötsch, 2009). Since the 1990s approximately 7,000 hectares of arable land in the White Carpathian Mts. have been transformed into grassland by means of spontaneous succession, sowing commercial grass-clover seed mixtures, and since 1999 also by sowing a regional seed mixture (Jongepierová *et al*., 2007; Mitchley *et al*., in prep.; Prach *et al*., in prep.). The latter mixture consists of seeds from existing species-rich meadows obtained in two ways: (1) reproduction of collected seed, (2) direct harvesting with a combine or brush harvester. The brush harvester was introduced in 2007 and the effectiveness of its use in meadow seed harvesting was unknown. We were particularly interested in which species are obtained with such a method and in what quantities, depending on harvest date. These data were collected and evaluated in an experiment at a single *Bromion* meadow site.

Material and methods

The donor site, a *Bromion* meadow located in a semi-natural dry grassland complex with interspersed trees in the buffer zone of Čertoryje National Nature Reserve (510 m a.s.l., White Carpathian Mts.), is characterised by an average daily air temperature of about 8°C and an average annual precipitation of about 700 mm (Tolasz, 2007). It has been managed extensively (one cut per year, and moderately fertilised only during 1970-1987). At the site a total of 138 vascular plant species have been recorded. The research was set up in 3 replicates for two different seed harvesting methods; each plot was 250 m² in size. In 2009 seed was harvested with a brush harvester using two methods: a) once only (H1, on 27 July), and b) three times per site (H3, on dates 2 July, 27 July and 21 August). Four samples of harvested seed material corresponding to the production of 1 m² were taken from each plot on each harvest date. The samples were weighed, cleaned with sieves and with a seed blower Retsch DR 100. Seeds were separated manually and analysed for number of seeds and their weight per species. The number of seeds (per m²), seed weight (g m^{-2}) and number of species found in the sample were analysed using ANOVA (STATISTICA 9.1). Differences between the methods and dates were tested with the Tukey HSD test.

Results and discussion

The results for the harvesting methods (Table 1) showed that 3 harvest dates per site (H3) produced the highest total yield of seed (0.392 g m^{-2}) with a well-balanced content of grass and forbs (including legumes) by number of seeds (49:51), which correspond to 70:30 by weight percentage. The number of seeds per 1 m² was significantly higher in the first harvest (164.8) than in the second (36.3) and the third (22.4) harvests. Concerning weight, the greatest amount of seed was obtained in the first harvest (0.328 g), when the mixture contained 78% grasses. The second and the third seed-harvests had a significantly lower yield of seed, and containing mainly forbs including legumes (62% and 91% by weight, respectively). The seed yield was significantly lower (0.114 g m^{-2}) in the single seed-harvest (H1) in comparison to the total yield of the H3 method. A positive correlation was found between seed number and weight in the harvested seed (r = 0,859, $P < 0.01$).

Table 1. Characteristics of seed mixtures harvested in a *Bromion* meadow in 2009 (means of 3 replicates)

Method of harvest	Date	No. of seeds m^{-2}	Seed weight (g m^{-2})	No. of plant species m^{-2}
H1/date 2	27.07.2009	162.6^{a}	0.114^{b}	18.0^{b}
H3/date 1	02.07.2009	164.8^{a}	0.328^{a}	17.0^{b}
H3/date 2	27.07.2009	36.3^{b}	0.044^{bc}	18.3^{ab}
H3/date 3	21.08.2009	22.4^{b}	0.020^{c}	16.0^{b}
H3/total		223.4^{a}	0.392^{a}	25.7^{a}

^{abc} Values with different superscripts differ ($P < 0.05$)

A comparison of seed characteristics between H1 and the first H3 harvests showed no significant difference in number of seed per 1 m² (Table 1). However, date of harvest significantly affected the composition of the mixtures, which differed strongly in the proportion of grasses and forbs including legumes (Figure 1). In the first H3 harvest (early July) heavy grass seeds prevailed in the mixture (59% of total seed number and 78% of seed weight) and due to this fact the seed yield was significantly higher (0.328 g m^{-2}), whereas in the H1 harvest (late July) the ripe grass seeds had mostly fallen out, and light forb and legume seeds predominated in this mixture (89% of total seed number and 74% of seed weight), which caused its significantly lower seed yield (0.114 g m^{-2}).

The numbers of plant species identified in the seed samples were (totals for the three replicates) 27 (H1), 24 (H3 - 1st harvest), 26 (H3 - 2nd), 23 (H3 - 3rd), and 34 (H3 - total). The seeds of 12 plant taxa were common to all harvests: the grasses *Brachypodium pinnatum*, *Bromus erectus* and *Dactylis glomerata*, the legumes *Vicia hirsuta* and *V. tetrasperma*, and the forbs *Cirsium* *pannonicum* (with some *C. arvense*), *Filipendula vulgaris*, *Galium boreale*, *G. verum*, *Plantago lanceolata*, *Ranunculus polyanthemos* (possibly with a small amount of *R. auricomus* agg.) and *Stellaria graminea*.

Conclusion

Harvesting seed three times per site in the *Bromion* grassland resulted in the highest total yield of seed with a balanced content of grass and forb (including legume) seeds and the highest plant species presence. However, from the economic point of view, harvesting seed in early July in one plot (to obtain mainly grass seed) and late July in another plot (for forbs and legumes) can be considered.

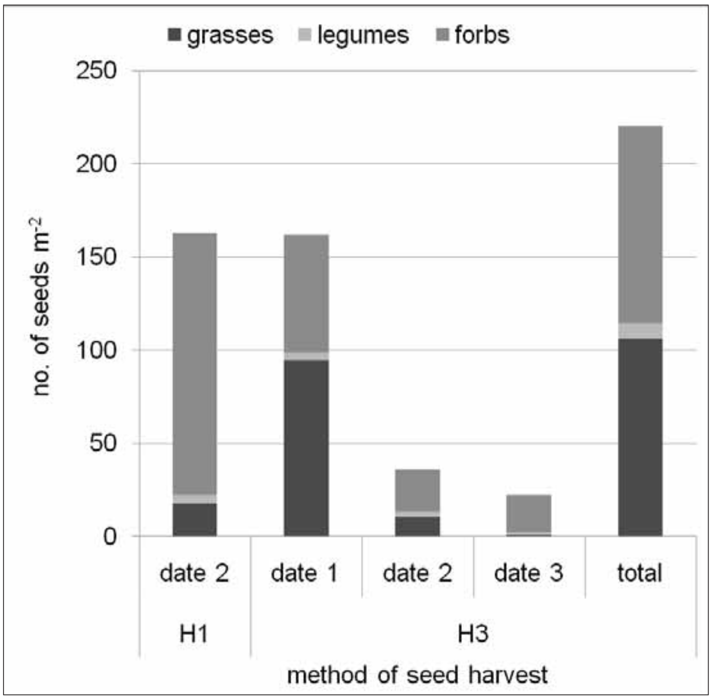

Figure 1. The proportion of grasses, legumes and forbs in the seed mixture (seeds m^{-2}) by seed harvest methods in a *Bromion* grassland. H1 (H3) - seed harvest once (three times) per site, date 1: 02.07.2009, date 2: 27.07.2009, date 3: 21.8.2009.

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Influence of habitat and management on genetic diversity of *Dactylis glomerata* in Switzerland

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Abstract

Genetic diversity, i.e. the diversity within species and populations, is an important component of biodiversity which may substantially contribute to the productivity, adaptability and sustainability of grassland ecosystems. Although the importance of grassland habitats as a reservoir of genetic resources is generally recognized, little is known about the effect of habitat characteristics on genetic diversity. We used orchard grass (*Dactylis glomerata*), a perennial forage grass well adapted to a broad range of temperate environments as a model species to, (i) develop and establish an optimized method to assess genetic diversity of *D. glomerata*, (ii) test optimized tool in a Swiss case- study area and to (iii) investigate the effect of environmental conditions and management practices on genetic diversity. Twenty orchard grass populations were sampled from contrasting habitats which differed with respect to environmental conditions (altitude, slope, exposition), management intensity (cutting/grazing frequency, fertilization) and farming system (organic and conventional agriculture). Genetic diversity was analyszed using molecular genetic markers (Simple Sequence Repeats). The insights gained may be particularly valuable for the *in situ* conservation of valuable genetic resources of grassland species and to develop indirect measures for a rapid assessment of genetic diversity in grassland habitats.

Keywords: *Dactylis glomerata*, grassland diversity, organic agriculture, SSR markers

Introduction

Grassland plays a main role in European land use (Isselstein *et al*., 2005) and provides a wide range of contrasting habitats varying in management regimes, agricultural productivity, socio-economic value and conservation status (Hopkins and Wilkins, 2006). Natural and semi-natural permanent grasslands provide particularly valuable reservoirs of genetic resources of forage grass species. They are indispensible as genetic breeding stock and for the *in situ* conservation of genetic variation (Boller *et al*., 2005). However, grassland habitats and their diversity are constantly decreasing due to agricultural intensification during the last decades (Gibson *et al*., 2007). Compared to other ecosystems,; conservation of European grassland biodiversity is highly dependent on traditional, extensive grassland management (Isselstein *et al*., 2005). In the frame-work of the EU BioBio Project (http://www.biobio-indicator.wur.nl) which aims at developing indicators for biodiversity in conventional and low-input agriculture, it was decided to use a model grass species to investigate the influence of farming practices and habitats on genetic diversity. *Dactylis. glomerata* a is an outbreeding and wide spread grass species native to Europe, Asia and North Africa, but widely introduced and well adapted to all temperate zones in the world (Zeng *et al*., 2008). A better knowledge of genetic diversity within and among populations with regard to habitat diversity and local management may help to understand the complex interactions of the different levels of biodiversity and to design strategies to optimally conserve and utilize grassland habitats as reservoir of genetic resources. This requires a set of habitats different in management harbouring populations of the target species as well as tools to rapidly and reliably detect genetic diversity in a large number of population samples. Therefore, this study aimed at: 1) selecting and characterising a set of habitats with substantial presence of *D. glomerata*, 2) the development of an optimised method for the detection of genetic diversity in *D. glomerata* based on multiplex PCR and simple sequence repeat (SSR) markers, and 3) testing the optimised method for the characterisation of twenty *D. glomerata* populations from contrasting habitats with regard to agricultural practices and environmental conditions.

Materials and methods

Collection sites and plant material

In the case- study area of the BioBio project in Stalden (OW), Switzerland, five conventional and five organic farms were selected. On each farm, two field plots with contrasting management intensity based on utilization frequency (intensive (a) up to 5 cuts per year, start 1th May; extensive (b) 1-2 cuts per year, start 15th July) and fertilization (fertilization (a); no fertilization (b)) were selected, resulting in a total of twenty well- characterised habitats (Table 1). From each habitat, 32 plants represented by individual tillers, separated by a distance of at least one meter, were collected and used for DNA extraction.

Analysis of genetic diversity

DNA from 32 individuals of each of the 20 populations was extracted using the NucleoSpin® 96 Plant II (Marchery-Nagel, Düren, Germany) extraction kit. Fifty simple sequence repeat (SSR) primer pairs were screened and PCR conditions were optimised to yield 11 multiplex PCRs containing three SSR primer pairs each. Primer compositions were arranged with regard to avoid overlapping of the sizes of amplicons derived from individual primer pairs. SSR amplification of 12 primer pairs (4 multiplex reactions) was performed on all 640 *D. glomerata* individuals using touchdown PCR with 25 cycles at the target annealing temperature and a final extension of 15 min at 72°C. Fragments were sized on a 48 capillary 3730×l DNA Analyzer (Applied Biosystems) and alleles were scored for presence or absence and entered into a binary data matrix. Variance components were estimated using analysis of molecular variance (AMOVA; Excoffier *et al*., 2005) and relationships among populations were visualised using cluster analysis and Euclidean squared distance based on marker frequencies per population.

Results and discussion

The 12 primer pairs used for preliminary analysis detected a total number of 96 alleles which were polymorphic among 640 individual plants of tetraploid *D. glomerata*. The data wereas treated as deriving from tetraploid organisms and up to four marker alleles were scored per locus by several primer pairs. The number of alleles ranged from four to 11, with an average of eight alleles per locus. Analysis of molecular variance (AMOVA) based on binary data revealed most of the variation to be due to variation within populations (98.78%), while the variation among farms and among plots within farms was very small but still significant (Table 2). Although a high level of within- population variation is generally observed in outbreeding species, the value observed in this study is considerably higher when compared to values found previously in cultivars of *D. glomerata* (Kölliker *et al*., 1998). However, Peter-Schmid *et al*. (2008) observed similarly high values of within- population variation for *Lolium multiflorum* populations from permanent grasslands. Cluster analysis based on marker frequency per population did not allow to separate *D. glomerata* populations according to farms, level of intensity or farming practices (conventional *vs.* organic; data not shown), probably due to the high level of within- population variation.

Conclusion

The optimised multiplex PCR protocol was highly efficient and reliable to analyse genetic diversity in natural populations of *D. glomerata*. Preliminary analyses indicate that management intensity, habitat characteristics and farming practices had only marginal influence on genetic diversity of *D. glomerata* populations and most of the variation was observed within, rather than among, populations.

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Table 1. Selected farms from the BioBio case study under conventional (conv) or organic (org) management.

Farm ID	Farm management	Plot management	Altitude (m)	Slope (°)	Exposition
1	org	a	763	15	W
1	org	b	765	54	SE
4	conv	a	936	22	S
4	conv	b	909	18	S
5	conv	a	755	38	E
5	conv	b	829	22	S
7	conv	a	830	22	SE
7	conv	b	957	35	S
8	org	a	822	13	N
8	org	b	940	36	S
12	org	a	881	35	S
12	org	b	899	36	S
13	org	a	806	11	SE
13	org	b	791	20	S
14	conv	a	728	31	S
14	conv	b	621	36	SE
16	org	a	685	44	SE
16	org	b	724	25	S
18	conv	a	947	54	SE
18	conv	b	991	11	E

Table 2. Analysis of variance (AMOVA) for 20 *D. glomerata* populations from 10 farms based on 12 SSR markers and 32 individuals per population.

Source of variation	df	Variance components[1]	Percentage of variation (%)
Among farms	9	0.01371	0.18
Among plots within farms	10	0.08301	1.08
Within plots	620	7.57193	98.74

[1] Components were significant at $P < 0.001$, the probability of obtaining a more extreme random value computed from non-parametric procedures (1,000 data permutations).

Effect of organic fertilization on level on botanical composition of a *Festuca* gr. *rubra* L. meadow in the boreal floor in Romania

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Abstract

Organic fertilizer application and traditional use for long periods of time have influenced the rich plant diversity in the Apuseni Mountains, Romania). The objective of this study was to identify the effect of manur application on the plant diversity and productivity of *Festuca* gr. *rubra* L. grasslands. Four treatments (T_1: control, T_2: 10 t ha^{-1} manure, T_3: 20 t ha^{-1} manure, T_4: 30 t ha^{-1} manure) were evaluated experimentally. After ten years, important changes at the sward level were observed. Phytocenosis control is naturally represented by *Festuca* gr. *rubra* L. grassland type. Then, following the application of organic fertilizers, *Trisetum flavescens* L. - *Agrostis capillaris* L. appeared. The large quantities of organic fertilizers produced a considerable restraint of the plant diversity.

Keywords: grassland, fertilization, dry matter, botanical composition, biodiversity

Introduction

Grassland biodiversity is an important consideration in many agri-environmental policies (Orth *et al*., 2010). The meadows found near the perimeter of the Gârda de Sus commune, Apuseni Mountains, Romania are highly phyto-diversified (Gârda, 2010), due to traditional management performed over long periods of time. Most traditional management techniques used organic fertilization with manures, combined with the mixed uses (mowing and grazing) (Morea, 2008). However, in habitats with low soil nutrient availability, richness and diversity can be positively affected by moderate intensification of grassland management (Cǒp *et al*., 2010). Furthermore, a low intensity of management frequencies is needed to maintain characteristic species composition (Tonn and Briemle, 2010). Manure fertilization contributes to grasslands' phyto-diversity, while overgrazing in spring or frequent mowing are disadvantageous (Nettier *et al*., 2010). Questions remain as to what level of organic fertilization optimally maintains the phyto- diversity of meadows. As such, the objectives of this study were: 1) observe the reaction of a *Festuca* gr. *rubra* L. grassland to organic fertilization, and 2) establish the manure quantity at which a minimum change in botanical diversity and dry matter (DM) yield growth were produced.

Materials and methods

The study was initiated in 2001, in the Gheţari village, Gârda de Sus commune, Romania using a randomized block design with four replications and four experimental treatments (T_1 - control, T_2 -10 t ha^{-1} manure, T_3 - 20 t ha^{-1} manure, T_4 - 30 t ha^{-1} manure). Each plot was 10 m². Manure was collected from cattle and horses (mixed with bedding matter) and was spread in early spring. Floristic studies were conducted at the beginning of July using the Braun- Blanquét method. Harvest took place on 7 July, at 5 cm cut height above the ground. For floristic data, the mean abundance-dominance (ADm) and constancy (K) were calculated. Data regarding the share of economic groups (*Poaceae*, *Cyperaceae-Juncaceae*, *Fabaceae* and diverse), species number and Shannon Index (SI) were processed by analysis of variance. Four classes of constancy were used, so that the number of classes and replications were equal. Data processing of DM yield was made by analysis of variance. Results presented in this paper relate to the 10th experimental year.

Results and discussion

Manure spreading on *Festuca* gr. *rubra* L. grassland generated considerable changes at the sward level (Table 1). The DM yield of the control was reduced. However, the manure application induced significant differences ($P < 0.001$) across all treatments.

Table 1. The influence of organic fertilizers upon the dry matter (DM) yield (*** = $P < 0.001$) for *Festuca* gr. *rubra* L. grasslands treated with manure in Gheţari, Romania in 2010.

Experimental variants	DM t ha^{-1}	%	Difference	Significance
control	0.94	100.0	0.00	-
10 t ha^{-1} manure	1.62	172.7	0.68	***
20 t ha^{-1} manure	2.35	251.3	1.41	***
30 t ha^{-1} manure	2.83	302.4	1.89	***

After manure application, major changes were observed at the sward level (Table 2). After applying organic fertilizer, the control grassland type (*Festuca* gr. *rubra* L. - *F.r.*) evolved toward other successional stages. In the treatment with 10 t ha^{-1} manure, *Festuca* gr. *rubra* L.-*Agrostis capillaris* L. (F.r-A.c) type was observed and in treatments with 20 and 30 t ha^{-1} manure, *Trisetum flavescens* L.-*Agrostis capillaris* L. (*T.f.-A.c.*) occured. The *F.r.* type contained 52.9% *Poaceae* (P), 1.1% *Cyperaceae-Juncaceae* (C-J), 10.8% *Fabaceae* (F) and 38.1% species from other botanical families (OBF). This plant community included a mean of 30.3 species and had a SI of 1.96. The *F.r.-A.c.* type contained 35.6% P, 0.4% C-J, 15.4 % F and 49.7% OBF. Compared to the control, this type showed a decrease in P ($P < 0.05$) and an increase in OBF ($P < 0.05$). The floristic diversity of the *F.r.-A.c.* type was represented by 33 species and had a SI of 1.94. The number of species increased in comparison with the control and the SI slightly decreased compared with the control, but these variations were not totally due to experimental factors. The *T.f.-A.c.* type contained 33.1-33.8% P, 0-0.1% C-J, 12.1-15.4% F and 59.1-59.9% OBF. The floristic structure of this grassland type was different from the control, with a reduction of P ($P < 0.05$, $P < 0.01$) and C-J ($P < 0.05$) and increased OBF ($P < 0.01$). Species number decreased towards the control, but statistical significance was not detected (ns). The SI was lower compared to the control, with a value between 1.58 and 1.6 ($P < 0.01$).

Conclusions

The treatment using small quantities of manure (T_2) generates a slight increase in the DM yield and small changes at the phyto-diversity level. Larger quantities of manure (T_3, T_4) lead to high growths of yield, but with a considerable restraint of the plant diversity.

Acknowledgements

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Table 2. The influence of manure upon plant diversity in grasslands near Gheţari, Romania in 2010.

Variants	Control		10 t ha^{-1} manure		20 t ha^{-1} manure		30 t ha^{-1} manure	
Phyto-sociologic indexes	ADm	K	ADm	K	ADm	K	ADm	K
Grassland type[1)]	*F.r.*	-	*F.r.-A.c.*	-	*T.f.-A.c.*	-	*T.f.-A.c.*	-
Poaceae	52.9	-	35.6^{0}	-	33.8^{0}	-	33.1^{00}	-
Agrostis capillaris L.	15.9	IV	11.3	IV	12.8	IV	12.8	IV
Briza media L.	0.5	II	0.4	III	-	-	-	-
Cynosurus cristatus L.	0.5	IV	0.5	IV	0.3	II	0.1	I
Festuca pratensis Huds.	-	-	0.1	I	0.4	III	0.9	III
Festuca gr. *rubra* agg. L.	32.5	IV	15.9	IV	4.4	IV	3.3	IV
Trisetum flavescens L.	1.6	IV	8.1	IV	17.5	IV	20.0	IV
Cyperacaee and *Juncaceae*	1.1	-	0.4^{ns}	-	0.1^{0}	-	0^{0}	-
Luzula multiflora Ehrh.	1.1	IV	0.4	III	0.1	I	-	
Fabaceae	10.8	-	15.4^{ns}	-	12.1^{ns}	-	15.4^{ns}	-
Lotus gr. *corniculatus* L.	5.4	IV	3.3	IV	2.2	IV	0.5	IV
Trifolium pratense L.	4.3	IV	3.9	IV	3.3	IV	4.9	IV
Trifolium repens L.	0.5	IV	2.6	III	1.1	IV	0.5	IV
Vicia gr. *cracca* L.	0.5	IV	5.4	IV	5.4	IV	9.1	IV
Other botanical families	38.1	-	52.7*	-	59.9**	-	59.1**	-
Alchemilla gr. *vulgaris* agg. L.	14.4	IV	12.8	IV	5.0	IV	5.0	IV
Carum carvi L.	-	-	0.4	III	0.5	IV	0.3	III
Centaurea pseudophrygia agg C. A. Mey.	5.6	III	15.3	IV	28.4	IV	23.4	IV
Colchicum autumnale L.	4.8	III	3.3	IV	1.1	IV	3.3	IV
Gymnadenia conopsea L.	0.5	III	0.4	III	0.1	I	0.1	IV
Myosotis sylvatica Ehrh. Ex Hoffm.	-	--	0.4	III	0.4	III	0.3	II
Pimpinella major L.	1.6	IV	5.4	IV	4.9	IV	5.4	IV
Polygala vulgaris L.	0.5	III	0.1	I	-	-	-	-
Potentilla erecta L.	3.3	IV	0.5	IV	-	-	-	-
Prunella vulgaris L.	0.5	II	0.4	III	-	-	0.1	I
Rumex acetosa L.	0.5	IV	0.5	IV	0.5	IV	1.6	IV
Scabiosa columbaria L.	0.5	II	-	-	-	-	-	-
Taraxacum officinale Weber ex F. H. Wigg.	0.5	II	1.1	IV	2.6	III	4.4	IV
Thymus pulegioides L.	1.6	II	0.1	I	-	-	-	-
Veronica chamaedrys L.	-	-	1.1	IV	9.7	IV	8.1	IV
Viola tricolor L.	0.5	IV	-		0.1	I	0.1	IV
Other species	16	-	16	-	17	-	16	-
Species number	30.3	-	33^{ns}	-	28.3^{ns}	-	27.3^{ns}	-
Shannon Index	1.96	-	1.94^{ns}	-	1.6^{00}	-	1.58^{00}	-

(ADm = mean abundance-dominance, K = constancy, * = $P < 0.05$, ** = $P < 0.01$, ^{0} = $P < 0.05$, ^{00} = $P < 0.01$, ^{ns} = non-significant); [1)] Grassland types: *F.r.* = *Festuca* gr. *rubra* L., *F.r.-A.c.* = *Festuca* gr. *rubra* L.-*Agrostis capillaris*, L., *T.f.-A.c.* = *Trisetum flavescens* L.-*Agrostis capillaris* L.

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Forage quality of native grasses in mountain pastures of southern Norway

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Abstract

Free-range grazing on mountain pastures is common practice for sheep and cattle farming in southern Norway. Investigations have shown that animal growth and milk production decrease towards the end of the grazing period. This has been explained by the decrease in forage quality and quantity. In two seasons, three grass species and *Carex* spp. were sampled at four locations early or late in the summer. Forage quality was determined by NIRS with a broad calibration for grasses. The energy value was highest in *Agrostis capillaris* and *Avenella flexuosa*, followed by *Deschampsia cespitosa* and *Carex* spp. The energy value decreased through the season; however, *A. flexuosa* kept a high energy value even in early autumn. The protein value declined steadily through the grazing season. *Avenella flexuosa* was lower in protein than the other species, especially early in the season. This investigation indicates that the decline in energy value is not the main reason for declining animal response at the end of the grazing season. Factors such as low forage intake and low content of protein might be more important.

Keywords: quality, grazing, *Avenella flexuosa*, *Deschampsia cespitosa*, *Agrostis capillaris*, *Carex*

Introduction

Outfield mountain pastures are important for Norwegian agriculture. About 2 million sheep obtain about 50% of their feed by free grazing outfield pastures, and more than 200 000 cattle, both for milk and beef production, utilize mountain pastures. The vegetation period is short in Norway. For sheep the grazing period in the mountains normally is from middle of June to the beginning of September. For dairy cattle the season is even shorter. Some investigations have shown that milk production of dairy cows and growth rate of lambs decrease towards the end of the grazing period (Nedkvitne and Garmo, 1986; Svalheim *et al*., 2004). This has been explained by a decrease in forage quality, but might also be caused by reduced forage intake. Different quality parameters such as low energy value, protein content, mineral content or a combination of factors could contribute to the poor animal performance. The development of forage quality during the summer season in Norwegian outfield pastures has not been thoroughly examined, although there have been some old investigations with chemical analyses. With NIRS technology small samples can be analysed for many parameters simultaneously with a proper calibration equation. We therefore collected plant samples from four sites over two years to examine the forage quality of *Avenella flexuosa* L., *Deschampsia cespitosa* L., *Agrostis capillaris* L. and *Carex* species. These species are all important for grazing over large areas in Norway.

Materials and methods

Plant samples for quality analysis were collected over two years (2008 and 2009) at four sites in the mountain regions of south-eastern Norway; Kvikne in Nord-Østerdalen, Heidal in Gudbrandsdalen, Vestre Slidre in Valdres and Geilo in Hallingdal; all sites between 850 m and 1050 m above sea level in the low-alpine region and sub-alpine region (birch forest) just above or below the tree border line. The samples were collected three times per season, early, middle and late; average times were July 5, August 11 and September 10. The data were analysed with ANOVA with year, site, time of season and species as variables.

About 50-100 g fresh material of the grass species *A. flexuosa*, *D. cespitosa* and *A. capillaris* were carefully picked by hand, and a sample of *Carex* species was also included. The *Carex* samples contained different species. *Carex bigelowii* Torrey ex Schweinitz was most frequent, but other *Carex* species were also present in many samples. The samples of *A. flexuosa* and *D. cespitosa* contained only fresh, green leaves, while the *Agrostis* and *Carex* samples also contained some fresh stem material. Most samples came from primary growth, although there was some regrowth in *Deschampsia* and *Agrostis* in August and September. All dead or brown leaves were sorted out. Grass growth close to animal dung was avoided.

After sampling, the grass samples were dried at 60°C for 48 h. Dried samples were ground in a Cyclotec mill through a 1 mm mesh screen and analysed for forage quality with near-infrared radiation spectroscopy. A broad calibration (more than 1500 samples) with a large variation of grass species at different developmental stages was applied. Standard error of prediction (SEP) for protein was 6.1 g kg DM^{-1} ($R^2 = 0.99$) and for digestibility 26.7 g kg DM^{-1} ($R^2 = 0.83$) (Fystro and Lunnan, 2006). Most of the collected samples gave reflection spectra close to the calibration samples, although some samples, especially *Carex*, were divergent.

Results and discussion

Differences in forage quality between sites and years were small, and therefore average values over sites and years are reported here (Figure 1). Digestibility and energy values were high early in the grazing season. There was a steady decline towards the end of the season for *A. capillaris*, *D. cespitosa* and *Carex* spp. *Avenella flexuosa* differed from the other species with only minor changes through the season. This gave a statistically significant interaction between species and sampling time ($P < 0.05$). In September, *A. flexuosa* showed a marked increase in the content of water-soluble carbohydrates (WSC) while the content of neutral detergent fibres (NDF) was reduced. The average WSC content in mid-season was 210 g kg DM^{-1}, whereas the value in September was 290 g kg DM^{-1}. This increase in WSC keeps the energy value at a high level, although the fibre quality declines in Avenella as in the other species. The rise in WSC in *Avenella* is probably a result of low temperature, high photosynthetic activity and low growth rate in late summer. *Avenella flexuosa* is very important for grazing in many plant communities in Norway, and this finding shows that the energy intake might be high even late in the season. The energy value of *Deschampsia cespitosa* was lower than *Avenella* and *Agrostis*, but higher than *Carex*.

The content of crude protein declined steadily towards the end of the grazing season (Figure 1). *Avenella flexuosa* had a lower content than the other species, especially early in the season. The low protein content in mid- and late season may give a deficit of protein for rumen microbes, and is possibly a constraint for animal production. This deficit can be met by giving high protein concentrates in milk production, but in meat and beef production usually no concentrates are applied with free grazing. Some herbs contain more protein than grasses (Garmo, 1986), and protein deficit can probably to some extent be met by changing the diet.

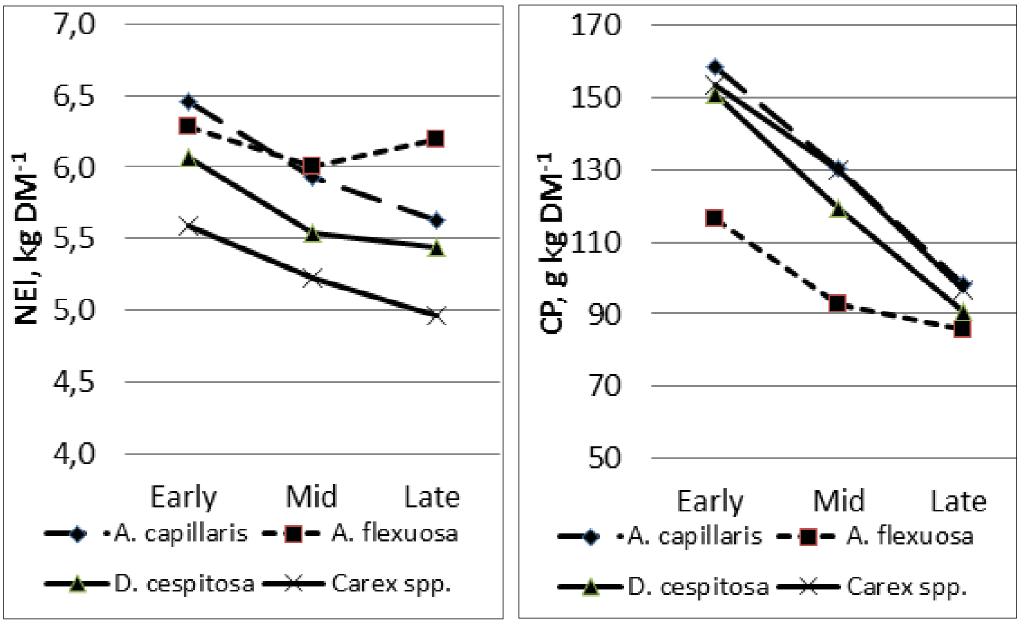

Figure 1. Energy value, net energy lactation, MJ kg DM^{-1} (left) and crude protein content (g kg DM^{-1}) in three grass species and *Carex* spp. at three times in the grazing season. Average of four sites and two years. SEmean is 0.07 MJ kg DM^{-1} for NEl, and 5.3 g kg DM^{-1} for CP.

Conclusions

The forage quality of three grass species and *Carex* spp. declined towards the end of the grazing season. *Avenella flexuosa*, however, sustained a high energy value even late in the season. This finding indicates that lack of protein may be more important than lack of energy. Other factors such as shorter days, night frosts, lower herbage availability and low content of some minerals in the herbage may also contribute to a lower forage intake and lower animal production late in the season.

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Preservation and sustainable utilisation of the wild legume flora in the mountainous regions of Serbia

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Abstract

The wild legume flora of Serbia comprises about 250 species. The most diversified genera are *Trifolium* L., *Vicia* L., *Lathyrus* L., *Chamaecytisus* Link and *Astragalus* L. A specific importance is given to *Lens nigricans* (M. Bieb.) Godr., *Ornithopus compressus* L., *Trigonella gladiata* Steven ex. M. Bieb, *Vicia laeta* Ces. and *Vicia melanops* Sm., because of their potential domestication and the need for preserving these species from a serious threat of extinction. Since 2002, several wild vetch species have been collected and now are maintained in the Institute of Field and Vegetable Crops. The most advanced results in conservation have been achieved in *Vicia grandiflora* Scop. and *Vicia sativa* subsp. *nigra* (L.) Ehrh. *Pisum sativum* L. subsp. *elatius* (Steven ex M. Bieb.) Asch. and Graebn. var. *elatius* (Steven ex M. Bieb.) Meikle; abundant in the Serbian south east, and could be a source of economically valuable traits such as stress tolerance into cultivated pea.

Keywords: *ex situ* conservation, genetic resources, *in situ* preservation, *Pisum*, *Vicia*, wild legume species

Introduction

Legumes play important role in the agriculture of Serbia and the other West Balkan Countries regions. Soya bean (*Glycine max* (L.) Merr.), common beans (*Phaseolus* spp.), pea (*Pisum sativum* L.), vetches (*Vicia* spp.), lucerne (*Medicago sativa* L.) and red clover (*Trifolium pratense* L.) are considered economically the most important legume crops in the country (Mihailović and Mikić, 2010). Annual and perennial forage field legumes are used in the form of green forage, dry forage, forage meal, silage and haylage, while mostly perennial species with only few annual legumes are suitable for grazing (Mikić *et al*., 2006).

Despite many advantages, the legume crops in Serbia today are facing the same challenges as in other European countries, reflected in a decreasing area of cultivation. The existence of a rich wild and local agricultural legume flora may play an important role in overcoming the present difficulties. A joint strategy of the majority of relevant national subjects has been developed and concerted actions are being carried out in order to both re-introduce neglected legume crops, such as grass pea (*Lathyrus sativus* L.), and to introduce currently wild species into the Serbian agriculture as cultivated crops (Ćupina *et al*., 2007; Mikić *et al*., 2011). This brief review aims at presenting its most significant achievements.

National catalogue and *in situ* preservation

The wild legume flora of Serbia shares its wealth with other Balkan countries and comprises about 250 species. The most diversified genera are *Trifolium* L., with 68 species, *Vicia* L., with 35 species (Diklić, 1972), *Lathyrus* L., with 30 species (Kojić, 1972), *Chamaecytisus* Link, with 27 species, and *Astragalus* L., with 23 species. These genera, especially the first three, contain economically important species and are a considerable source of desirable traits for enhancing forage production.

Particular attention is payed to the wild relatives of crops, such as *Lens nigricans* (M. Bieb.) Godr., *Ornithopus compressus* L., *Trigonella gladiata* Steven ex. M. Bieb, *Vicia laeta* Ces. and *Vicia melanops* Sm., because of their potential domestication. An additional reason for developing a long-term strategy for preserving all these species is a serious threat of extinction, especially in the cases of *V. laeta* and *Lathyrus pancicii* (Jurisic) Adamovic.

Recently, numerous efforts have begun to update the obsolete official reports. During recent years, numerous expeditions have been carried out, mostly to the mountains of Fruška Gora in the north (Ćupina *et al*., 2006) and the mountains in the south east of the country. Apart from building up comprehensive passport databases, the ultimate goal of all these actions is to bridge the gap between the botany and ecology and applied research in a long-term coordinated programme to the national and European benefit.

Ex situ **conservation and sustainable utilisation**

The collected seeds of the wild legume species are maintained in the Forage Crops Department of the Institute of Field and Vegetable Crops in Novi Sad. So far, hundreds of accessions have been added to the existing collections and now are included in the process of characterisation and evaluation of the most important traits and characteristics.

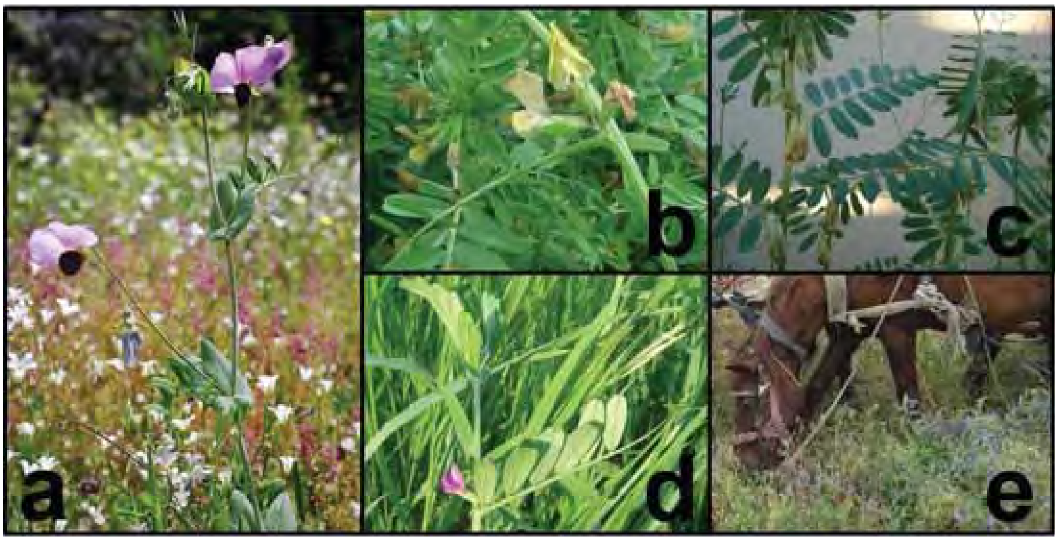

Figure 1. Five targeted wild legumes of the Serbian flora: a population of *Pisum sativum* subsp. *elatius* var. elatius in the valley of river Pčinja (a) and urban populations of *Vicia grandiflora* (b), *Vicia pannonica* (c), *Vicia sativa* subsp. *nigra* (d) and *Vicia villosa* (e)

As the only wild pea taxon in Serbia, *Pisum sativum* L. subsp. *elatius* (Steven ex M. Bieb.) Asch. and Graebn. var. *elatius* (Steven ex M. Bieb.) Meikle (Figure 1a) has been having a growing interest as a potential donor of desirable traits such as abiotic and biotic stress tolerance in cultivated pea (Zlatković *et al*., 2010). It is possible that it was also previously grown, as the first analysis of the ancient DNA from the charred seeds of the same locality show (Jovanović *et al*., 2011; Petr Smýkal, pers. comm.).

Among the collected vetch species, four are considered the most promising as future forage crops. Large-flowered vetch (*V. grandiflora* Scop.) has proven extremely winter-hardy and early when grown *ex situ*, in the field, with a potential for more than 11 t ha^{-1} of forage dry matter (Mikić *et al*., 2009). Most populations of this species suffer from a non-uniform maturity, but a multi-flowered/podded mutant (Figure 1b) could assist in improving seed production and make its commercial success more certain (Mikić and Mihailović, 2010). Wild populations of Hungarian vetch (*V. pannonica* Crantz, Figure 1c) have rather stable forage yields and may produce up to 12 t ha^{-1} of forage dry matter (Mihailović *et al*., 2009), while narrow-leafed vetch (*V. sativa* subsp. *nigra* (L.) Ehrh., Figure 1d) may reach 7 t ha^{-1} of forage dry matter (Mikić *et al*., 2008). Hairy vetch (*V. villosa* Roth, Figure 1e) has the greatest potential for forage production, with up to 50 t ha^{-1} of green forage (Mihailović *et al*., 2008), but also with excessive growth, long growing period and poorly uniform time-set seed production.

Conclusions

The work on the legume genetic resources in Serbia is well-developed but its aspect faced towards the wild legume flora is still at its beginnings. However, the results achieved during the past several years give a solid basis for further steps in both their conservation and their use in their ‘second-life’ as forage field crops.

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Grasslands as valuable agricultural land use in less favoured area of Estonia

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Abstract

In Estonia, the less favoured areas (LFA) occupied approximately 40% (362 765 ha) of agricultural land covered by different Common Agricultural Policy (CAP) area-based payments in 2010. These areas are characterized mainly by unfavourable soil conditions resulting in lower yields and income, which could possibly lead to abandonment. The main threat for abandoned agricultural areas is overgrowing by bushes and reeds resulting in a loss of valuable species-rich agricultural landscapes. Analysing the LFA land-use structure in Estonia indicated that up to 82% of the area under agri-environment semi-natural habitat management support, 56% of semi-natural grasslands and 57% of permanent grasslands were located in areas with natural handicaps in 2010. The sowing of permanent grasslands is the most suitable land management practice in areas where the high content of rock fragments or shallow soils on limestone prevent the use of more intensive cultivation practices.

Keywords: less favoured area, Estonia, permanent grasslands, semi-natural grasslands, LFA support measures

Introduction

Estonia's less favoured areas (LFA), initially identified and designated within 97 rural municipalities in 2004, cover 2.259 million ha, which comprises 50% of the total land area. Those areas with natural restrictions are characterized mainly by unfavourable soil conditions (such as shallow soil profile, light sandy texture, water logging and erosion) leading to lower yields and restrictions for the growing of certain agricultural crops. These areas are also characterized as consisting of smaller land parcels compared to the average size of land parcels (10.6 ha) in Estonia. Lower potential revenues lead to less inclination to manage LFAs, which could lead to their abandonment and an out-migration of rural populations. Traditionally, semi-natural grasslands have formed a large proportion of the LFA areas, but they have, over the last fifty years, declined significantly by approximately 95% (Sammul *et al*., 2000). Currently Estonia's land management policy promotes the need to maintain, as well as extensively increase, the mosaic landscape of managed grasslands as a bio-diverse resource.
The goals of the present study work were (i) to characterise the LFAs from the perspective of sustainable land use, focussing on aspects of semi-natural and permanent grasslands; and (ii) to evaluate the influence of LFA support measures on sustainable agricultural development in those areas with environmental and economic restrictions.

Material and methods

The study used data from Estonia's Land Parcel Identification System and Integrated Administration and Control System (LPIS/IACS) and the Agricultural Registers and Information Board (ARIB) for land-use analysis. The data were applied using GIS software to create a map to indicate the proportion of permanent and semi-natural grasslands in the LFA within Estonia's rural municipalities. In order to analyse the economic parameters of LFA support, the study used the Farm Accountancy Data Network (FADN) database.

Results

The aggregate of LFA (362,765 ha) comprises approximately 40% of Estonia's total agricultural land area (899,290 ha) (Table 1). While permanent grasslands, semi-natural grasslands and semi-natural habitats comprise approximately 31% of the agricultural area, they comprise almost 45% of LFAs.

Table 1. Land use in ARIB support register in 2010, with focus on different grasslands

Land use	Total, ha	% of total	LFA, ha	% of LFA
Agricultural land	899 290	-	362 765	-
Permanent grassland	221 071	24.6	125 437	34.6
Semi-natural grassland*	31 679	3.5	17 676	4.8
Semi-natural habitats**	22 336	2.5	18 420	5.1

* semi-natural grasslands are registered according to the farmer's judgement (and can include cultivated grasslands older than 10 years)

** semi-natural habitats can obtain special agri-environment semi-natural habitat management support but none of the other area based supports (e.g. Single Area Payment Scheme) can be applied to for that land

Permanent grasslands are widespread in the rural municipalities of the islands, coasts and the north-east and south-east borders (Figure 1).

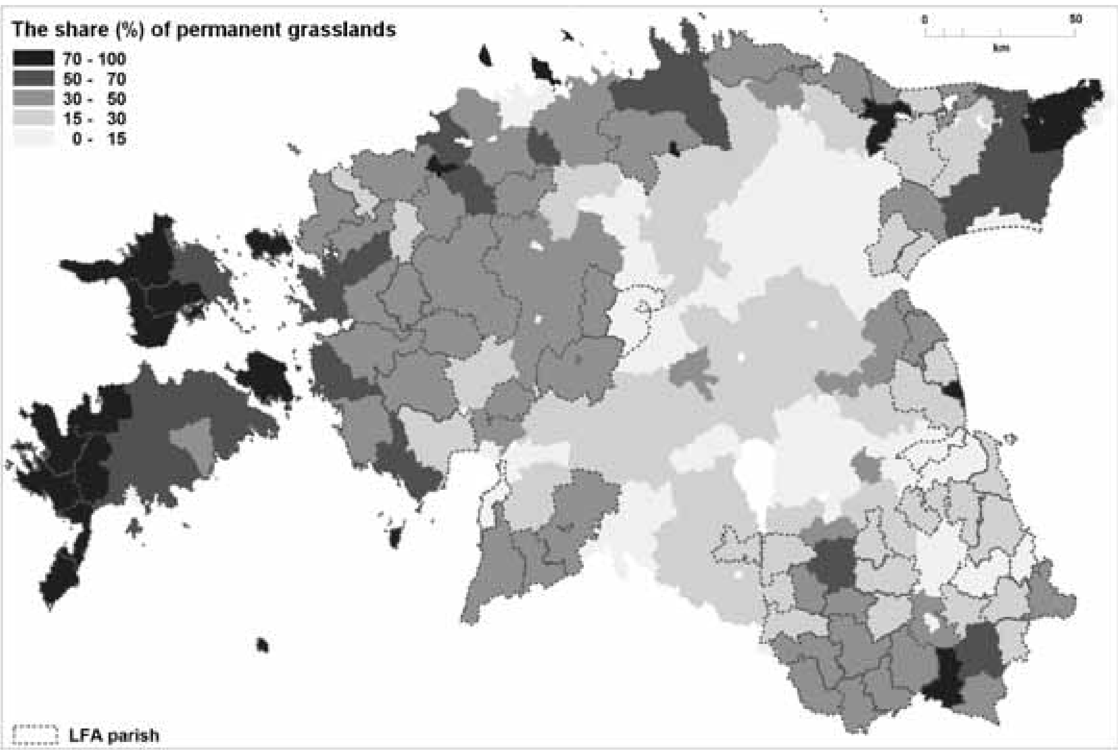

Figure 1. Share (%) of permanent grasslands (including semi-natural grasslands) from agricultural land covered by ARIB support system

Permanent grasslands have traditionally been located in areas where soil conditions, such as high content of rock fragments (the western islands) and shallow soils on limestone (northern

coastlands) prevent the use of more intensive cultivation practices. Permanent grasslands are also prevalent in the hilly southern rural municipalities of Estonia where water erosion causes soil loss, and in western rural municipalities where soils with high water saturation prevail.
Semi-natural habitats (consisting largely of floodplain, coastal, alvar and wooded meadows) are spread mainly throughout the western islands and the western coastlands. In order to maintain the management of these less-productive but biodiversity-rich habitats, the special Rural Development Plan Agri-Environment (RDP AE) measures supported 22,336 ha in 2010, of which 18,420 ha are in less favoured areas.

Discussion

The aim of demarcating LFAs and developing the necessary support mechanisms is to continue agricultural production in areas not particularly suitable for intensive land management. The main threat to abandoned agricultural areas is overgrowing by bushes and reeds (mainly in coastal grasslands), which means the valuable species-rich agricultural landscape is lost. The best solution for maintaining and increasing the areas of semi-natural and permanent grasslands is extensive management. Land-use analysis indicates that 56% of semi-natural grasslands, 57% of permanent grasslands and 82% of semi-natural habitats are situated in LFA areas.
The evaluation of agri-environmental measures leads to the conclusion that LFA support measures have been relatively effective in avoiding the abandonment of agricultural land in these areas. But the question arises whether these measures, which could support the increasing of biodiversity, soil and water quality and the mosaic landscape, or traditional extensive management practices are the best solution for the LFA regions. The share of semi-natural grasslands and habitats in LFA is less than 10% and the forecast is that this proportion will not increase. Indeed, in Estonia, the current trend since 2001 is of a substantial decrease in agricultural producers (Estonian Statistical Board). The reduction of producers has led to a concentration of ownership, in which the average size of agricultural area of a farm has increased from 16 ha to 48 ha, and in the context of animal husbandry the rate of concentration into bigger units has been one of the fastest in the EU (Valdvee, 2011).
In the context of economic parameters, the analysis shows that LFA support, together with other agricultural measures, has enhanced the competitiveness of less favoured areas. Data for 2009 show that although the average grain and milk yields in LFAs have been lower than in non-LFAs, profitability in LFAs, due to the increases in a variety of agricultural payments, has been 29% higher than in non-LFAs (Aamisepp, 2011). Nevertheless, as LFA support is an area-based support, the distribution of payments show that in 2009, just 10% of the larger producers received 69% of the funding.
We can conclude that extensive management of LFAs, of which a large proportion are species-rich semi-natural or permanent grasslands, will contribute substantially to a higher level of biodiversity and to the mosaic landscape in particular areas. Therefore, the agricultural payment schemes for LFAs should also promote the sustainable management of grasslands.

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Effect of different extensive management treatments on the plant diversity of an upland meadow without forage utilisation

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Abstract

Effect of different managements on plant diversity of an upland permanent grassland was studied in the Jizera Mts., Czech Republic, from 2000 to 2010. Treatments applied were: cutting twice per year; mulching once, twice and three times per year and abandonment (control). Botanical composition was observed yearly at the end of May and the number of vascular plant species and Shannon´s indices were calculated. During the experiment total number of plant species increased especially in multiple-managed treatments, whereas it slightly decreased in unmanaged and once-mulched treatments. Also, the number of species with cover ≥ 1% was temporarily (2000-2008) increased in treatments with more frequent defoliation, but a decrease was recorded in the last two years. Shannon´s index of diversity oscillated about 2.5 in all managed treatments while it rapidly decreased on unmanaged plots to less than 1.9. Twice-mulching per year can be an alternative management for upland grasslands without forage utilisation.

Keywords: grassland, mulching, cutting, abandonment, diversity, sward

Introduction

As a consequence of reduction of farm staff, the importance of grassland for forage use rapidly decreased in the Czech Republic especially on marginal areas in the last decade of the 20th century. Large areas remained without any management and these meadows or pastures often degraded. On abandoned grasslands the sward structure changed, and plant species richness and diversity decreased. Tall dicotyledonous plants and invasive species spread, and shrubs and trees have started to colonise unmanaged stands. Therefore mulching appeared to be a simple and low-cost procedure (Prochnow *et al*., 2000) that could be used to manage many marginal grasslands or fallow farm land to prevent sward degradation and/or aforestation. After mulching, the plant biomass subsequently decomposes and released nutrients can return to ecosystem, whereas the regular multiple mowing of biomass usually leads to oligotrophication of stands by gradual nutrient losses. Most studies on mulching in the Czech Republic and other European countries (e.g. Kahmen *et al*., 2002; Mašková *et al*., 2009) were carried out in calcareous stands, wetland and mountain areas. However, results from the most widespread common upland grasslands are missing. Therefore the aim of our study was evaluate the changes of species richness and diversity in a common type of upland meadow under different management regimes over a 10-year period.

Material and methods

The experiment was carried out in the Jizerské Mts. in the northern part of the Czech Republic from 2000 to 2010. Altitude is 420 m, average annual temperature is 7.2°C and annual precipitation is 803 mm. The bedrock is a biotic granite underlying acid cambisol with pH_{KCl} 6.2, C_{ox} 2.7%; contents of available P, K and Mg were 28, 138 and 290 mg kg^{-1}, respectively.

The grassland had been sown in the 1980s and intensively managed afterwards (cutting twice per year and N, P, K fertilisation). However, in the five years before the experiment it was extensively used (occasional cutting or grazing) and d uring the experiment average forage production of the meadow (*Arrhenatherion*) was about 6.5 t DM per ha. Treatments were arranged in four complete randomized blocks in 5 m×10 m plots, of which the central 8.0×3 m area was assessed to avoid edge effects. Treatments were: 2x cutting with removal of the biomass (2C), unmanaged grassland (U), 1x mulching in July (1M), 2x mulching in June and August (2M) and 3x mulching in May, July and September (3M). During the experiment no fertilisation was applied.
Mulching was done with a Uni Maher UM 19 machine. Percentage cover of plant species was recorded at the end of May in each study year (nomenclature follows Kubát *et al*., 2002). Plant species diversity changes were determined by calculating Shannon´s diversity (SD) index and Shannon´s evenness (SE). Repeated measures ANOVA (interaction year and treatment) were used to analyse vegetation data.

Results and discussion

Initial total number of plant species was about 30 per plot in all treatments. During the study we recorded gradual changes in the number of plant species under the different treatments ($P < 0.001$). In the multiple-defoliation treatments the number of species increased, especially on the 2C treatment (to almost 40 species). Species richness successively decreased on the once-mulched and unmanaged treatments: in last two years the numbers were 28 (1M) and 25 (U) (Figure 1). Increased species on frequently mulched treatments was in accordance with Moog *et al*. (2002) who found that mulching twice a year can be suitable management for the conservation of species-rich grasslands. Among the managed treatments, no significant differences were found when we compared number of species with cover ≥ 1%. However, on unmanaged plots it decreased significantly, especially during the first three and last five years.

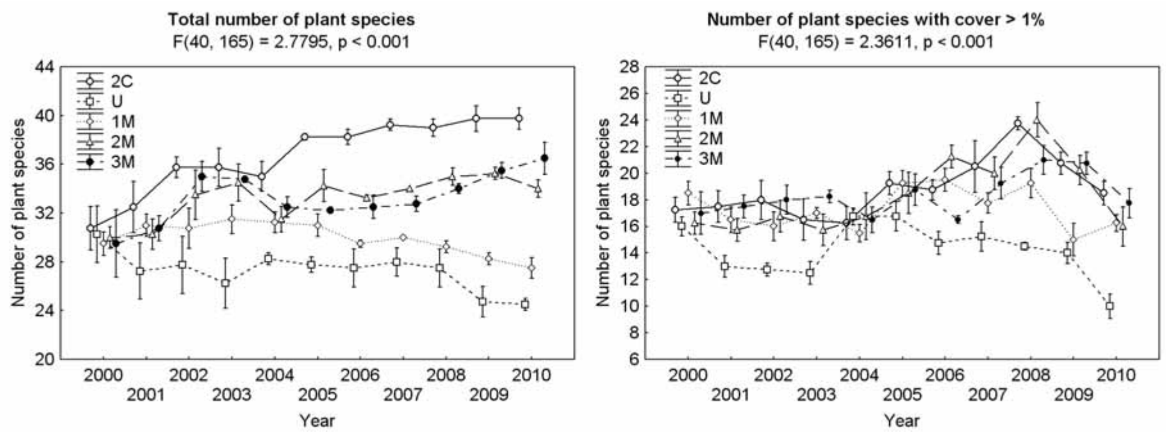

Figure 1. Total number of species and number of species with cover ≥ 1% under different management treatments during the study years (2000-2010)

Not only total number of plant species, but also representation of all single species is important for diversity expression. The SD index was about 2.5 at start of the experiment and it decreased with some temporary fluctuation on the unmanaged treatment (Figure 2). After initial increase this index declined on the 3-times mulched treatments from year 4 to year 6, but then increased. The SD index of this treatment had similar values as the twice-cut one after 10 years of the experiment. There was high fluctuation of SD index among the study years; however, a negative effect of abandonment was evident. On the other hand, there was slight increase of plant species diversity on multiple-managed treatments. Bernhardt-Römermann *et al*. (2009) reported that mulching is not suitable for long-term alternative management of species-rich calcareous grassland with traditional grazing management, because the mulching caused decrease of diversity in comparison with grazing. We suppose that mulching can be an acceptable management mainly for abandoned grassland because it can prevent reversion to forest, especially in marginal upland areas in the conditions of the Czech Republic. Nadolna (2009) similarly found that Shannon´s index value on a once-cut treatment with biomass left on surface did not differ from cut treatment with biomass removal. There was markedly higher diversity in comparison with unmanaged plots. However, Mašková *et al*. (2009) mentioned that the species richness on a mown treatment increased similarly to that on a mulched treatment, but Shannon´s diversity index and evenness were significantly lower on the mown treatment than mulched or fallow ones, probably related to nutrient depletion.

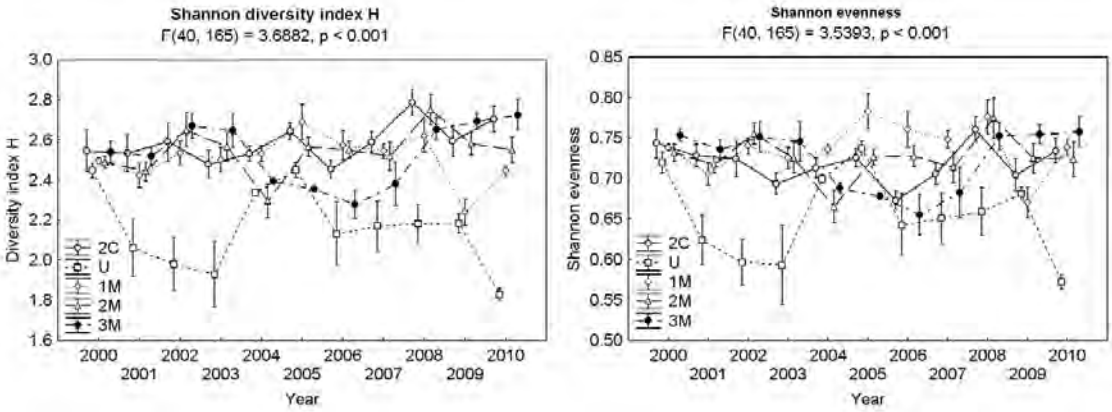

Figure 2 Changes in diversity of sward under different management treatments

Conclusions

The total number of plant vascular species increased on multiple-managed treatments, especially on the twice-cutting treatment with removal of biomass. However, it decreased on the once-mulched and as well as on unmanaged treatments. Similarly, plant species diversity was higher on frequently managed swards in comparison with abandonment or once-mulching. Mulching twice per year could be applied as an alternative management for upland grasslands (alliance *Arrhenatherion*) without forage utilisation.

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Site preconditioning of the development of meadow communities in mountain and lowland areas

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Abstract

The impact of site conditions was assessed on the floristic diversity of meadow communities from *Phragmitetea*, *Molinio-Arrhenatheretea* and *Nardo-Callunetea* classes developed in different topographic regions of mountains and lowland. For this purpose, site conditions were compared in the identified communities in which, using the phyto-indication, the soil phosphorus, potassium and magnesium concentrations were assessed. Meadow soil formed in mountainous areas, compared to lowland areas, has higher concentrations of macroelements (P, K, Mg). On the other hand, indices of moisture, pH and nitrogen content in soil are lower in mountainous conditions. The greatest differences between sites of corresponding plant communities were found in the soil reaction, as well as nitrogen and potassium concentrations, which can be attributed to differences in the geomorphology of the respective regions and levels of utilization intensity.

Keywords: *Phragmitetea*, *Molinio-Arrhenathretea*, *Nardo-Callunetea*, habitat, Ellenberg's and Zarzycki's indicator numbers

Introduction

By affecting both directly and indirectly site conditions, in particular the moisture content, man greatly influences meadow communities. Site conditions exert the strongest influence on the development of plant communities (Grynia and Kryszak, 1997; Janssens and Peeters, 1998). Site changes exert influence on floristic composition transformations of meadow communities by among others, through incursions of many common synanthropic species (Verkaar *et al*., 1997). Furthermore, site conditions of plant communities are also influenced by the geomorphology of a given region, in particular, location above sea level with which weather conditions and soil type are connected. The aim of these studies was to compare site conditions affecting the development of rush (from the *Phragmitetea* class), meadow (from the *Molinio-Arrhenatheretea* class) and turf (from the *Nardo-Callunetea* class) communities in two geomorphologically different regions - lowland and mountainous.

Materials and methods

The investigations were conducted on sites of rush-meadow-turf communities developed on grasslands situated in the Wielkopolska Lowland and Kłodzka Valley. For this purpose, approximately 200 phytosociological releves (taken with the assistance of Braun-Blanquet method) of phytocenoses of individual plant communities developed in the mountains and on the lowland of the following classes were used: *Phragmitetea* (1), *Molinio-Arrhenatheretea* (5) and *Nardo-Callunetea* (2). For each releve, site indices of moisture content (F), soil reaction (R) and nitrogen content in the soil (N) were assessed using the phytoindication method developed by Ellenberg *et al*. (1992), while organic matter content (H) and soil texture composition (D) were made according to Zarzycki *et al*. (2002) which, in this paper, are presented as arithmetic means for a given community. In addition, for 10 representative phytosociological releves of each community, laboratory analyses were performed to assess the soil content of available forms of P and K (by Egner-Rhiem method) and of Mg (method of Schachtschabel).

Results and discussion

The site conditions of the examined communities developed in the mountains and on the lowland exhibited considerable variations, which were associated with the location of these regions above sea level, area geomorphology, weather conditions and the specific utilization. In most cases, grass communities developed on mineral-humus soils differed with respect to their texture composition. In mountainous conditions, sandy clays or dust formations were dominant, whereas in lowland areas the prevailing formations were heavy clays or silts. Both in the mountains and lowland, they were characterized by low P, K and Mg contents, and the content of macroelements increased with the decreasing site moisture content (Table 1).

Table 1. Phosphorus, potassium and magnesium concentrations in the distinguished lowland and mountainous plant communities (mg kg^{-1} of soil).

	P		K		Mg	
Phytosociological unit	lowland	mountain	lowland	mountain	lowland	mountain
			Phragmitetea class			
Phalaridetum arundinaceae	2.5	6.8	17.4	14.5	2.9	7.5
			Molinio-Arrhenatheretea class			
Alopecuretum pratensis	1.7	5.0	15.0	19.6	3.3	7.2
Arrhenatheretum elatioris	1.4	5.3	27.1	74.7	4.5	7.9
Lolio-Cynosuretum	7.3	9.5	19.6	23.5	2.2	9.8
Com. *Deschampsia caespitosa*	2.8	3.5	74.0	82.1	5.3	9.4
Com. *Poa pratensis-Festuca rubra*	7.0	17.0	103.2	80.2	18.8	12.7
			Nardo-Callunetea class			
Com. with *Nardus stricta*	-	2.8	-	16.8	-	15.2
Polygalo-Nardetum	2.3	-	84.9	-	11.8	-

However, soils of meadow communities developed in mountainous regions, in comparison with lowland soils, exhibited higher content of all analysed macroelements, with the exception of the soils of the *Poa pratensis-Festuca rubra* community developed on lowland, which showed higher contents of P, K and Mg. Higher concentrations of Mg in soils of the *Nardo-Calluneta* class communities, located both in the mountains and on lowland, stand apart from those recorded for the remaining soils (Table 1). This could have been caused by a higher site eutrophication resulting from the overall impact of the accumulation of chemical elements as a result of surface run-off from higher areas, as well the current extensive utilization.

Site moisture content of meadow communities, with the exception of *Phalaridetum arundinaceae* phytocenoses, was higher on the lowland, despite the precipitation in this region being considerably less than in the mountains (from 700 mm to over 800 mm). This was caused by the operating drainage system, as well as by there being less run-off in the region with little geomorphological variability. Meadow sites of the communities occurring in the mountains were characterised by smaller differences in moisture content.

Trophic nature and soil reaction also exert a strong influence on the development of meadow communities (Grynia and Kryszak, 1997; Zarzycki, 1999; Bator, 2005). The soils of the examined grass communities from the mountainous areas exhibited lower pH values as well as lower nitrogen concentrations, which was associated with the organic matter content and soil texture composition (Table 2).

Table 2. Phytoindication evaluation of site conditions of lowland and mountainous plant communities.

	Ellenberg’s index						Zarzycki index					
	F		R		N		D		H		Rainfall (mm)	
Phytosociological unit	L	M	L	M	L	M	L	M	L	M	L	M
Phragmitetea class												
Phalaridetum arundinaceae	7.4	8.6	4.7	6.9	5.7	7.2	3.9	3.8	2.0	1.9		
Molinio-Arrhenatheretea class												
Alopecuretum pratensis	5.8	5.2	4.7	3.8	6.5	4.4	4.4	3.8	2.1	2.0		
Arrhenatheretum elatioris	5.0	4.1	4.7	3.9	5.2	5.0	3.8	3.8	2.0	2.0		
Lolio-Cynosuretum	3.9	6.6	3.8	2.2	6.7	4.6	4.1	3.8	2.0	2.1	550-600	700-800
Com. *Deschampsia caespitosa*	6.1	5.7	1.5	1.4	3.9	3.5	4.1	3.9	2.1	2.0		
Com. *Poa pratensis-Festuca rubra*	4.6	4.2	2.2	2.6	5.2	4.2	3.9	4.0	2.1	2.2		
Nardo-Callunetea class												
Com. with *Nardus strictae*	-	4.8	-	4.9	-	3.9	-	3.6	-	2.1		
Polygalo-Nardetum	4.8	-	5.6	-	4.0	-	3.8	-	1.9	-		

Ellenberg’s indicator numbers, F - moisture, R - soil reaction, N - nitrogen content in soil; Zarzycki’s indicator numbers, H - organic matter in soil, D - soil texture composition

Higher nitrogen concentrations determined in the soils of plant communities developed on the lowland could be attributed to the application of mineral fertilization as well as to more intensive management methods, especially pasture utilization. The greatest differences between sites of corresponding plant communities were observed in the soil reaction and nitrogen and potassium concentrations, which was caused by geomorphological differences between the regions as well as different levels of utilization intensity.

Conclusion

The obtained results showed that there were differences in site conditions of communities developed in the mountains and on the lowland. They resulted from differences in total annual precipitation, soil nutrient availability and were associated with the geomorphology of the respective regions as well as utilization intensity. The above conditions affected natural and use values of the studied meadow communities.

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Preservation of forage quality and biodiversity by utilization of mountain meadows

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Abstract

Long-term trials (up to 18 years) on three permanent grassland types - *Trisetetum*, *Geranio-Trisetetum* and *Meo-Festucetum* - were carried out on representative mountain sites of Thuringia (Germany) to determine yield, forage quality and botanical composition of grassland communities in response to utilization system. Treatments were: (1) first cut at silage stage, 3 cuts annually, optimal amount of fertilizer (nitrogen (N), phosphorus (P), potassium (K)) according to the yield; (2) first cut at hay stage, 2 cuts annually, 60 kg N/ha/yr, P and K on a level of nutritive yield; (3) first cut at beginning of July, without N fertilization but P and K on a level of nutritive yield, except on *Meo-Festucetum*. Results describe the effects of several grassland management systems with varying intensity levels for dry matter yield, forage quality parameters (contents of crude protein, crude fibre, energy, minerals and digestibility of dry matter) and botanical composition in terms of typical species. Results show that for meadows a three-cut system is necessary in order to maintain a favourable forage quality. Conservation of communities in a typical setting requires low-input systems.

Keywords: mountain meadow, fertilization, yield, forage quality,botanical composition, Thuringia, utilization date

Introduction

Mountain meadows are an important aspect of landscape management and of great ecological significance. Their management (fertilization and utilization) is very different due to the high species richness and heterogeneous sites. The objectives of a long-term study were to determine the effects of three management systems on productivity, forage quality and grassland community of three different types of mountain meadows.

Materials and methods

The experimental design and treatments are shown in Table 1. The experiments were carried out on plots with 4 replications, over a period of 18 years at sites in the Thuringian Mountains (Germany).

Table 1. Experimental treatements and design

			mineral fertilization kg ha^{-1} p.a.		
Grassland community	Treatment	utilization dates	nitrogen	phosphorus	potassium
Trisetetum	1	22.05. / 06.07. / 18.09.	200	25	220
	2	21.06. / 04.08.	60	20	160
	3	04.07. / 08.09.	0	15	100
Geranio-Trisetetum	1	28.05. / 11.07. / 25.09.	130	30	149
	2	18.06. / 29.08.	55	25	125
	3	02.07. / 16.09.	0	20	97
Meo-Festucetum	1	07.06. / 25.07. / 18.09.	150	25	220
	2	22.06. / 17.09.	60	20	160
	3	07.07.	0	0	0

Dry matter yield and parameters of forage quality such as contents of crude fibre, crude protein, energy and minerals as well as dry matter digestibility were analysed. Determination of plant species was conducted according to the method of Klapp-Stählin (Voigtländer and Voss, 1979). Data were interpreted by means of analysis of variance.

Results

There were large differences in dry matter yield and forage quality between the three treatments for all three grassland communities (Table 2).

Table 2. Dry matter yield and forage quality of the first cut

			first cut			
		DM yield kg ha^{-1}	crude fibre	crude protein	DM digestibility	energy
grassland community	treatment	per year	g kg^{-1} DM		%	MJ NEL kg^{-1} DM
Trisetetum	1	7,540	219	184	71.7	6.42
	2	7,050	315	88	54.9	4.79
	3	6,480	303	85	55.5	4.99
Tukey HSD (*P* < 0.05)		490	28	20	5.4	0.47
Geranio-Trisetetum	1	6,270	271	132	60.8	5.58
	2	5,810	301	93	54.9	5.06
	3	4,250	278	87	57.0	5.41
Tukey HSD (*P* < 0.05)		480	15	10	2.9	0.28
Meo-Festucetum	1	5,200	264	155	66.2	5.79
	2	4,550	292	105	58.7	5.27
	3	2,060	298	82	57.9	5.26
Tukey HSD (*P* < 0.05)		920	34	22	3.6	0.38

Dry matter yield, digestibility and energy values decreased considerably from treatment 1 to treatment 3. Significant losses of yield occurred with a first cut at the beginning of July, in particular in the *Meo-Festucetum* community. Digestibility and energy strongly decreased from treatment 1 to treatment 2, associated with a remarkable increase in crude fibre and a decline in crude protein content. The herbage mineral concentrations depended on grassland community, and differences between treatments were element-specific (Table 3).

Table 3. Mineral contents in herbage harvested at the first cut

		P	K	Mg	Ca	Mn	Fe	Cu	Zn
grassland community	treatment	g kg^{-1} DM				mg kg^{-1} DM			
Trisetetum	1	3.8	33.8	3.4	6.1	60	315	8	36
	2	2.3	21.3	2.9	5.8	72	183	4	30
	3	2.4	15.2	4.0	8.9	62	146	5	34
Geranio-Trisetetum	1	3.3	25.2	2.3	5.5	115	166	7	31
	2	2.6	20.2	2.3	6.0	110	150	5	27
	3	2.5	18.6	3.3	10.0	141	186	5	28
Meo-Festucetum	1	3.1	28.0	1.2	2.6	460	90	7	45
	2	2.7	22.1	1.0	2.9	526	77	6	44
	3	2.3	8.6	1.1	3.4	796	96	5	52
requirement		3.6[2)]	20.0[1)]	1.6[2)]	5.8[2)]	50[3)]	50[3)]	10[3)]	50[3)]

1) suitable for grassland growth
2) recommended amount in the ration for dairy cows (daily milk yield 30 kg per cow), German Society for nutrition
3) recommended value for dairy cows (mg kg^{-1} feed ration dry matter), German Society for nutrition

The content of phosphorus and potassium declined from treatment 1 to treatment 3. Magnesium and calcium concentrations were sufficient in all treatments, except in *Meo-Festucetum.*

Manganese and iron were never lower than the recommended values, whereas concentrations of copper and zinc were insufficient for all treatments.
The composition of grassland communities was influenced by management (Table 4).

Table 4. Botanical composition of grassland communities in relation to treatment

	% of biomass								
	Trisetetum			*Geranio-Trisetetum*			*Meo-Festucetum*		
Treatment	grasses	herbs	legumes	grasses	herbs	legumes	grasses	herbs	legumes
1	63	36	1	57	39	4	80	20	0
2	70	23	7	61	34	5	73	27	0
3	68	16	16	52	33	15	64	36	0

The proportion of herbs declined linearly from treatment 1 to treatment 3, whereas legumes increased in *Geranio-Trisetetum*, and especially in *Trisetetum*. In *Meo-Festucetum* legumes were absent and the proportion of herbs increased linearly from treatment 1 to treatment 3. Total species number was stable: *Trisetetum* 24-27 species, *Geranio-Trisetetum* 36-40 species and *Meo-Festucetum* 11-13 species (data not shown). The grassland communities maintained a typical setting according to the botanical composition. In treatment 3 the sward was characterized by a higher level of indicator plants of poor soils.

Discussion

A close relationship was observed between management system and dry matter yield and forage quality. It is noteworthy that *Trisetetum* showed the smallest dry matter yield differences between treatments. Therefore, first of all it is important to guarantee a favourable amount of applied fertilizer and the time of cutting (silage stage, hay stage) according to the aim of grassland utilization. In comparison with taking the first cut at silage stage, first cut at hay stage caused yield loss in connection with a deterioration of forage quality. This is in agreement with Hochberg (1987). The three investigated treatments maintained the mountain grassland communities in a condition that had an acceptable range of abundance of typical species. According to Janssens *et al*. (1997) the availability of nitrogen, phosphorus and potassium for plants has a direct impact on the competition between species, but at our sites the typical setting of the communities (botanical composition) was not impaired. Species-rich communities were stable in terms of the number of indicator species.

Conclusions

- Cutting at silage stage up to emergence of inflorescence is a guideline on meadows to achieve good forage quality and an acceptable setting of the grassland communities.
- First cut at hay stage or later produces forage suitable only for beef cattle and ewes.
- Conservation of communities in a typical setting requires low-input systems.
- Combination of high forage quality for dairy cows with high biodiversity is impossible.

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Botanical composition, productivity and plant density of six-year-old birdsfoot trefoil swards

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Abstract

A field trial under non-irrigated conditions was carried out in the Danube plain region of Central North Bulgaria during 2004-2009. Birdsfoot trefoil (*Lotus corniculatus* L.) was studied in a pure stand and in binary mixtures with cocksfoot (*Dactylis glomerata* L.) and with wheatgrass (*Agropyron cristatum* L.). The proportion of birdsfoot trefoil was greater in swards of the mixtures with wheatgrass for first two years of utilization. In the last two years, the proportion of birdsoot trefoil significantly decreased in the mixtures with wheatgrass and was three times less than in mixtures with cocksfoot. Dry matter yield from the mixtures of birdsfoot trefoil with cocksfoot was higher by 14% compared to birdsfoot trefoil with wheatgrass. At the end of the study birdsfoot trefoil density in the mixture with wheatgrass was six times less than that of the pure stand and the mixture with cocksfoot.

Keywords: birdsfoot trefoil, cocksfoot, wheatgrass, mixture, plant density

Introduction

Birdsfoot trefoil is a suitable component for perennial mixtures, which are more sustainable to unfavourable conditions compared with pure stands (Leep *et al*., 2002; Peeters *et al*., 2006; Vasilev and Vasileva, 2007). The choice of suitable grass component is important for the retention of birdsfoot trefoil in the mixture, its productivity and permanence. Cocksfoot grows intensively in the spring and summer months (Jacobs and Siddoway, 2007), and wheatgrass in spring and autumn (Walton, 1983). The aim of this study was to establish the botanical composition, productivity and density of six-year-old birdsfoot trefoil stands in mixtures with cocksfoot and wheatgrass.

Materials and methods

A field trial in the experimental field of the Institute of Forage Crops, Pleven, Bulgaria was carried out during 2004-2009. The long plot method was used with 6 treatments, 4 replications and plots size 10 m². The following treatments were tested: 1. birdsfoot trefoil - pure stand; 2. mixture birdsfoot trefoil + cocksfoot; 3. mixture birdsfoot trefoil + wheatgrass; 4. cocksfoot - pure stand; 5. wheatgrass - pure stand; 6. mixture cocksfoot + wheatgrass. Birdsfoot trefoil cv. ‚Targovishte 1', cocksfoot cv. ‚Dabrava' and wheatgrass local population were used. The component ratio in the mixtures was 50:50. Botanical composition, dry matter yield and number of plants per m² were recorded. The differences were found in comparing mixtures to the pure stand birdsfoot trefoil. The experimental data was statistically analysed using MS Excel, ANOVA at $P < 0.05$.

Results and discussion

Botanical composition of the mixtures depends on the biology of the species and their development by years ('t Mannetje, 2003). Our data showed that with advancing age of the stands, the proportion of birdsfoot trefoil in pure stand and in mixture with wheatgrass decreased, while in the mixture with cocksfoot, its proportion increased to the end of the period (Figure 1). On average, for the first two years of utilization, the proportion of birdsfoot trefoil was 18% higher in the mixture with wheatgrass than the mixture with cocksfoot. During the third year the proportion of birdsfoot trefoil was similar; it significantly decreased in the mixture with wheatgrass in the last two years, and it was approximately three times less than in mixtures with cocksfoot.

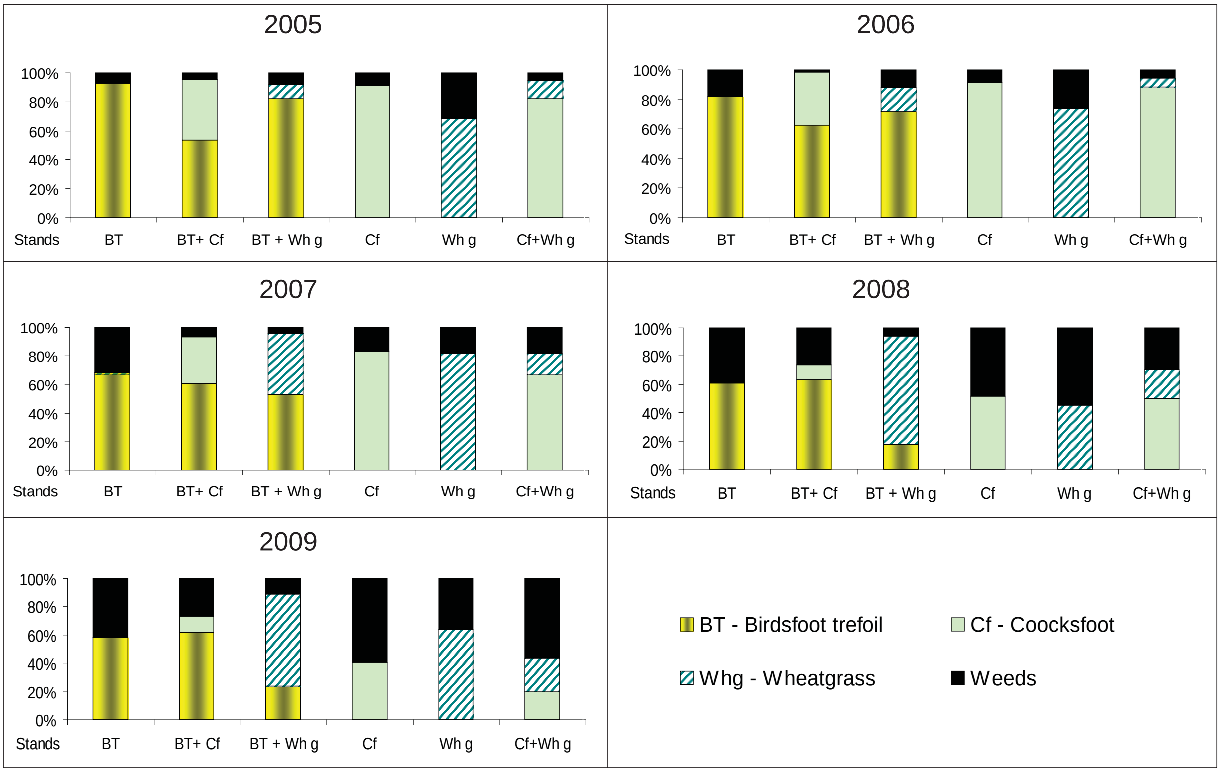

Figure 1. Botanical composition of the swards by years for the period of the study

Table 1. Dry matter yield from birdsfoot trefoil swards by cuts (kg ha^{-1})

Swards	Cuts	I	II	III	IV	V	Average for the period kg ha^{-1}	%
1	Birdsfoot trefoil	2,071	1,847	1,198	1,080	283	6,479	100.0
2	Birdsfoot trefoil + Cocksfoot	2,481	1,997	1,202	1,062	329	7,071	109.1
3	Birdsfoot trefoil + Wheatgrass	2,380	1,496	995	1,200	310	6,381	98.5
4	Cocksfoot - pure stand	1,368	1,092	719	412	303	3,894	60.1
5	Wheatgrass - pure stand	1,113	938	404	494	185	3,134	48.4
6	Cocksfoot + Wheatgrass	1,672	1,025	760	415	250	4,122	63.6
	LSD 5%	136	98	92	86	65	303	

Weed presence was greater in pure stands of birdsfoot trefoil, as well as in the mixture with cocksfoot, during the last two years. Productivity of fresh mass of the swards is mainly influenced by the biological potential of the species involved, botanical composition by cuts and age of the swards. With advancing age of the swards, density of the species in mixtures decreased, varying according to species (Vasilev and Vasileva, 2007). There were no differences in dry matter yield in pure stands and mixtures with wheatgrass. An increase from 14% in favour of the birdsfoot trefoil was recorded in the mixture with cocksfoot (Table 1 and Table 2).

Data on the number of birdsfoot trefoil plants per m², recorded in various swards, showed a relative homogeneity in pure swards and mixture with cocksfoot (CV varied from 26.26 to 27.00%), but the mixture with wheatgrass was highly heterogeneous (CV 45.40%) (Table 3).

Table 2. Dry matter yield from birdsfoot trefoil swards by years (kg ha^{-1})

Swards	Years I	II	III	IV	V	Average for the period kg ha^{-1}	%
1 Birdsfoot trefoil	13,003	6,773	3,147	6,929	2,545	6,479	100.0
2 Birdsfoot trefoil + Cocksfoot	14,637	6,574	4,952	6,726	2,463	7,070	109.1
3 Birdsfoot trefoil + Wheatgrass	13,523	7,179	4,552	4,535	2,118	6,382	98.5
4 Cocksfoot - pure stand	9,800	2,763	1,891	3,754	1,250	3,893	60.1
5 Wheatgrass - pure stand	6,387	2,034	2,058	3,895	1,297	3,134	48.4
6 Cocksfoot + Wheatgrass	9,874	2,852	2,367	3,388	2,129	4,122	63.6
LSD 5%	696	742	415	444	234	303	

Table 3. Plant density of birdsfoot trefoil swards at the beginning of the fifth (2008) and sixth (2009) years

Swards	2008 number plants m^{-2}	2008 CV%	2009 number plants m^{-2}	2009 CV%
Birdsfoot trefoil - Pure stand	44.5	26.26	14.8	51.19
Birdsfoot trefoil + Cocksfoot	45.0	27.00	14.5	42.59
Birdsfoot trefoil +Wheatgrass	4.0	45.40	2.4	83.75
LSD 5%	2.9		1.8	

In the fifth and sixth years, there were no statistically significant differences in the plant density of birdsfoot trefoil between the pure stand and that of the mixture with cocksfoot, while the number of plants in mixture with wheatgrass was eleven and six times less, respectively. In the fifth year the statistical sampling was relatively homogenous in pure swards and mixture with cocksfoot (CV < 30%), while that of the mixture with wheatgrass was heterogeneous (CV > 30%). In the sixth year the number of birdsfoot trefoil plants per unit area decreased three times compared with the previous year in the pure sward and mixture with cocksfoot. Statistical sampling was heterogeneous as in mixtures with wheatgrass.

Conclusions

Dry matter productivity and the proportion of birdsfoot trefoil were higher in the mixture of birdsfoot trefoil with cocksfoot as compared with the mixture with wheatgrass. There were no differences in the plant density of birdsfoot trefoil between the pure stands and that of the mixture with cocksfoot, while the number of plants in mixture with wheatgrass was six times less.

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Farming intensity, habitat and plant diversity in a Swiss grassland region

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Abstract

In the EU FP7 project BIOBIO, potential biodiversity indicators are currently being examined in 16-20 farms (organic, non-organic and low-input) within each of 16 case study regions across Europe. Here, the diversity of habitats and plants in two grassland systems (organic or under agri-environment scheme) was investigated in a mountainous region of Switzerland. Farming intensity was used to interpret the diversity pattern. The results show that neither the farming intensity nor the habitat and plant diversity of the investigated farms significantly depended on the farming system. Farm size explained the diversity of habitats and plants better than farming intensity. Plant diversity depended significantly on habitat diversity.

Keywords: organic farming, habitat richness, plant species richness, farming intensity, livestock density

Introduction

Identifying factors that influence biodiversity decline is a pre-requisite for actions to mitigate this decline. Agricultural policy makers are particularly interested in how farmland biodiversity is affected by different farming systems (e.g. organic, non-organic or low-input) and their management. Moreover, indicators for biodiversity that reveal differences between farming systems are of primary interest. Although such indicators have been developed at large scale in Europe (e.g. De Roeck, 2005) they have rarely been investigated at the farm scale or only by means of indirect measures of biodiversity (Huelsbergen and Kuestermann, 2005; Jeanneret *et al*., 2007). The EU FP7 project BIOBIO aims at developing indicators for biodiversity at farm level in 16 case study regions across Europe. Within the project, direct, i.e. habitat, species and genetic indicators, and indirect farm management indicators were recorded in 2010. In Switzerland, two types of grassland farms were surveyed; organic farms and farms under the national agri-environment scheme (AES) which includes 7% ecological compensation area and an equilibrated nutrient balance. We hypothesized that direct biodiversity indicators exemplified by plant and habitat diversity are dependent on the farming system and on main farm characteristics such as farm size and livestock density.

The study area and methods

All investigated farms belong to the village of Stalden (OW), in central Switzerland. The 10 organic and 9 farms under agri-environment scheme (AES) were randomly sampled from a pool of 66 farms. All farms are grassland-based ruminant producers stocked with cattle and are situated between 605 and 1133 m a.s.l. Overall, the investigated farms manage 233 ha (mean: 12.3 ha). In spring 2010, habitats of all farms were mapped using the BioHab method (Bunce *et al*., 2011). In the field, the farm area was separated in areal (at least 400 m^2 and 5 m wide) and linear (at least 0.5 m×30 m) habitats. Criteria to delimit habitats are major changes in vegetation structure and management characteristics. Typical habitats are meadows with high nutrient input, meadows with moderate nutrient input, pastures, hedgerows and grass strips. Per farm and habitat, one plot was randomly selected for vegetation survey. The abundance of plant species was recorded on 100 m² for areal plots and on 10 m² for linear plots. Habitat richness and plant species richness per farm were investigated as potential indicators for habitat and plant diversity. The livestock density, as a proxy for overall farming intensity, was calculated based on farmer interviews. Statistical analyses were conducted using generalised linear models.

Results and discussion

Differences in management practices between organic and AES farms in the study were small. There was no significant difference in livestock density between the two farming systems (Table 1). In contrast to organic farms, the use of mineral fertilizers and pesticides is allowed in AES farms, which may affect the diversity of plants in particular. However, in the Swiss case study, AES farmers made limited use of these products. This may be one reason why no difference between the two farming systems could be detected with regard to habitat and plant species richness (Table 1).

Table 1. Comparison of farming intensity, habitat and plant diversity in organic farms (N = 10) and farms under agri-environment scheme (AES) (N = 9). LU: Livestock Unit

Target	Farming intensity		Habitat diversity		Plant diversity	
	Livestock density [LU/ha]		Habitat richness		Plant species richness	
Indicator [unit]	Organic	AES	Organic	AES	Organic	AES
Mean ± SE	1.8 ± 0.3	2.1 ± 0.1	7.2 ± 1.9	6.6 ± 0.8	93.5 ± 20.1	87.6 ± 8.5
min-max	1.2-2.3	1.3-3.0	5-12	4-11	69-133	59-137
P-value (t-test)	0.113		0.574		0.617	
Total number			of habitats 21		of plant species 280	

Livestock density was dependent on farm size (t = -2.76, $P < 0.05$). Larger farms tended to be less intensively managed (Figure 1a). The effort of farm managers to optimize their workload may explain this tendency. Livestock density was dependent on farm size on AES farms (filled points) but not in organic farms (open points). There was no significant interaction between farming system and farm size.

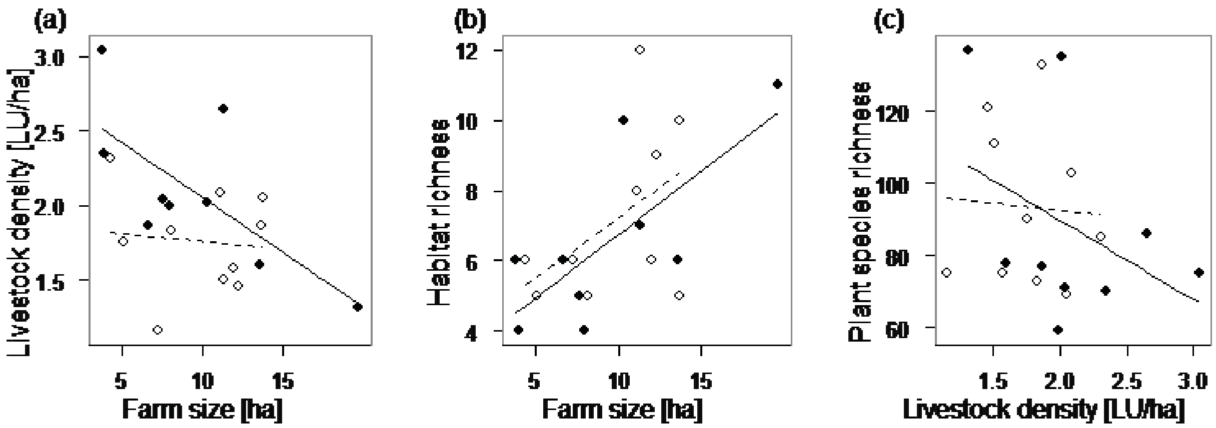

Figure 1. Relationship between (a) farm size and livestock density, (b) farm size and habitat richness, (c) livestock density and plant species richness; for organic and AES farms of a grassland region in Switzerland. Organic farms: open points, dotted lines for predicted values; AES farms: filled points, solid lines for predicted values. (a) and (b) significant, (c) not significant.

With increasing farm size, the habitat richness increased (Figure 1b). Habitat richness significantly depended on farm size (t = 2.48, $P < 0.05$). Although large farms had a higher habitat richness overall, they had lower habitat density because the most abundant types of habitats were repeated several times on large farms. Due to this repetition, farm size may not have a major effect on habitat richness at landscape scale. Habitat richness tended to increase with decreasing livestock density but this effect was not significant.

Livestock density had no significant influence on plant species richness at farm scale (t = -1.27, $P = 0.22$; Figure 1c). However, a negative effect of farming intensity on plant species richness is a well-known phenomenon at plot scale (Plantureux *et al*., 2005). Farm size influenced plant species richness significantly (t = 2.47, $P < 0.05$). With increasing farm size, the plant species richness increased. Furthermore, to predict plant species richness, the most precise variable in an additive model was habitat richness (t = 5.74, $P < 0.001$). In none of the models there were significant interactions between the farming system and the other explanatory variables.

Conclusions

The three potential indicators: farming intensity, habitat richness and plant species richness did not significantly distinguish between organic and AES farms in this study. Farm size significantly influenced habitat and plant species richness. Habitat and plant species richness were not significantly dependent on livestock density as a proxy for farming intensity. Habitat richness explained plant species richness better than the other indicators and could be used as a surrogate. In the context of the BIOBIO project, future analyses will be conducted with an extended set of potential indicators to identify farm-scale biodiversity indicators and to evaluate major factors which act on farmland biodiversity.

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Agri-environmental funding schemes - a tool for supporting the conservation of semi-natural grassland in Poland

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Abstract

In Poland, 45 different types of grassland exist on the agriculturally utilised area (AUA) of which half are of semi-natural character (10.5% of AUA). The aim of the study was to evaluate the role of agri-environmental funding schemes in supporting the conservation of semi-natural grassland. The study was carried out in 2010 on the basis of available information and questionnaires sent to stakeholders and farmers. The results showed that the ecological importance of semi-natural grassland for society, in the opinion of stakeholders, is intermediate (42.3%), high (30.8%) or very high (19.2%), but most farmers are not aware of the ecological importance of semi-natural grassland (52.6%). On a scale from 1 (highest) to 4 (lowest), the most important benefits of semi-natural grasslands were: reservoir of biodiversity (1.4), essential part of landscape (2.2), cultural heritage (2.8) and basis of grassland production (3.7). Different measures of agri-environmental funding schemes help to maintain/improve semi-natural grassland. Acceptance of these measures in 2008-2009 was at the level of 3.1% of all farm holdings and 4.6% of AUA.

Keywords: semi-natural grassland, agri-environmental schemes

Introduction

Grasslands in Poland cover 3.95 million hectares, which corresponds to 20.7% of the total AUA or 12.6% of the entire area of the country. The above-mentioned area comprises permanent natural and semi-natural grasslands. In recent years, the area of grasslands which are not utilised for fodder production has increased considerably, reaching approximately 1 million ha in 2004 and it declined to the level of 768,205 ha in 2009 (GUS, 2010). The characteristics of Poland's surface features mean that 89.5% of grasslands are in the categories of lowland meadows and pastures (Goliński, 2007). The aim of the study was to evaluate the role of agri-environmental funding schemes in supporting the maintenance of semi-natural grassland.

Materials and methods

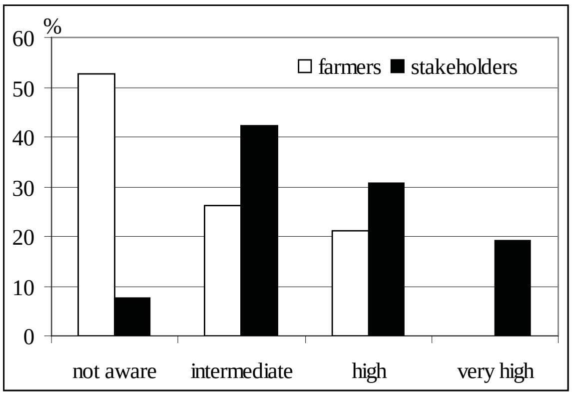
The study was carried out in 2010 based on information available in literature and obtained from questionnaires sent to stakeholders and farmers within the framework of the Salvere project 'Semi-natural grassland as a source of biodiversity improvement'. Stakeholders were asked to fill in questionnaires about the impact of agricultural policy on High Nature Value Farmland and to give their own perception of the importance of semi-natural grassland. Responses were obtained from 38 different organizations belonging to policy makers, advisory services, education, NGOs, media, water agencies, etc. Apart from the above-respondent groups, the questionnaires about the awareness of the ecological importance of semi-natural grassland were sent to farmers who manage permanent grassland in different parts of Poland. Responses were obtained from 63 farmers. The data were analysed by ANOVA. Tests for the main effects were performed by F-tests. Means were separated by the LSD and were declared at $P < 0.05$.

Results

The obtained results from the questionnaires show that the most important reasons for the decline of semi-natural grassland area can be attributed to land/farm abandonment, followed by low productivity, lack of agricultural policy, intensification and disadvantageous management (Table 1). In the opinion of stakeholders, the main benefit of semi-natural grasslands is as a reservoir of biodiversity.

Table 1. Results about semi-natural grasslands obtained from stakeholders (n = 38)

Reasons for the decline of semi-natural grassland area	Priority scale (1-highest, 5-lowest)	Benefits of semi-natural grassland	Priority scale (1-highest, 4-lowest)
land/farm abandonment	1.32[a]	reservoir of biodiversity	1.39[a]
low productivity	2.47[b]	essential part of landscape	2.16[b]
lack of agricultural policy	2.94[c]	cultural heritage	2.76[c]
intensification	3.34[c]	basis of grassland production	3.68[d]
disadvantageous management	4.92[d]		
$LSD_{0.05}$	0.403		0.394



According to the results obtained from the questionnaires (Figure 1), farmers are not aware of the ecological importance of semi-natural grassland (52.6%). For 26.3% farmers, the ecological importance of semi-natural grassland was intermediate and for 21.1%, it was high. In the opinion of stakeholders the ecological importance of semi-natural grassland is intermediate (42.3%), high (30.8%) or very high (19.2%).

Figure 1. Ecological importance of semi-natural grassland

Discussion

In the period of 2000-2008, the area covered by meadows in Poland declined from 8.0% to 7.8%, and that of pastures declined from 4.4% to 2.3% of the total AUA (GUS, 2010). In this period, the area covered by forests increased from 29.0% to 30.4%. Part of the area newly covered by forests consisted of semi-natural grassland because of a lack of policy regulations until 2006. Other reasons for the decrease of semi-natural grassland were non-agricultural land use (urbanisation), land reclamation - drainage (increase in the period 2000-2008 from 37.7% to 39.8%), invasion of alien species, etc. (Liro, 2010).

From September 2004 onwards, the national agri-environmental funding schemes were implemented on the entire area of Poland and comprised two measures: ecological agriculture/organic farming and protection/maintenance of native local breeds of farm animals. The remaining five measures (sustainable agriculture, maintenance of extensive meadows, maintenance of extensive pastures, soil and water protection, creation of buffer zones) were restricted to 69 priority zones, specified according to high nature values. These zones covered 32% of the country area. 71,559 farmers participated in these schemes which covered 1,068,872 ha of AUA with a budget of 318.9 million EURO (Liro, 2010). From among the measures, it was the activities connected with environmental protection (over 65,500 beneficiaries), particularly soil and water protection (51,496 applications - 60% of total agri-environmental funding

schemes) that had the most interest. This was confirmed by Stypiński (2010) in his study about practical realisation of agri-environmental agreements in Podlaskie voivodeship. Only 17,274 applications were prepared for maintenance of biological diversity measures. According to *ex post* evaluation for Rural Development Programme 2004-2006, implementation area of the agri-environmental funding schemes on NATURA 2000 areas reached 214,196 ha (4.54% AUA) and outside NATURA 2000 areas 53,313 ha - 1.13% AUA (Liro, 2010).
In order to continue the national agri-environmental funding schemes in the years 2007-2013, some changes were included. The number of measures was increased from 7 to 9 and of sub-measures within the measures from 26 to 41. All measures can be implemented on the entire area of the country (the priority zones were cancelled). Payments were diversified for the NATURA 2000 areas (ca. 10% higher) and outside the NATURA 2000 areas. According to estimations (Liro, 2010), the target of the number of beneficiaries is 200,000 farmers (9.2% of all farm holdings) and the area target is 1.5-1.8 million ha (10% of AUA).
In 2008 and 2009, the number of new applicants reached the level of 37,183. The most frequent applications concerned measure 3 'Extensive permanent grasslands' with 20,644 applications. Measures 4 and 5 'Protection of endangered bird species and natural habitats outside of Natura 2000 areas' and '…in Natura 2000 areas', respectively, seems to be difficult for implementation as only 507 and 518 applications, respectively, were submitted. The acceptance of these measures in the period of 2008-2009 was at the level of 3.1% of all farm holdings and 4.6% of AUA (Liro, 2010).
The philosophy of agri-environmental funding schemes seems to be something new to Polish farmers, the majority of whom are not aware of the ecological importance of semi-natural grassland. Therefore, special action explaining the purpose of measures and justifying the necessity to observe specific rules will be indispensable for the acceptance of these funding schemes and bringing them closer to farmers.

Conclusions

The most important perceived benefit of semi-natural grasslands is their role as a reservoir of biodiversity. The different measures of agri-environmental funding schemes help to maintain/improve semi-natural grassland in Poland. The most frequent measure applied by farmers in the funding schemes in 2008-2009 was for extensive management of meadows and pastures.

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Plant density and seed production of *Rhinanthus minor* under long-term Ca, N, P and K fertiliser application in the Rengen Grassland Experiment (Germany)

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Abstract

Rhinanthus minor L. is a summer annual and facultative hemiparasitic plant common in low-productivity grasslands. Survival of this species is strictly dependent on sufficient seed production in each vegetative season. We aimed to evaluate the effect of different fertiliser treatments on plant density per m², seed production per individual plant and seed production per m2. All data were collected in unfertilised control, Ca, CaN, CaNP, CaNPKCl and CaNPK$_2$SO$_4$ treatments of the Rengen Grassland Experiment in June 2010. Plant density per m²ranged from 5 to 745 in CaNPKCl and control treatments, seed production per individual plant from 24.9 to 65 seeds in control and CaNPK$_2$SO$_4$ treatments, and total seed production per m2 from 195 to 18142 seeds in CaNPKCl and control treatments, respectively. High density of small plants in low productivity control contrasted highlywith low density of tall plants in fully fertilised treatments. We concluded that for sufficient seed production per plot, high plant density of small *R. minor* plants is more relevant than low density of tall plants with high number of seeds.

Keywords: *Arrhenatherion*, *Polygono-Trisetion*, *Violion caninae*, yellow rattle

Introduction

Rhinanthus minor L. is a summer annual, facultative hemiparasitic therophyte species common in low productivity grasslands (Westbury, 2004). *R. minor* was formerly considered a weed due to low yield and forage quality, but today is highly valued for its ability to decrease competitive ability of highly productive forage species thereby facilitating restoration of species-rich grasslands. Survival of *R. minor* is strictly dependent on sufficient seed production in each vegetative season as it produces short-lived seeds. In monoculture, performance of individual *R. minor* plants is highest in substrates with high nutrient availability, but this can be *vice versa* when *R. minor* occurs in the real permanent grassland in mixture with potential host species. *R. minor* is highly sensitive to shade from tall canopy of potential host species especially at seedling stage. This might explain why *R. minor* is generally less common or absent in highly productive grasslands with aboveground annual biomass production > 5 t ha^{-1} (Hejcman *et al*., 2011). The aim of the research reported in this paper was to estimate the seed production of *R. minor* in different plant communities which developed over 65 years under different fertiliser treatments in the Rengen Grassland Experiment (RGE). We asked how is the plant density per m², seed production per individual plant and seed production per m² affected by fertiliser treatments in the RGE.

Materials and methods

The RGE was established in 1941 on low productive *Violion caninae* grassland in the Eifel Mts. (SW Germany, altitude: 475 m a. s. l.; precipitation: 811 mm; temperature: 6.9ºC) in a completely randomized block design with six fertiliser treatments (Control, Ca, CaN, CaNP, CaNPKCl and CaNPK2SO4, see Table 1) and five replicates (30 plots in total, individual plot size 5×3 m). Sixty-five years of fertilizer application resulted in development of different plant communities in close neighbourhood on a meadow that was cut twice per year in early July and in mid October. In each experimental plot, the number of *R. minor* plants was counted in m² monitoring plot in late June 2010. Ten randomly selected plants were then collected per plot and seed number per individual plant was determined in the laboratory. Seed production per m² was then calculated by multiplying plant density per m² with seed production per individual plant. One-way ANOVA followed by Tukey‘s *post-hoc* test were used to evaluate effect of treatment on obtained data.

Results and discussion

Density of *R. minor* plants was significantly affected by treatment and was highest in the unfertilized control where 745 plants per m² were recorded (Table 2). Very low density of plants, less than 3% relative to control, was recorded in all treatments with Ca, N and P application. In contrast to plant density, seed production per individual plant was significantly lowest in the control treatment where 24.9 seeds per individual plant were recorded. In $CaNPK_2SO_4$ treatment, seed production per individual plant was about 263% higher than in the control. Total seed production per m² was significantly affected by treatment and was highest in the control where 18142 seeds per m² were recorded. Total seed production per plot ranged from 1 to 3% relative to control in all treatments with Ca, N, P application.

Although high nutrient availability substantially increased the number of seeds per individual plant of *R. minor*, high number of seeds per individual plant was not able to overcome the effect of the low plant density on seed production per plot. Therefore the lowest seed production per plot was recorded in highly productive *Arrhenatherion* grassland in fully fertilized treatments where highest seed production per individual plant of *R. minor* was recorded. Low density of *R. minor* plants in fully fertilized plots with tall canopy of dominant grasses was given predominately by the competitive exclusion of seedlings, as they are known to be highly shade-intolerant (Keith, 2004) and by the lower ability of seedlings to attach to host plants. It is known that host plants develop different root architecture and exhibit higher meristematic activity under high compared to low phosphorus supply, and thus decreasing the probability of the parasitic plant becoming attached (Davies and Graves, 2000).

Conclusion

We concluded that plant density is more relevant for sufficient production of seeds per area than seed production per individual plant. This is supported by the fact that differences in plant density per plot can be substantially higher (almost 100 times in this study) than differences in seeds production per individual plant (almost 3 times in this study). Substantially lower differences in seed production per individual plant compared to differences in plant densities are given by the strict physiological limitation of seed numbers per individual plant. High density of small plants is therefore an efficient strategy for survival of *R. minor* in permanent low productivity grasslands.

Acknowledgement

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Table 1. Amounts of nutrients (kg ha^{-1}) supplied annually to the treatments since 1941 according to Schellberg *et al*. (1999), classification of plant communities which developed because of different fertilizer application into alliances according to Chytrý *et al*. (2009), total annual aboveground dry matter biomass production of vascular plants (BP, t ha^{-1}) according to Hejcman *et al*. (2010a) and standing dry matter biomass of bryophytes (SB, t ha^{-1}) in 2006 according to Hejcman *et al*. (2010b).

Treat. abbrev.	Applied nutrients	Alliance	BP	SB
A - Control	unfertilized control	*Violion caninae*	2.5	1.8
B - Ca	Ca = 715, Mg = 67	*Polygono-Trisetion*	2.9	0.46
C - CaN	Ca = 752, N = 100, Mg = 67	*Polygono-Trisetion*	4.9	0.02
D - CaNP	Ca = 936, N = 100, P = 35, Mg = 75	*Arrhenatherion*	6.5	0.25
E - CaNPKCl	Ca = 936, N = 100, P = 35, K = 133, Mg = 90	*Arrhenatherion*	8.9	0.15
F - $CaNPK_2SO_4$	Ca = 936, N = 100, P = 35, K = 133, Mg = 75	*Arrhenatherion*	9.6	0.09

Table 2. Plant density (number of plants) per m² (PD), plant density per m² relative to control (PDR), mean seed number per plant (SPP), seed number per plant relative to control (SPPR), seeds production per m² (SP) and seeds production per m² relative to control (SPR). ± values indicate SE. Calculated by one-way ANOVA followed by Tukey's post-hock test, treatments with the same letter are not significantly different. All ANOVA analyses were significant on 0.001 probability level.

Treat. abbrev.	PD	PDR	SPP	SPPR	SP	SPR
A - Control	745^{a} ± 113	100%	24.9^{a} ± 2.1	100%	18142^{a} ± 2608	100%
B - Ca	641^{a} ± 71	86%	27.2^{a} ± 2.2	109%	16560^{a} ± 2064	91%
C - CaN	29^{b} ± 22	4%	37.4^{ab} ± 3.1	150%	1365^{b} ± 1137	8%
D - CaNP	15^{b} ± 6.4	2%	45.0^{b} ± 3.4	181%	545^{b} ± 192	3%
E - CaNPKCl	5^{b} ± 5	<1%	48.4^{bc} ± 6.9	194%	198^{b} ± 198	1%
F - $CaNPK_2SO_4$	8^{b} ± 5	1%	65.4^{c} ± 9.3	263%	498^{b} ± 330	3%

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Dynamics of biomass production in extensively managed meadows at the eastern edge of the Alps

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Abstract

The dynamics of biomass production in different meadow types in the nature reserve 'Lainzer Tiergarten' west of Vienna between 1999 and 2009 were analysed. Three common meadow types (5 replicates each) and two rare ones were selected for applying different cutting frequencies (once a year, every second year, never) on fenced plots. On each of the differently treated subplots five representative micro-plots (625 cm²) were established to measure above-ground biomass every year. Additionally, five biomass micro-plots were measured every year from outside each plot. Biomass data varied highly at the scale of micro-plots from year to year. Generally, we found an increase of above-ground biomass during the 11 years of the experiment on all subplots. This increase was significant on subplots cut every second year whereas the increase of biomass on subplots with one annual cut was not significant. But even the plots outside the fence (no change in any management aspect) showed on average a slight increase of biomass. The lowest values were correlated with serious drought events in 2000, 2003 and 2007. In the years after drought hay yield was still lower than average. The effect of water availability was found to overrule nutrient availability as a critical factor for hay and litter production and for the correlated decrease in biodiversity.

Keywords: hay meadow, abundance, cutting frequency, meadow species, cover percentage

Introduction

Biodiversity loss in meadows is caused by changes of traditional management, i.e. intensification or abandonment (MacDonald *et al*., 2000). Meadow plants are well adapted to regular mowing or grazing. Thus any cessation of biomass removal will have serious effects on their performance. During the first years of secondary succession, biomass is accumulated in abandoned meadows and later on is remineralised (Stöcklin and Gisi, 1989; Schreiber, 1997). In lowland grasslands of Austria yield is correlated with water availability (Schaumberger *et al*., 2010). Thus production as well as remineralisation rate of litter balance depends on length and frequency of drought periods. A long-term experiment on different management options for nutrient-poor grasslands near Vienna provided detailed data on annual yield, litter accumulation and biodiversity changes (Karrer, 2001). The quality and quantity of produced hay is of high importance for future management options of meadows in conservation areas.

Materials and methods

Twenty percent (500 ha) of the nature reserve 'Lainzer Tiergarten' at Vienna (Austria) is covered by extensively managed grassland, all mown once a year at different dates depending on conditions for agri-environmental subsidies. Former light manuring had ceased by 1996. In 1999, a long-term experiment was established to identify an optimal management and monitoring system for preserving grassland biodiversity (Karrer, 2001). Seventeen permanent plots were established in different grassland types (Table 1). Plots were fenced to avoid the influence of browsing by wild animals, mainly wild boars. All plots were divided into subplots each of 25 m² cut at different frequencies (once a year, every second year, never). On all subplots five micro-plots of 625 cm² each were randomly selected for harvesting hay biomass annually or every second year. No harvesting took place on the continuously abandoned subplots. Additionally, five control micro-plots were collected outside the fence, where wild animals affect plant growth. Data were collected continuously from 1999 to 2009.

Table 1. Site characters and typology of 17 permanent meadow plots in the 'Lainzer Tiergarten' (mM = mean Ellenberg value for moisture, mN = mean Ellenberg value for nitrogen)

Syntaxonomic unit	No. replicates	Water supply	Nutrient supply	mM	mN
Mesobrometum	5	Temporarily dry	Poor	4.5	3.9
Molinietum	5	Temporarily wet	Poor	5.4	3.7
Festuco-Trisetetum	5	Temporarily moist	Well supplied	5.0	5.0
Danthonio-Brometum	1	Temporarily dry	Poor	4.4	3.5
Nardetum	1	Temporarily moist	Very poor	5.0	3.1

Results and discussion

The nutrient levels of the different meadow types (indicated by mean Ellenberg values in Table 1) were clearly displayed by the yields of the meadow types (Table 2). High standard error corresponds to the high micro-plot variation within subplots but also to high variation from plot to plot within the same plant community. Nevertheless, the differences of biomass means were significant between Mesobrometum and the two other common types, whereas the nutrient-rich Festuco-Trisetetum and the nutrient-poor but wet Molinietum had comparable values.

Table 2. Mean hay yield (per micro-plot) in different meadow types of the 'Lainzer Tiergarten' along 11 years

Type of meadow	n	Mean biomass (g/m²)	95% confidence interval Lower limit	95% confidence interval Upper limit	Standard error
Mesobrometum	135×5	347.000 - 722.209	471.592	546.680	1.272
Molinietum	135×5	435.469 - 792.631	578.448	668.000	1.518
Festuco-Trisetetum	135×5	526.750 - 688.905	578.332	651.817	1.246
Danthonio-Brometum	135	379.665	339.207	420.139	1.363
Nardetum	135	307.185	268.538	345.838	1.303

There was a distinct increase of biomass for all meadow types and all cutting frequencies (Figure 1). The results of the cumulative effect of nutrient availability in the treatment 'mown every second year' were rather impressive.

In the case of traditional cutting (once a year), the Festuco-Trisetetum clearly turns out to be the most productive,

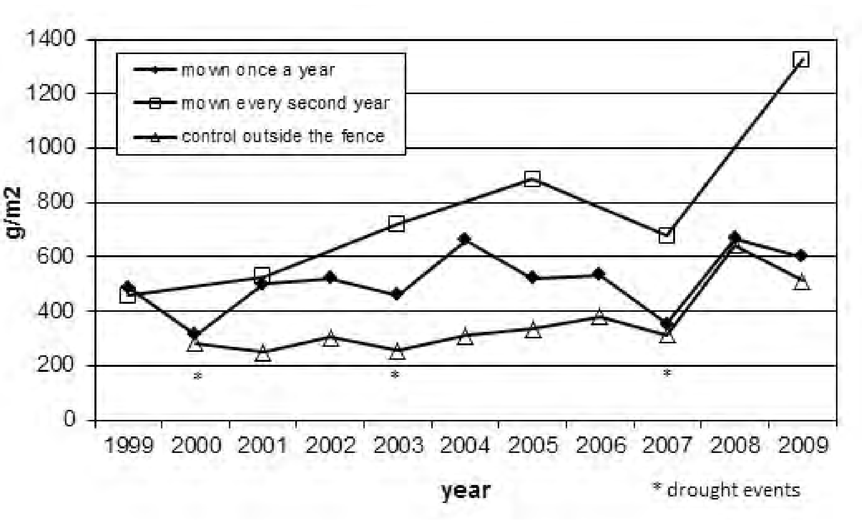

Figure 1. Mean hay yield between 1999 and 2009 at varying cutting frequencies

significantly different to both Molinietum and Brometum (Table 3). The yield of subplots which are cut every second year are ranked by the water availability gradient. The effect of the latter is seen to overrule the nutrient capacities of all compared meadow types (see Table 1).

Table 3. Mean hay yield (per micro-plot) in three common meadow types and at different cutting frequencies along the years when all 3 variants were cut

Cutting frequency	Meadow type	Mean	95% confidence interval lower limit	95% confidence interval upper limit	Standard error
Cut once a year	Festuco-Trisetetum	632.128	581.726	682.530	1.697
	Brometum	430.465	398.635	462.295	1.072
	Molinietum	459.211	428.040	490.382	1.050
Cut every second year	Festuco-Trisetetum	816.438	743.107	889.770	2.469
	Brometum	793.273	711.294	875.252	2.761
	Molinietum	961.187	876.899	1045.938	2.847
Control outside (cut once a year and grazed at low intensity)	Festuco-Trisetetum	396.657	355.895	437.419	1.373
	Brometum	303.669	270.366	336.973	1.122
	Molinietum	449.042	379.446	518.638	2.344

Conclusion

Hay production in extensively managed meadows of the nature reserve Lainzer Tiergarten is limited not only by the natural gradient of biomass accumulation (decreasing cutting frequency) but also by water availability. When cut annually, hay yield of meadows differs in congruence with the nutrient gradient (indicated by Ellenberg values). In contrast, if they are cut only every second year the increase in yield is higher in the relatively nutrient-poor but wet Molinietum. This is mainly caused by the very effective internal nutrient cycles of *Molinia caerulea*, which outcompetes almost all other species from plots that are completely abandoned (see Angeringer and Karrer, 2009). Consequently, the wet meadows in the investigated area, which is representative of subcontinental eastern Austria, show the fastest rate of species decline if abandoned, faster than relatively nutrient-rich meadows on moist soils (Angeringer and Karrer, 2009). This effect is caused by the immense production of litter by *M. caerulea*. The influence of the severe droughts in 2000, 2003 and 2007 influenced most negatively the productivity of the Trisetetum but not so much the Brometums and the wet Molinietum.

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Establishment of species-rich grasslands on arable land

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Abstract

High nature value grassland covers about 323,000 ha in Slovakia. At present, this grassland is threatened with cessation of agricultural management in marginal areas and also with construction of new motorways, sport resorts, etc. The governmental ‚Nature Protection Institute' develops and submits proposals for the high nature value grasslands protection and biodiversity improvement in accordance with the 'Act no. 543/2002 Coll. on the nature and landscape protection'. However, there is lack of knowledge dealing with species-rich grassland restoration. In 2009, two demonstration trials were established at the *Tajov* site (647 m a.s.l.) with the aim to use the species-rich semi-natural grasslands as a source of valuable material for establishing new high nature value areas. Green and dry hay harvested at donor sites with plant communities of *Arrhenatherion* and *Mesobromion* was transferred to arable land. Out of 26 target species, 22 were transferred; an 84.6% successful transmission rate.

Keywords: restoration, green hay, dry hay, semi-natural grasslands, high nature value farmland

Introduction

Species-rich semi-natural grasslands are an important but threatened habitat throughout Europe (Van Dijk, 1981). Protection of flower-rich hay meadows at a European level follows the Habitats Directive which identifies rich traditional hay meadows as a priority habitat for conservation. Although the maintenance management of species-rich grasslands has been increasing through EU subsidies since 2004, the trends in landscape restoration by improving the biodiversity of degraded grasslands and agricultural land are still negative in Slovakia. One of the reasons for low interest in management of rural and cultural landscape is lack of knowledge and field experience of restoration and establishment of species-rich grasslands. Considering that semi-natural grassland is the only existing source to provide ecological restoration of grassland with appropriate seed or plant material (Kirmer and Tischew, 2006; Krautzer and Pötsch, 2009), trials for demonstrating the application of plant material from species-rich grassland sites were established in central Slovakia. This paper presents the results from restoration of arable land to grassland by cutting species-rich donor meadows and transferring seed- and plant material seeds as dry and green hay to the receptor site.

Materials and methods

The demonstration trial was established in central Slovakia, near Banská Bystrica, at Tajov site (altitude 647 m a.s.l.; the ‚Starohorské vrchy' mountain range; 48°44'N, 19°02'E; geological substratum: carbonate rock and dolomitic limestone). The donor sites were *Arrhenatherion* and *Mesobromion* communities and the receptor site was arable land destined for conversion to grassland. The previous crop was silage maize. The distance between the donor and the receptor site was about 2 km. Over 2009 and 2010, the restoration success of the receptor site was studied through vegetation analysis.Two methods of establishing grassland were studied: 1) fresh herbage applied as ‚green hay' (GH); and 2) herbage applied as ‚dry hay' (DH). The donor sites were cut in early July 2009. At Treatment 1, green hay from the donor site was applied as a 30-35 cm layer to the receptor site (arable land) immediately after cutting. At Treatment 2, cut herbage was dried at the donor site and then applied as dry hay on the receptor site. Two weeks later the green hay, and one month later the dry hay, were removed from the receptor site, as the thick layer (30-35 cm) would have prevented seed emergence. The receptor site had been converted to grassland in 2009, but the new sward was mostly composed of weeds and therefore one cut was taken to control weeds. In the following year, the sward was well-established, with a low proportion of bare ground. Before establishing the receptor site, soil samples were taken from the donor and receptor sites (0-100 mm) to determine the content of C_{ox} (Tjurin), Nt (Kjeldahl), P, K, Ca, Mg (Mehlich III) and pH (*n*KCl). Phytocoenological records (relevés) were done at the donor site in 2009, and at the receptor site before cutting in 2010 (by agricultural method - sum of all species cannot exceed 100%).

Results and discussion

Soil analyses showed high content of total N and humus, low P content and acid soil reaction at donor sites. The soil of the receptor site was neutral with medium humus supply, medium N and P content, appropriate K content and a very high Mg content (Table 1). To establish species-rich grassland on former arable land with high nutrient content, the sowing of grass-dominated seed mixtures could be a more successful way (Lawson *et al*., 2004).

Table 1. Soil properties (0-100 mm)

	Donor sites		
	Arrhenatherion	*Mesobromion*	Receptor site
pH (*n*KCl)	5.82	4.75	7.16
Total nitrogen (%)	5.20	3.99	2.03
Phosphorus (mg kg^{-1})	4.52	29.61	72.23
Potassium (mg kg^{-1})	154.73	122.69	114.18
Magnesium (mg kg^{-1})	1224.80	153.40	690.30
Humus (g kg^{-1})	125.42	90.80	26.59

The dominant target species of the *Arrhenatherion* community (26) were *Arrhenatherum elatius* L., *Avenula pubescens* Huds., *Briza media* L., *Dactylis glomerata* L., *Dianthus carthusianorum* L., *Festuca pratensis* Huds., *Festuca rubra* L., *Knautia kitaibelii* Schult., *Leucanthemum vulgare* LAM., *Lotus corniculatus* L., *Poa pratensis* L., *Rhinanthus minor* L., *Salvia pratensis* L., *Silene vulgaris* Moench., *Trifolium pratense* L., *Trifolium repens* L. and *Trisetum flavescens* L.. The dominant target species of *Mesobromion* community (26) were *Bromus erectus* Huds., *Festuca rupicola* Heuff., *Dianthus carthusianorum* L., *Knautia kitaibelii* Schult., *Leucanthemum vulgare* Lam., *Lotus corniculatus* L., *Medicago falcata* L., *Pimpinella saxifraga* L., *Poa pratensis* L., *Primula veris* L., *Salvia pratensis* L., *Salvia verticillata* L., *Tragopogon orientalis* L., *Trisetum flavescens* L. etc. There were 41 species recorded at the *Arrhenatherion* donor site and 43 species at the *Mesobromion* one (mean of three replicates). The ground cover of grasses was higher at the *Mesobromion* community (Table 2). There were no differences visible between the applications of dry versus green hay at the receptor site (Table 3). 22 of the total of 26 target species were recorded in the renovated sward in both communities. Grassland establishment was more successful at the *Mesobromion* target community because the renovated sward resembled the original one. At the *Arrhenatherion* receptor community, grasses dominated the sward (58.5%) before the 1st cut, whereas before

Table 2. Botanical composition of sward at donor sites

		Donor sites							
		Arrhenatherion		*Mesobromion*		*Arrhenatherion*		*Mesobromion*	
Relevé (dates)	Relevé no.	Ground cover of grasses (%)	Number of grasses	Ground cover of grasses (%)	Number of grasses	Ground cover of herbs (%)	Number of herbs	Ground cover of herbs (%)	Number of herbs
3.7.2009	1	59.5	12	74.0	10	40.5	26	26.0	32
3.7.2009	2	54.0	12	72.0	8	46.0	30	28.0	33
3.7.2009	3	62.0	11	69.5	8	37.7	32	30.1	37

Table 3. Botanical composition of sward at receptor sites

		Receptor sites							
		Arrhenatherion		*Mesobromion*		*Arrhenatherion*		*Mesobromion*	
Relevé (dates)	Treatment	Ground cover of grasses (%)	Number of grasses	Ground cover of grasses (%)	Number of grasses	Ground cover of herbs (%)	Number of herbs	Ground cover of herbs (%)	Number of herbs
22.6.2010	GH	60.0	13	56.5	12	40.0	19	39.5	28
22.6.2010	DH	58.0	13	55.0	12	41.6	23	44.6	34
14.9.2010	GH	18.0	10	63.0	10	82.0	18	36.0	29
14.9.2010	DH	20.0	19	60.0	10	80.0	19	40.0	29

the 2nd cut the proportion of herbs was 80%, of which about 50% was red clover (*Trifolium pratense* L.) and that of grasses dropped to 20.0%.

Conclusions

It was concluded that there is a possibility to return arable land to grassland by cutting species-rich donor meadows and applying the plant seeds contained in herbage as green or dry hay to receptor sites. As demonstrated by the experiment, 22 species have been established at the receptor site so far, out of the total 26 target species present in the *Arrhenatherion* and *Mesobromion* donor swards (84.6% successful transmission rate). Positive results have been achieved in both meadows, but the *Mesobromion* community is more similar to the original donor sward and has appeared more successful than the *Arrhenatherion* community, probably due to very similar natural conditions at the donor and receptor sites.

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Effects of abandonment of montane grasslands on plant species composition and species richness - a case study in Styria, Austria

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Abstract

Long-term abandonment of grassland generally causes a decrease in plant species richness. The questions, how long abandoned grassland may remain species-rich and whether the persistence varies between different sites, have been examined insufficiently so far. Thus, in this successional study we analysed over a period of 9 years the effects of abandonment on plant species composition and species richness in a montane grassland in Styria, Austria. We differentiated two topography-related habitat types: a pasture on a steep, south-facing slope with a nutrient-poor soil, and a meadow on a flat site below the slope with a more fertile soil. In spring 2001, one permanent plot (plot size: 50 m²) in each habitat type was established. Our results show that the long-term effects of abandonment on grassland vegetation depend largely on local site conditions, and nutrient availability in the soil seems to be an especially important factor. On the flat site, within 4 years of abandonment floristic composition changed dramatically, a high species turnover and a strong decrease in species richness could be observed. In contrast, on the steep, south-facing slope we found only minor effects, even after 9 years of abandonment.

Keywords: biodiversity, permanent plots, secondary succession, species turnover

Introduction

In Austria and in many other European countries, two contrsting trends in grassland management can be observed. In climatically favoured areas, a further intensification of grassland management is to be expected. In mountain regions, however, abandonment of grassland will take place especially on sites with unfavourable climatic, pedological and/or topographical conditions. In general, the long-term abandonment of grassland causes a decrease in plant species richness (Prévosto *et al.*, 2011). The questions, how long abandoned grassland may remain species-rich and whether the persistence varies between different sites, have been examined insufficiently so far. Thus, the primary aims of this successional study were: (i) to monitor the plant species composition and species richness of a montane grassland in Styria (Austria) after abandonment and (ii) to analyse the importance of local site conditions for vegetation changes during secondary succession.

Materials and methods

This study on grassland succession was conducted at the Buchauer Sattel located near Admont in the northern part of Styria (Austria) at an altitude of 895 m a.s.l. The climate is relatively cool and humid, with a mean annual air temperature of 6.6°C and an annual precipitation of 1400 mm (ZAMG, 2002). During the growing season (April-September) 60% of the annual precipitation occurs. To study the effects of abandonment as a function of local site conditions, we differentiated two topography-related habitat types: a relatively low-productive, species-rich pasture on a steep (30°), south-facing slope and a more productive and less species-rich meadow on a flat site below the slope. Before abandonment, the unfertilized pasture was extensively grazed by sheep and the meadow, which had two cuts every year, was fertilized with farmyard manure. In both habitat types, the soil represents a deep, base-rich Chromic Cambisol developed over a calcareous moraine. In the A horizon soil texture is loamy silt. Soil water regime is periodically moist in the topsoil. On the flat site wet periods are longer and dry periods are considerably shorter than on the slope. At the time of abandonment, the topsoils were in the cation exchange buffer range (Table 1). On the flat site C_{org} to N_{tot} ratio was narrower, whereas electrical conductivity, effective cation exchange capacity and lactate soluble phosphorus content were higher, indicating a better soil-nutrient availability on the flat site compared to the slope. In this habitat type, nutrient deficiency in the soil is the main limiting factor for plant growth. Dryness seems to be of minor importance due to the cool and humid climate in combination with a deep, humus-rich, fine-textured soil, indicating a high water-holding capacity. Originally, the flat site was covered by a *Trisetetum flavescentis* community and the slope by a *Festuco commutatae-Cynosuretum* community. Both vegetation types, especially the first-mentioned, are common and widely distributed in Austria. In spring 2001, one permanent plot in each habitat type was established. Both permanent plots had the same plot size of 50 m². They are representative for each habitat type and are largely homogenous from a soil science point of view. At each plot we recorded the individual cover of all vascular plant species according to the method of Braun-Blanquet. The experimental site is surrounded by a mixed forest of spruce, silver fir and beech (*Picea abies, Abies alba, Fagus sylvatica*).

Table 1. Soil chemical properties at the time of abandonment (A horizon, 0-10 cm).

Site	% C_{org}	% N_{tot}	C_{org}:N_{tot}	$CaCl_2$ pH	µS cm^{-1} EC	$cmol_c$ kg^{-1} CEC_{eff}	% BS	mg kg^{-1} P_{CAL}	mg kg^{-1} K_{CAL}
Slope	4.42	0.38	11.63	4.3	36	9.0	75	8	50
Flat site	4.52	0.41	11.02	4.8	57	11.6	93	15	48

EC = electrical conductivity; CEC_{eff} = effective cation exchange capacity ($BaCl_2$-extract); BS = base saturation ($BaCl_2$-extract); P_{CAL}, K_{CAL} = lactate soluble phosphorus and potassium content.

Results and discussion

The investigated habitat types differed in their response to abandonment. On the flat site we observed relatively large vegetation changes during the first four years of secondary succession. From that time onwards, the successional changes in species composition and species richness were comparatively smaller, indicating a period of stagnation. During the investigation period herbs increased in cover from 40% in 2001 to 97% in 2009 at the expense of both grasses and legumes. The beta-turnover according to Shmida and Wilson (1985) shows a comparatively high species turnover (Table 2). Abandonment favoured mainly *Chaerophyllum hirsutum* and *Ficaria verna*. Their cover values increased considerably. During the first four years after abandonment, the tall herb *Chaerophyllum hirsutum* became dominant, resulting in a decline of the evenness value. Alpha-diversity (total number of vascular plant species within a plot size of 50 m²) decreased from initially 48 plant species in 2001 to 22 in 2009. During secondary succession only two new species appeared, whereas 28 species disappeared. Among the newly recorded species *Galeopsis tetrahit* increased in cover. This late-developing therophyte may benefit from the numerous gaps in the sward. Species with decreasing cover and species which disappeared were mainly characteristic grassland species, resulting in a change of the vegetation type. Up to now, we found no species of shrubs or trees. In contrast, on the steep, south-facing slope vegetation changes were small, even after 9 years of abandonment. Alpha-diversity decreased from initially 73 plant species in 2001 to 70 in 2009. Obviously, the lack of disturbance did not result in a rapid decline in species richness. During secondary succession, we observed 8 newly appearing species, whereas 11 species disappeared. Among the 'newcomers' we found mainly plant species which are characteristic of forest margins (e.g. *Agrimonia eupatoria*, *Cuscuta epithymum*, *Hieracium laevigatum)*. Abandonment favoured particularly *Astrantia major* ssp. *major*, *Betonica officinalis*, *Clinopodium vulgare*, *Molinia caerulea*, *Prunus spinosa*, *Pteridium aquilinum* and *Trifolium medium*. Up to now, the cover value of woody plants is relatively low. Among the woody plants (tree seedlings of *Acer pseudoplatanus* and *Fraxinus excelsior*, shrubs such as *Crataegus monogyna* and *Prunus spinosa*), initially present, only *Prunus spinosa* increased. The early successional stage is characterized by a high species richness and evenness value (Table 2), indicating the absence of dominant species. The abandoned plant stand is rich in species of herbs, colourful when in bloom, resulting in a high aesthetic value. Until now, we found no rare and highly endangered vascular plant species in either of the habitat types. The observed smaller successional changes on the slope compared to the flat site are likely the result of a different nutrient availability in the soil. Also the small differences in soil water regime may have an influence primarily due to the fact that soil moisture affects nutrient availability in the soil. Because of the less-fertile soil on the slope, resulting in a comparatively lower above-ground plant biomass production and hence better light conditions at the soil surface, more light-demanding grassland species of short stature at maturity could survive after abandonment. In contrast, on the flat site many light-demanding grassland species were suppressed primarily by the dominant species *Chaerophyllum hirsutum* through shading. Thus, on nutrient-rich grassland soils abandonment favours the spread of a few highly competitive, tall plant species, resulting in rapid successional changes and a strong decrease in species richness.

Table 2. Vegetation changes after abandonment in the period 2001 to 2009.

	Slope	Flat site
α-diversity 2001	73	48
α-diversity 2009	70	22
Change in α-diversity	-3	-26
Number of new species	8	2
Number of extinct species	11	28
Evenness value 2001	85	84
Evenness value 2009	79	47
Beta-turnover 2001-2009	0.13	0.41

Conclusion

The results of our successional study suggest that the long-term effects of abandonment on grassland vegetation depend largely on local site conditions. Nutrient availability in the soil seems to be an important factor for vegetation changes during secondary succession. In order to prevent a considerable decrease in plant species richness, management operations have to be done in habitats with nutrient-rich soils in shorter intervals (approximately every three years) than in habitats with nutrient-poor soils (at least every five to ten years). Furthermore, our results suggest that abandoned grassland does not get lost immediately as agricultural area, because the appearance and/or spread of trees and shrubs are in most cases a slow process.

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Assessing the adequacy of stocking rates on protected pasture vegetation

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Abstract

The management of protected grasslands aims at achieving a balance between stocking rate and forage availability in order to prevent undesired vegetation dynamics. The methods available to estimate the potential carrying capacity differ in the required input data and the information provided. A four-year survey was carried out in the pastures of the Natura 2000-site of Castelfeder (50 ha, 220-408 m a.s.l., South Tyrol, Italy). The quantity and the quality of the forage on offer of three grassland types were investigated: dry and semi-dry grasslands, extensively managed pastures and nutrient-rich pastures. The actual stocking rates were compared to the potential carrying capacity calculated by applying three different methods: pastoral value, forage and energy yield on offer. The changes both within and between the grazing seasons of the grassland dry matter and energy yield were found to be in contrast with the rather constant stocking rates. Different methods to estimate the potential carrying capacity gave quite different results.

Keywords: protected grasslands, carrying capacity, pastoral value, forage yield, energy yield

Introduction

The management plan of grasslands in protected areas aims at achieving a balance between stocking rate and forage availability in order to prevent undesired vegetation dynamics. The methods used to estimate the potential carrying capacity (PCC) should take into account the specific characteristics of the vegetation types (D'Ottavio *et al*., 2009) and the effects of variability of the climatic factors on the yield fluctuations over time (Peratoner *et al*., 2009). To verify the suitability of three different methods for estimating PCC, values obtained by these methods were compared to the actual stocking rates (SR) on pastures monitored over a period of four years.

Materials and methods

The study was carried out in the Natura 2000-site of Castelfeder, a protected area of 108 ha in the valley of the River Etsch (Montan, South Tyrol, Italy). The area is characterized by a mean yearly temperature of 12.4°C and a precipitation of 821 mm, with two peaks in June and October respectively. The investigated pastures cover an area of about 50 ha from 220 to 408 m a.s.l. and consist of three main vegetation types: 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). From 2007 to 2010 the cattle, horses, donkeys, sheep and goats of different breeds and ages kept on the pastures were assessed between the beginning of May and mid October. In the middle of May of 2007 and 2009, abundance-dominance vegetation surveys led to a summary definition of the botanical composition of the pasture types. From 2007 to 2010, the forage growth rate and cumulative yield of each pasture type was determined with the Corrall-Fenlon-method as described by Peratoner *et al*. (2009). Every two weeks, crude protein (CP), ash (CA) and acid detergent fibre (ADF) were determined according to Naumann *et al*. (1997) and energy content in Forage Unit (FU) was computed according to RAP (1999). Weekly values were obtained by interpolation of the measured ones.

The PCC of the whole area was estimated by means of three different methods:

(i) *Pastoral value (PV)* according to Daget and Poissonet (1971) and D'Ottavio *et al*. (2009) and by adopting the specific indexes reported by Roggero *et al*. (2002). A fragility coefficient of 0.9 was applied to slopes greater than 50%. PCC, expressed as annual Forage Unit yield (FU ha^{-1} yr^{-1}), was calculated according to Roggero *et al*. (2002), assigning 66 FU to 1 point of corrected PV.

(ii) *Energy yield (EY)* PCC, expressed in FU ha^{-1} grazing $period^{-1}$, was calculated by adding up the weekly product of forage energy content and yield for each pasture type.

(iii) *Forage DM-yield (FY)* PCC, expressed as total forage dry matter (DM) on offer on the area in terms of Mg DM ha^{-1}, was computed as described for EY. For both EY and FY seasonal utilisation rates (K) of 0.8 for RP and EP and K of 0.5 for DG were used.

PCC assessed by PV and EY was compared to the SR estimated according to I.N.R.A. (1980) considering the FU daily feed requirement of the animals in terms of maintenance and growth, grazing (an increment of 20% of the maintenance and growth requirement was used), gestation and milking. PCC assessed by FY was compared to the total forage intake of the animals estimated according to INRA (1980) on the basis of their body weight. This was estimated by means of regression equations obtained from local auction data and based on animal breed, age and gestation.

Results and discussion

The cumulative DM and energy yield exhibited consistent differences between pasture types over the whole observation period (Table 1). Large differences were observed also between years, with more-than-double increases between the least and the most productive years.

The PCC methods yielded quite different results (Table 2). PV predicted an energy amount on offer exceeding the estimated animal requirement by one third. Both EY and FY showed

Table 1. Effect of year and pasture type on the cumulative DM (Mg ha^{-1}) and energy (FU ha^{-1}) yield. Mean separation by Tukey HSD at $\alpha = 0.05$. Within each year, means without a common letter significantly differ one from another.

	DM yield (Mg ha^{-1} $year^{-1}$)				Energy yield (FU ha^{-1} $year^{-1}$)			
Pasture type	2007*	2008*	2009	2010	2007*	2008*	2009	2010
DG	807^c	1,856^c	1,420^c	1,572^c	544^c	1,338^c	1,190^c	1,192^c
EP	1,582^b	3,591^b	2,309^b	2,381^b	1,229^b	2,904^b	1,961^b	1,836^b
RP	3,514^a	6,599^a	4,680^a	4,012^a	3,038^a	5,572^a	4,010^a	3,337^a

* Analysis with log-transformed data. Back-transformed means are shown.

Table 2. Animal requirements (×1,000) and PCC (×1,000) calculated for the whole grazing season with PV, FY and EY. Numbers in bracket beside each PCC value represent the balance (×1,000).

	Animal requirements		PCC		
Year	Energy (FU $year^{-1}$)	Dry matter (Mg $year^{-1}$)	PV (FU $year^{-1}$)	EY (FU $year^{-1}$)	FY (Mg $year^{-1}$)
2007	40.8	76.8	58.9 (+18.2)	33.2 (-7.5)	42.0 (-34.8)
2008	38.9	75.9	58.9 (+20.0)	71.9 (+33.0)	89.4 (+13.5)
2009	43.3	85.3	58.9 (+15.6)	52.1 (+8.8)	61.3 (-23.9)
2010	39.2	78.9	58.9 (+19.7)	47.7 (+8.5)	60.7 (-18.2)

great fluctuations between years, ranging between negative and positive values, as animal requirements were relatively stable, while energy and DM on offer strongly varied depending on climatic factors. EY and FY, as well as the respective balances, were found to be very closely related to each other (R^2 = 0.99*** and R^2 = 0.94*** respectively), although they exhibited great differences in terms of estimated balance.

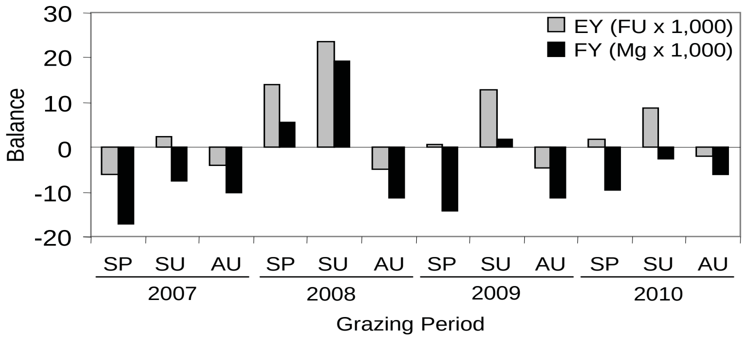

Figure 1. Balance between PCC estimated by EY and FY and SR in each grazing period (SP: spring (46 days), SU: summer (92 days), AU: autumn (30 days) from 2007 to 2010.

A comparison of FY and EY with the animal requirements for each grazing period separately showed large fluctuations of the balance as well (Figure 1), with summer balance exhibiting usually the highest values. Also on this level a close relationship between FY and EY and the respective balances was found (R^2 = 0.99** and R^2 = 0.94** respectively).

Conclusions

The different methods used to evaluate the adequacy of stocking rates led to very different results which need to be verified. The higher energy on offer assessed by pastoral value was probably affected by taking only a part of the actual grazing season into account for estimating the animal requirements. Moreover, the summary vegetation surveys did not allow accounting for changes in pasture productivity between years and within the growing season. The results obtained by forage DM-yield and energy yield balance may be affected by neglecting the gestation and milking requirements of goats and sheep, for which information was missing, and the not quantifiable browsing of the wood and shrub vegetation by the numerous goats.
The stocking rate should be adapted taking into account the specific characteristics of the vegetation types and the yield fluctuations over time as affected by the climatic factors. To ensure the conservation of protected grassland, some modification of the stocking management should be verified and considered in order to avoid under- and/or over-stocking conditions.

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Differences in the long-term succession of semi-natural and newly sown permanent grassland associations

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Abstract

Our long-term field experiment (1992-2009) was focused on the course of succession in semi-natural (PG) and renewed (RG) grassland associations in relation to four levels of trophism (without fertilization; P+K; N_{90}+PK; N_{180}+PK). The results show a significant decrease of the proportion of grasses in both types of grasslands, especially in the late phase of succession, and an increase of the percentage of forbs, mainly *Polygonum bistorta*. As to the graded level of trophism, both grasslands were dominated by the grass component replacing the forbs. Legumes showed a greater proportion (ca. 10% of DM yield) only in the P+K fertilisation treatment. In spite of a greater general change of the grasslands, RG showed a relatively rapid return to the original state (naturalization).

Keywords: grass stand, permanent, newly sown, succession, structure

Introduction

Succession in permanent grassland is connected with the terms 'primary' (without anthropogenic impact) and 'secondary,' (from anthropogenic actions such as the influence of fertilization (Krajčovič *et al*., 1968)). Hejcman *et al*. (2007) warn about the limited occurrence of competitive grass species in the later phase of succession due to the lack of available K and P in the soil, even at relatively high levels of N fertilization. The increased proportion of forbs after reducing the main nutrient levels in soil was reported by Isselstein (1994). Inadequate management practices such as excessive N-fertilization may result in a deep change of the species composition structure and hence impaired herbage quality (Hrabě and Halva, 1993). This paper aims to point out differences in the course of long-term succession between a semi-natural stand and a renewed sward. The main goal of the paper is to evaluate the long-term influence of various fertilizer levels on changes in species composition and trends in these changes in the initial phase of secondary succession (years 1-6), the post-initial phase (years 7-12) and the stabilization phase (years 13-18).

Material and methods

The experiment site is located in a protected landscape area in the Bohemia-Moravian Uplands (sub-mountainous: 650 m a.s.l.). The average yearly temperature is 6.3°C (during the growing season 12.4°C); the yearly precipitation amount is 786 mm (465 mm during the growing season). Soil type was a stagnosol, acidic Pleosticene gneiss. Soil was sandy loam, slightly gravelly and with a boggy upper sod layer. The soil pHKCl was 4.45, the water regime was mesohygrophytic and the nutrition regime mesoligotrophic.

Sanquisorba-Festucetum comutatae semi-natural swards were mown once a year up to 1991 without fertilizing. In 1992 the experiment was started and the sward was mown three times a year. In 1991 part of the original grassland was cultivated without ploughing and resown with a mixture of *T. pratense*, *T. repens*, *D. glomerata*, *L. perenne* and *F. brauni* cv. Felina (3, 2, 8, 4 and 12 kg ha^{-1}). Experimental design was completely randomized with 4 replications. Each experimental unit was 15 m². Three fertilizer treatments were applied after 1992: H_0 - without fertilization;

H_1 - fertilized with P_{30}+K_{60} kg ha^{-1}; H_2 - N_{90}+P_{30}+K_{60} kg ha^{-1}; H_3 - N_{180}+P_{30}+K_{60} kg ha^{-1}. The N supply was split into three applications for each mowing (April, June and August).

Proportion of botanical groups in forage production was measured as DM proportion from an area 1.0 m² for two replications. The plants were divided into 3 groups: grasses, legumes and forbs (including *Juncus* and *Carex*). The results were statistically analysed by one-way ANOVA and followed by Tukey's test with *P*-value 0.05 ($P \leq 0.05$), using Statistica 8.0.

Results and discussion

Our results corroborate previous findings published in numerous scientific papers (e.g. Velich 1986; Jančovič *et al*., 1999 and others) about the significant decrease in the proportion of grasses and the increase of forbs (Table 1). The proportion of legumes in the course of succession generally increased but it was significant only in the PK-fertilization treatment. The 'phenomenon' of increase of forbs and decreasing proportions of grasses in grasslands under low-input management results, according to Isselstein (1994), from the enhanced competitiveness of forbs due to the response to abiotic environment change. According to Klimeš (2000), an indicator of the stability of stand composition and production is the rate of their change evaluated for individual periods and compared with the initial stand structure (CZP), as well as between the respective succession phases - so-called fluctuation (FZP). The values show a significant CZP difference between PG (av. = 7.6%) and RG (av. = 28.3%). It follows that the highest CZP and FZP values are in the post-initial phase of succession (S2) and the lowest values in the last phase of succession (Table 2).

Table 1. Changes in grass, legumes and other herbs proportion during succession seminatural (PG) and renewed (RG) grassland. Kameničky; 1. cuts, 1992-2009

	Dominance (in %) of vegetation segments					
	grasses		legumes		other herbs	
Phases of succesion	PG	RG	PG	RG	PG	RG
initial (1-6 year)	60.8[a]	79.8	3.8[a]	3.6	35.3[a]	16.6
stabilization (7-12 year)	48.6[b]	54	2.6[a]	3.7	48.8[b]	42.3
post - stab. (13-18 year)	47.8[b]	56.8	5.4[a]	9.0	46.8[b]	34.2

Values followed by the same letter in each column are not significantly different ($P \leq 0.05$)

Table 2. Total and fluctuation change of species composition (%) in individual phases of succession

	1. Initial	2. Postinitial		3. Stabilization	
Stand	CZP	CZP	FZP	CZP	FZP
Permanent (PG)	8.7	6.6	13.4	7.4	2.4
Newly sown (NG)	12.1	37.8	15.8	35.0	8.0

Table 3. Dominance (% weight) of grasses, legumes and other herbs dominance during succession in seminatural (PG) and new sown (NG) grassland swards in relation to trophism level. Kameničky II., 1. cut, 1992-2009

	Abundance (%)					
	grasses		legumes		other herbs	
Fertilization	PG	NG	PG	NG	PG	NG
without N, P, K	41.1[a]	51.6	2.9[a]	5.6	56.0[a]	42.8
P_{30}+K_{60} kg ha^{-1}	39.8[a]	58.5	10.9[b]	10.3	49.3[a]	31.2
N_{90}+P_{30}+K_{60} kg ha^{-1}	59.2[b]	67.3	1.6[a]	3.4	39.2[b]	29.3
N_{180}+P_{30}+K_{60} kg ha^{-1}	69.7[c]	76.9	0.2[a]	2.2	30.1[c]	20.9

Values followed by the same letter in each column are not significantly different ($P \leq 0.05$)

The conclusive factor for the change in stand composition is the level of nutrition, namely the N supply. Table 3 clearly shows the increasing share of grasses and the decreasing proportion of other herbs in both types of stands. As compared with PG, the renewed stand had a significantly higher proportion of grass and leguminous components and a lower share of other forbs. The reason is a larger uptake of biological nitrogen from symbiosis as well as the release of nutrients from the mineralization of soil organic matter after soil cultivation. Based on the changes in the dominance of *A. pratensis* and *P. bistorta* (Figure 1) namely in the period of succession, we can judge upon the definition of a so-called phase of stand starvation (Velich, 1986) and upon a material alternation between the species.

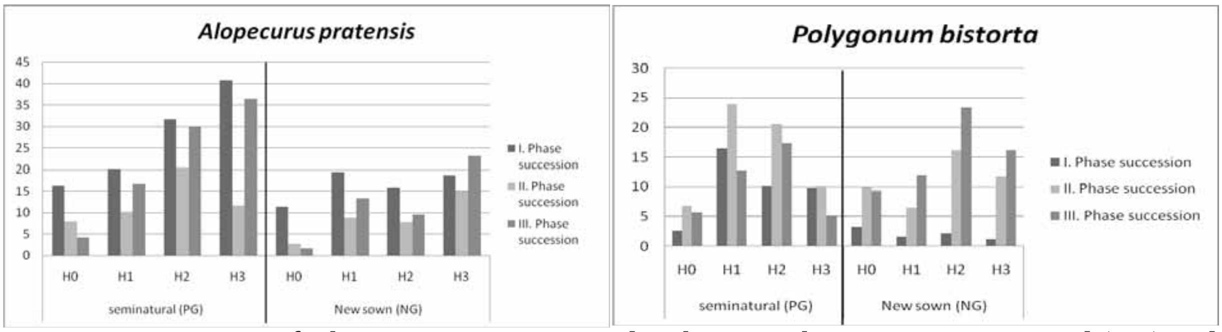

Figure 1. Proportion of *Alopecurus pratensis* and *Polygonum bistorta* in seminatural (PG) and renewed (new sown, RG = NG). I. Phase succession (years 1-6), II. Phase (years 7-12) and III. Phase (years 13-18). Kameničky II., 1992-2009

Conclusion

Results of our long-term research into the succession of permanent grass stands - semi-natural and newly sown - indicate an identical trend, i.e. a gradual (in time) decrease in the dominant share of grass components to the benefit of increasing dominance of other herb species. In relation to the level of fertilisation, a trend shows (significantly) that with increasing fertilization intensity swards move towards increasing dominance of grasses and a decreasing share of other species. Legumes significantly increase their dominance only under the P+K fertilization treatment. The decreased proportion of the dominant *Alopecurus pratensis* in the post-initial period and its alternation with *Polygonum bistorta* points once again to the problem of the 'period of starvation' in the course of succession.

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Production and marketing of regional seeds

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Abstract

The increasing loss of semi-natural grasslands is a very serious threat to rural development that results in negative consequences for ecology, economy and society. Site-specific species are well adapted to local conditions. With the correct selection of regional species, erosion-stable, appealing and often valuable nature-conservation plant associations can be formed. The positive ecological and economic effects of site-specific restoration have already been proven in many trials. A good method for the exploitation of site-specific seed material is the large-area production of seed of suitable species with the aid of agricultural techniques. Species that are often used, and required in larger amounts, can be produced at a comparatively reasonable price and implemented on appropriately large project areas. Together with the basic scientific work undertaken at the Raumberg-Gumpenstein Research Institute, the company of ‚Kärntner Saatbau‘ assumed responsibility for the commercial realisation of the seed production of site-specific species. ‚RENATURA‘ is the brand name given to the result of many years of innovative cooperation through science and practice. The result of these endeavours have been regional seed mixtures containing up to 100% of site-specific seeds for the colline, montane, subalpine and alpine zones of Austria.

Keywords: regional seed mixtures, ecological restoration, site-specific species

Regional seed mixtures for the subalpine and alpine zones of Austria

First attempts were made in the 1980s in Carinthia in this field (Lichtenegger, 2003). The basis for production of subalpine and alpine ecotypes was laid down in the subsequent ten years at the Agricultural Research and Education Centre (AREC) Raumberg-Gumpenstein (Krautzer, 1995). In the initial stages, seeds of site-specific ecological species were gathered manually at various sites. In an extensive series of trials, various seed origins were tested for their suitability for seed production for valley locations. Following the conclusion of the trials, a spectrum of various grasses, leguminous plants and herbs proved to be especially suitable for seed production and also for implementation in alpine-restoration mixtures.
Together with the basic scientific work, which took place at AREC, a partner for the commercial realisation of the project became necessary. This was the beginning of cooperation with Kärntner Saatbau. The basis of commercial production of these species was worked on together with a great deal of enthusiasm. Following the surmounting of unavoidable setbacks, in 1995 the first seed mixtures for the restoration of ski runs and other graded areas in high locations could be offered. In the meantime, 100% of subalpine and alpine ecological species are used in the mixtures. The production encompasses a current spectrum of species comprising 16 grasses, four leguminous plants and four other herbs. The opportunity was thus created for innovative farmers and seed producers to undertake lucrative, non-regulated production. The demands placed on production technology are extremely high. Only a few seed producers with many years of experience are able to meet the extreme demands of production quality with sufficient yields.

The marketing of such niche products is subject to its own law and the market is relatively limited. A lack of legislative regulations permits, as before, the use of seed mixtures of ecologically unsuitable species, which are significantly cheaper. Site-specific seed mixtures can only be sold through intensive and high-grade expert supervision of the seed buyers. The latest experiences and knowledge is communicated every year at conferences, workshops, excursions and during inspections to persons such as ski-run operators, authorities, engineering offices, nature-preservation organisations, restoration firms, farmers and torrent- and avalanche authorities.

Regional seed mixtures for the colline and montane zones of Austria

Due to the increasing importance in Europe of biodiversity and sowing with site-specific seeds in lower regions, Kärntner Saatbau decided to devote a great deal more attention to this theme. Large-area production of site-specific, regional species for restoration in lower regions has been set up in the last five years. Through the intensive cooperation between those undertaking research, nature conservation and seed producers, an exemplary project could be brought into being: ‚Natural Seed From Upper Austrian meadows‘.

Regional seed origins of various species were gathered under the overall supervision of the nature conservation department of the province of Upper Austria. This collection was undertaken, in part, manually. The target species were thus harvested at the respective optimum point in time. The seed collected manually was and will be pre-reproduced at AREC Raumberg-Gumpenstein on small sites and monitored for their suitability for seed production in large areas. Another part of the original material for seed production was obtained from field threshing. With this method the donor areas are harvested at the time of optimum seed maturity of the target species. Harvesting takes place with a standard commercial combine harvester. After threshing the threshed material is dried and the different target species are separated by a special cleaning technique. As a result of these efforts, 16 species have in the meantime been reproduced. There are an additional 24 species in the process of pre-reproduction at AREC Raumberg-Gumpenstein.

Within the sphere of this work in recent years, a spectrum of special seed mixtures has been developed for restoration in lower regions. The focus was placed on areas that engender high costs for care and maintenance, such as roadside embankments or railway embankments (www.saatbau.at). Through the use of site-specific seed mixtures, the expenditures for maintenance could be drastically reduced. On the other hand, these mixtures are also used in private gardens, for the restoration of commercial areas or public green areas.

Marketing and distribution

The marketing of such mixtures is difficult. Most tenders for landscaping permit, as before, the use of seed mixtures that of ecologically unsuitable species or origin, which are generally cheaper. Site-specific, regional seed mixtures are currently only saleable through intensive and high-grade expert care of seed buyers. A fundamental criterion for the nature-conservation value of site-specific seeds, but also for the protection of potential seed buyers, lies in the proof of their regionalism. To provide consumers with appropriate assurance, certification procedures with a seal of quality that guarantee the region of origin of the seed (Rometsch, 2009; www.natur-im-vww.de) already exist in several European countries. Thus the origin, as well as the standard of the seed quality (purity, germinative capacity) is guaranteed. There are also intensive efforts undertaken in Austria to certify regional seed material from seed production, threshing or plant clippings. The entire process of the collection of the seed origins and their reproduction is in the meantime monitored by an independent office (www.rewisa.at) and the harvested material certified according to the ‚Control Guidelines for the Winning and Sale of Regional Wild Plants and Seeds' (Krautzer and Pötsch, 2009; Pühringer, 2010). In this way a transparent system is created in which the path of the seed from the areas of origin to the consumers is made apparent. Thus in the future a quantum leap with respect to the quality of tenders for restoration of semi-natural grassland, roadsides and landscaping should be achieved. In practice the use of site-specific seed mixtures often fails due to their inexpert use. Site-specific seed mixtures are tendered for use with a false technique or false soil structure (due to being too rich in nutrients). This, on the other hand, leads to problems with customer satisfaction because the combination of site-specific seed mixtures with a false technique and/or false soil structure does not lead to the expected result. The latest experience and knowledge should therefore be passed on to groups of persons, authorities, engineering offices, nature conservation organisations and restoration firms at conferences, workshops, excursions and during inspections. It will be necessary in the medium-term to undertake adaptation with respect to existing norms in landscaping.

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Selection of indicators by machine learning: Application to estimate permanent grassland plant richness

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Abstract

Indicators based on key species or other data from field observations are very useful to manage permanent grasslands or to control result-oriented agri-environmental schemes. These indicators must generally fulfil the following features: purpose relevance (i.e. optimize forage quality, maximize biodiversity, etc), minimization of the acquisition cost (time and money), stability in time and space, low specialized knowledge requirement, sensitivity. Permanent grasslands are complex ecosystems based on multispecific swards and multiple agronomic and ecological functions. Adequate methodologies are thus required to determine simple indicators. We tested the regression tree methodology coming from machine learning techniques (artificial intelligence) to predict the plant richness of mountain and lowland permanent grasslands in France. Four potential indicators were considered (alone or combined): species, genera, families, and colours of flowers. Each indicator was associated its ease of observation, and the prediction quality of the models was estimated by several criteria (coefficient of determination, relative absolute error). A combination of plant genera and colour of flowers was found to be the best compromise in order to estimate permanent grassland plant richness.

Keywords: indicators, richness, biodiversity, machine learning

Introduction

Several countries in Europe have applied output based approaches to agri-environmental management contracts (i.e. MEKA programme in Germany, Environmental Stewardship in U.K., Ecological Compensation Area in Switzerland, Grassland Agri-environmental measures 2007 in France ...). All these plans require control indicators for administration and farmers themselves. In the MEKA programme, the result is controlled by the observation of four species, within a list of 28 species elaborated on phytosociological rules (Opperman *et al*., 2003). The ecological and agronomic relevance of this type of criterion has been discussed by Plantureux *et al*. (2010). A key issue for scientists and administration is to find appropriate criteria to control the result, associating scientific relevance and practical feasibility. Machine learning techniques coming from computer science give new opportunities to select rapidly and simply such criteria. The purpose of the present work is to test the regression-tree method to provide relevant indicators that predict permanent grassland plant richness.

Materials and methods

The evaluation of the method was conducted in France with a dataset made up of 3792 permanent grasslands, with a full description of their botanical composition. The grasslands are record in the eFLORAsys database (Plantureux *et al*., 2010), half of which are located in the North-eastern part of France and the remainder widespread over the whole country. About 25% of the grasslands are in mountainous regions. Plant richness ranged from 5 to 79 species per grassland (observation area 5-10,000 m²). We selected the following potential indicators for evaluating plant specific richness (calculated by eFLORAsys): species, genera, flower colours, and combinations of genera and flower colours. In all cases, the presence/absence rather than species dominance in the sward was considered. For each indicator we tested the hypothesis that a limited number of values (i.e. a limited number of species or genera) was enough for predicting richness of each of the 3792 grasslands. Unlike the procedure performed in agri-environmental schemes, the species were not selected by specialists, but found by the computer (machine learning).

We tested the regression tree methodology coming from the machine-learning techniques (artificial intelligence) to predict plant richness. Regression trees aim to predict the value of a numerical outcome (here, plant richness) with respect to a set of dependant variables (here, presence/absence of the above potential indicators). Their behaviour is similar to decision trees, except that leaves contain linear models of the outcome variable, rather than single values (Quinlan, 1992). We first performed a feature selection pre-processing that extracts a subset of dependent variables by considering the individual predictive ability of each variable along with the redundancy between them (Hall, 1999). Then the regression tree was built and evaluated by cross-validation using Weka software (Hall *et al*., 2009). The accuracy of the model is measured by the Relative Absolute Error (RAE), the ratio between the sum of errors using the model, and the sum of errors using the mean as a constant predictor. The lower the RAE, the more accurate is the model. A model with RAE higher than 100% is worse than the mean as a predictor. This method was applied to obtain the smallest list of species to be considered to predict correctly the total plant richness. A similar procedure was performed for genera and flower colours, but considering combinations of flowering by month (i.e. white, yellow and red in May + white and blue in June + white in September).

Results and discussion

Main results for the potential indicators are presented in Table 1. We found 989 plant species within the 3792 grasslands, but 264 of them are enough to predict plant richness with a high coefficient of determination (CD = 0.98) and a low relative absolute error (RAE = 14%).

Table 1. Indicators for the prediction of plant species richness of the 3792 grasslands (France). Relative Absolute Error (REA) estimates model predicting quality.

Indicator	Criteria	Value	Coefficient of Determination	Relative Absolute Error
Species (best fit model)	Number of species	264 species	0.98	14%
Species (model with limited number of species)	Number of species	34 species	0.85	37%
Genera (best fit model)	Number of genera	135 genera	0.96	17%
Genera (model with limited number of genera)	Number of genera	43 genera	0.86	30%
Flower colours for each month	Number of combinations flower colour×month	77 combinations	0.86	35%
Flower colours in May	Number of colors	10 colours	0.62	61%
Combination of genera and Flower colours in June	Number of combinations genera×flower colour	41 genera×5 colours	0.90	29%

The best compromise between the species number (to simplify the previous indicator) and the model quality was found for a model with 34 species (over the 989 species). A list of 135 plant genera is able to predict plant richness, and the CD but not the RAE is almost unaffected by a reduction to 43 genera. A total of 77 combinations of flower colours and months are required

to correctly predict plant richness, but this leads to the need to examine grassland several times from April to September. Flower colours appearing in a single month cannot be considered as good indicators, the best of them (flower colours in May) presenting a very poor RAE. Finally a combination of genera and flower colours in June is comparable (CD and RAE) to genera, the number of genera to be determined just decreasing from 43 to 41.
Recognition of key species appears to be a powerful method to predict plant richness, but this indicator requires a specialized knowledge as some species selected by the methodology belong to the same genera (i.e. *Carex* or *Astragalus*) or are not common (i.e. *Coincya cheiranthos* subsp. *montana* (DC.) Greuter and Burdet or *Dryopteris carthusiana* (Vill.) H.P. Fuchs). Genera are more easily recognized by non botanists, and the indicator considering 43 genera (Table 2) appears the best compromise between feasibility and accuracy.

Table 2. List of 43 genera in the best fit model predicting plant richness of grasslands

Achillea - Agrostis - Ajuga - Anthoxanthum - Bellis - Brachypodium - Briza - Bromus - Carex - Carum - Centaurea - Cerastium - Cirsium - Colchicum - Crepis - Cynosurus - Daucus - Equisetum - Euphorbia - Festuca - Filipendula - Galium - Holcus - Koeleria - Lathyrus - Leucanthemum - Lotus - Luzula - Narcissus - Ononis - Ornithopus - Plantago - Primula - Prunella - Rhinanthus - Rumex - Senecio - Silaum - Stellaria - Succisa - Trisetum - Veronica - Vicia

Only considering the colours of flowers seems to be a very simple methodology. Nevertheless, our results showed that a good prediction required repeated observations over the growing season. A simplest observation (colours of grassland flowers in May) is unfortunately associated with a poor quality of prediction.

Conclusion

From a methodological point of view, the regression tree methodology is an efficient way to rapidly select qualitative potential indicators to predict quantitative values. The good correlations observed for the best models lead to the conclusion that a rapid and a reliable diagnosis of grassland biodiversity can be done from quite simple indicators (i.e. genera). Because of its simplicity, this assessment of biodiversity is time efficient, and can therefore be applied to control result-oriented agri-environmental scheme.

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How to classify permanent grasslands? Conclusions from a French national network

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Abstract

Since agronomists and ecologists began to study permanent grasslands, they have set various classifications to describe the variety of grasslands or to suggest clear interpretations of their functioning. First classifications due to phytosociologists described the structures of plant communities, and their relations with environment. Recent advances in plant ecology introduced typologies based on life plant traits. It is now clearly established that ecosystemic services provided by grasslands (i.e. grass production or Red List species protection) cannot be predicted by the same characteristics of vegetation. We aimed to compare these contrasting ways of classifying grasslands, estimating the redundancy of vegetation characteristics. Therefore, a national network of 178 grasslands was studied in 2009 with a common experimental protocol to determine the botanical composition. The main result is the low redundancy between taxonomical and functional (i.e. life traits) characteristics of vegetation, despite a dependence between these variables. Single-criterion based classifications must thus be avoided for the full prediction of grassland ecosystem services.

Keywords: Typology, grassland, taxonomy, functional classification, services

Introduction

Permanent grasslands occupy almost 40% of the land used in the EU. A huge variety of pedoclimatic and management conditions result in a wide variety of the types of vegetation. Agronomists and ecologists have described this diversity with various criteria: presence, frequency, dominance or abundance of species, sward biomass or height, forage quality, etc. More recently, progress in functional ecology has lead to measurement of plant life traits. On this basis, diverse classifications of permanent grassland have been established, depending on their initial purpose: describe, understand or predict. It is clearly stated that the agronomical and ecological services delivered by permanent grasslands greatly depend on the vegetation characteristics (De Bello *et al*., 2010). For example, forage yield is closely linked to criteria like grasses proportion and type, legumes proportion influence forage quality, and the maintenance of patrimonial and ordinary biodiversity rely on botanical composition. The aim of this work is to study the potential redundancy of some criteria involved in the classification of permanent grasslands. One key issue of this approach is to assess the need to perform a multicriteria *vs.* monocriteria study of grassland to predict agro-ecosystem services.

Materials and methods

A network of 178 French permanent grasslands was set in 2009, covering a broad climatic and edaphic gradient in France. It included most pedoclimatic areas from oceanic to alpine conditions and covered most of grassland types in France, excluding Mediterranean conditions. Altitudes of grassland range from sea level to 2000 meters. This environmental gradient was crossed with a management gradient, defined by a diversity of farm systems (dairy or meat cattle and sheep) and management practices (type and number of uses, type of animals and livestock density, type and amount of fertilization). Use of grasslands was divided into three categories: 44.38% only grazed, 12.36% only cut and 43.26% grazed and cut. The botanical composition was observed once during the spring 2009: full list of present species within an homogeneous station (1000 to 5000 m²), and visual estimation of species dominance in 8 quadrats (0.25 m²) randomly located in the station. Floristic relevés were managed with eflorasys (Plantureux *et al*., 2010), which was used to calculate the following 6 functional criteria (mean value for the grassland, weighted by species dominance): Leaf Dry Matter Content (LDMC), Specific Leaf Area (SLA), Leaf Life Span (LLS), Date of Inflorescence (DI), Number of Oligrotrophic species (NOS) (linked to ecological value) and the Proportion of Entomophily Species (PES) (linked to the pollination service). Two classifications of grasslands were set to determined taxonomic criteria, respectively based on Presence (PRE) and Dominance (DOM) of species. This was achieved with a Multiple Component Analysis (MCA) followed by an ascendant hierarchical classification, and a tree cut with a characterization of classes. To compare the criteria we made: i) a linear regression between the 6 functional characteristics, ii) a variance analysis between the 2 taxonomic characteristics (qualitative variable) and the 6 functional characteristics (quantitative variables), and iii) a chi² test between DOM and PRE.

Results and discussion

Main results for the links between vegetation characteristics are presented in Table 1. Most of the relations show a link between criteria, except for 2 criteria poorly linked to the others: the date of inflorescence and the proportion of entomophily species. Except for NOS with taxonomic criteria, the coefficients of determination are quite low, demonstrating that none of these criteria can be used to predict another one.

Table 1. Relations between vegetation taxonomic and functional characteristics of the French network of 178 permanent grasslands, Values indicate the coefficients of determination and are associated to statistical significances (ns, * = $P < 0.05$, ** = $P < 0.01$ or *** = $P < 0.001$)

	LDMC	SLA	LLS	DI	NOS	PES	DOM
Leaf Dry matter Content (LDMC)	.						
Specific Leaf Area (SLA)	0.33***	.					
Leaf Life Span (LLS)	0.42***	0.05**	.				
Date of inflorescence (DI)	ns	0.16***	ns	.			
Number of oligotrophic species (NOS)	0.26***	0.06***	0.18***	ns	.		
Proportion of entomophily species (PES)	ns	ns	ns	0.09***	0.02*	.	
Dominance of species (DOM)	0.41***	0.14*	0.41***	0.40***	0.51***	0.32***	.
Presence of species (PRE)	0.29**	0.19***	0.27***	0.45***	0.58***	0.31***	chi² = 516

Among functional criteria, LDMC is linked to SLA and LLS, as previously demonstrated by Ansquer *et al*. (2009). The relation between other functional criteria are either not statistically significant (i.e. LDMC and DI) or with a poor quality model explaining less than 30% of the variance. The relations between taxonomic criteria (DOM and PRE) and functional criteria are always significant (except for DOM and SLA). The same trend can be observed between DOM and PRE. Despite the value of the chi² test, the similarity between classifications of grasslands based on presence and dominance was weak.

All these relations mean that the criteria are not independent, but the conclusion of the redundancy of the criteria cannot be drawn. The example of LDMC will be used to demonstrate this statement. Figure 1a confirms the good link between LDMC and SLA, whereas Figure 1b indicates that the number of oligrotrophic species is not closely related to LDMC, despite a statistical significance in Table 1. Figures 1c and 1d show that even if some types of grassland (classified on presence or dominance) have higher or lower LDMC than other types, the variability within types can be as higher than the variability between types.

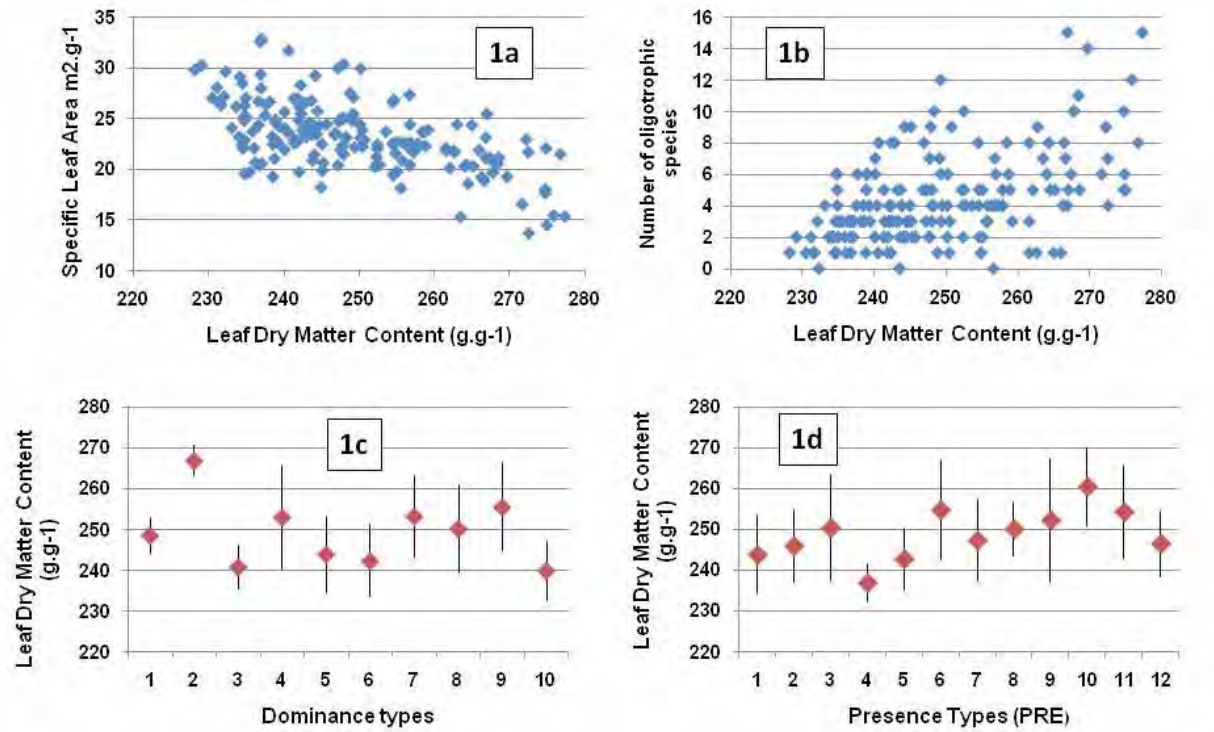

Figure 1. Relation between Leaf Dry Matter Content (mean life trait calculated at community level) and 4 criteria to classify permanent grasslands

Conclusion

The criteria used to classify grassland that we have tested are not redundant (except for LDMC *vs.* SLA and LLS), but at the same time are not fully independent. Taxonomical and functional characteristics are not redundant and each category of criteria provides specific information on sward features. Thus, to predict from vegetation characteristics the agronomical and ecological services provided by grasslands single criterion based classifications must be avoided.

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The impact of inorganic fertilizers on floristic composition of hay meadows in Cantabrian Mountains of Spain

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Abstract

A mountain meadow in the Montaña de León (Cantabrian Mountains, Spain) was divided into plots, each receiving a different NPK-fertilization treatment for 10 years (1978-88). The data obtained from the plots receiving binary (NP, NK and PK (n = 27)) and ternary (NPK (n = 27)) combinations and an unfertilized control plot were used in this paper. Some species richness parameters (number of species; Shannon-Wiener, evenness, and Simpson indices) and biomass production from each botanical species were calculated in the herbage harvested in June, both before starting fertilizer treatments and at the end of the experimental period. Botanical diversity indices decreased in plots that had been fertilized with NP and NPK combinations and, although the proportion of total biomass of each species was affected by fertilization, their effects only are discussed on the botanical composition and biomass of 'the most productive species' (80% of total dry matter forage production). *H. lanatus*, *L. perenne*, *D. glomerata*, *F. pratensis* and *A. elatius* made the most important contribution to forage biomass in all the treatments. However, presence of some other botanical species in the most productive species group was affected by fertilization. *R. acris* was incorporated into the group by NP and NPK treatments, *C. cristatus*, *P. lanceolata* and *A. odoratum* by NK and *C. cristatus*, *P. trivialis* and *T. repens* by PK.

Keywords: diversity parameters, long term fertilization

Introduction

Leon hay meadows cover an area of 23,500 ha and represent 18% of Spanish irrigated meadows. Most of them are located in the 'Montaña de Leon' region (Cantabrian Mountains). Forage produced on these meadows is fed to cows in the non-grazing (winter) feeding period, representing the main source of winter feed in beef cattle production systems of the region.

Although the use of mineral fertilizers has increased forage production in large areas of Europe, it has also caused species impoverishment. However, the effect of mineral fertilizers on floristic changes may be a slow process in irrigated meadows. Knowledge of botanical composition of forage is useful for managing feed resources at the livestock-farm scale (Duru *et al*., 2005). This study describes the effects of different NPK-fertilizer treatments on botanical composition of plots after ten years of annual fertilization.

Materials and methods

The study site is a permanent meadow of 3,600 m² located in Northwest Spain (Las Salas, 42°55'60N, 5°5'60W, León) at 1,010 m a.s.l. on a Gleyic Fluvisol. The mean annual precipitation is 1,200 mm, and the mean annual temperature is 9.1ºC. Before starting the experiment, floristic composition was determined. A total of 40 species (15 grasses, 4 legumes and 21 herbs) was recorded (García *et al*., 2011). The plant community belongs to the phyto-sociological group *Cynosurion cristatii* under the order *Arrhenatheretalia*, i.e. pastures and meadows on well-drained and relatively fertile mineral soils (Rodwell *et al*., 2000). In 1978, 64 plots each of 7×3.5 m were arranged in a 4^3 multifactorial design, combining four levels (kg ha^{-1} $year^{-1}$) of N (0, 60,120 and 180), P_2O_5 (0, 80, 160 and 240) and K_2O (0, 60, 120 and 180). For ten years, fertilizers were applied in a single dose at the end of the winter and two harvests (in late June and September) were conducted.The data used in this paper are from only 55 plots: those receiving binary (NP, NK and PK (n = 27)) and ternary (NPK (n = 27)) combinations and an unfertilized control plot. Mean herbage yield increased from 6,472 kg dry matter (DM) $year^{-1}$ (control plot) to 11,859 kg DM $year^{-1}$ in plots receiving NPK and 69-72% of DM was produced in the first cut (Rodríguez *et al*., 2003). In the last year of the experiment, during the first harvest, herbage samples (2 kg) were taken from the harvested material of each plot. The samples were separated into species to determine botanical composition. Diversity indices were derived from the botanical composition data to quantify the number of contributing species (species richness), contribution of each species to total biomass (% of dry matter; DM), Shannon-Wiener diversity index (H), Simpson diversity index (D), evenness of diversity (J´) and biomass (ln (% of DM) +1) of 'the most productive species' (80% of DM forage production; Vivier *et al*. (1971)). Data were analysed as a factorial design by ANOVA; differences between means were determined by LSD.

Results and discussion

Although all species that had been identified before starting the fertilization experiment were also registered in some of the experimental plots at the end of the experiment, floristic diversity was negatively affected by fertilizer treatment; all indexes significantly decreased ($P < 0.05$) with NP and NPK treatments compared to unfertilized control (Table 1).

Table 1. Diversity parameters after ten years of fertilization.

Fertilizer treatments	Nº	H	Hmax	J´	D	Dmax
Control	23^{a}	3.66^{a}	4.52^{a}	0.810^{a}	0.900^{a}	0.960^{a}
NP	17^{b}	2.85^{b}	4.10^{b}	0.693^{b}	0.787^{b}	0.941^{b}
NK	19^{b}	3.29^{ab}	4.23^{b}	0.777^{ab}	0.855^{ab}	0.946^{b}
PK	18^{b}	3.31^{ab}	4.17^{b}	0.793^{ab}	0.856^{ab}	0.942^{b}
NPK	17^{b}	2.85^{b}	4.04^{b}	0.705^{b}	0.803^{b}	0.938^{b}
P-value	*	*	*	*	*	*
sed	1.59	0.22	0.13	0.05	0.04	0.006

sed = standard errors of differences of means, * = $P < 0.05$, Nº = number of species, H = Shannon-Wiener index, J´ = eveness index, D = Simpson index.

Table 2. Biomass [ln (% of DM) +1] of the species affected by fertilizer treatments ($P < 0.05$).

	Control	NP	NK	PK	NPK	sed
Anthoxanthum odoratum	2.7^{ab}	1.5^{ab}	4.1^{a}	1.4^{ab}	1.0^{b}	1.1
Arrhenatherum elatius	0.01^{b}	5.0^{a}	6.9^{a}	6.9^{a}	9.0^{a}	1.3
Cynosurus cristatus	13.8^{a}	2.0^{b}	9.9^{a}	6.8^{a}	1.4^{b}	0.5
Poa trivialis	2.8^{ab}	3.0^{ab}	1.0^{b}	5.5^{a}	2.6^{ab}	0.4
Medicago lupulina	0.1^{a}	0.0^{b}	0.0^{b}	0.0^{b}	0.01^{b}	0.03
Trifolium pratense	10.8^{a}	0.3^{b}	1.6^{b}	2.0^{b}	1.2^{b}	0.5
Trifolium repens	2.6^{ab}	0.8^{b}	1.7^{b}	7.0^{a}	1.7^{b}	0.5
Bellis perennis	0.6^{a}	0.02^{b}	0.1^{b}	0.07^{b}	0.01^{b}	0.1
Carum carvi	2.5^{a}	0.1^{b}	2.4^{ab}	0.4^{b}	1.0^{ab}	0.5
Centaurea nigra	1.6^{a}	0.0^{b}	0.01^{b}	0.01^{b}	0.0^{b}	0.01
Crepis capillaris	1.1^{a}	0.0^{b}	0.0^{b}	0.0^{b}	0.0^{b}	0.00
Plantago lanceolata	14.0^{a}	1.4^{b}	7.1^{a}	2.0^{b}	0.8^{b}	0.4

sed = standard errors of differences of means

Table 2 shows the biomass of those species that were significantly affected ($P < 0.05$) by fertilizer treatments. In comparison with the unfertilized treatment, application of any fertilizer increased *A. elatius* biomass. In contrast, *M. lupulina*, *T. pratense*, *B. perennis*, *C. nigra* and *P. lanceolata* were negatively affected by any fertilization treatment. For the other species, the effect of fertilization depends on the type of fertilizer applied. Thus, *C. cristatus* increased with potasium in binary combination (NK and PK) whereas it decreased with fertilizer combinations that included nitrogen and phosphorus (NP and NPK). *P. trivialis* and *T. repens* increased with PK treatment, which could be attributable to the effect of P (García *et al*., 2011); on the other hand, *P. trivialis*, negatively affected by N and K when dosed alone (García *et al*., 2011), also decreased with NK fertilization.

Abundance of species depends on grassland management and fertilization is a critical factor (Duru *et al*., 2005). Table 3 shows 'the most productive group of species' which represented 80% of total forage production. The most abundant species (*D. glomerata*, *F. pratensis*, *H. lanatus* and *L. perenne*) are present in all the tested treatments. All of the fertilized plots also included *A. elatius*, whereas *T. pratense*, although present in all the tested treatments (Table 2), was excluded by fertilization from the most productive group (Table 3). *R. acris* was incorporated by NP treatment; *C. cristatus*, *P. lanceolata* and *A. odoratum* by NK; *C. cristatus*, *P. trivialis* and *T. repens* by PK and *R. crispus* and *R. acris* by NPK.

Table 3. Prop. of forage dry matter (%) of the most productive species at the end of experiment.

Control	%	NP	%	NK	%	PK	%	NPK	%
D. glomerata	16.1	*H. lanatus*	32.8	*H. lanatus*	24.8	*H. lanatus*	22.1	*H. lanatus*	28.7
P. lanceolata	14.0	*L. perenne*	17.4	*D. glomerata*	13.6	*D. glomerata*	11.1	*D. glomerata*	15.9
C. cristatus	13.8	*D. glomerata*	10.8	*C. cristatus*	9.9	*L. perenne*	10.3	*L. perenne*	11.2
H. lanatus	13.6	*F. pratensis*	8.2	*P. lanceolata*	7.1	*F. pratensis*	9.6	*A. elatius*	9.0
T. pratense	10.8	*A. elatius*	5.0	*A. elatius*	6.9	*T. repens*	7.0	*F. pratensis*	8.0
F. pratensis	3.8	*R. acris*	4.8	*F. pratensis*	6.7	*A. elatius*	6.9	*R. crispus*	4.4
R. crispus	3.7			*L. perenne*	6.1	*C. cristatus*	6.8	*R. acris*	4.3
L. perenne	3.0			*A. odoratum*	4.1	*P. trivialis*	5.5		
P. trivialis	2.8								

Conclusions

Fertilization decreased diversity, especially with NP and NPK combinations, whereas the effect of PK fertilizer was less negative for diversity and allowed an acceptable proportion of legumes. Floristic composition varied between fertilizer treatments, but *D. glomerata*, *F. pratensis*, *H. lanatus* and *L. perenne* showed the most important contributions to forage biomass in all the treatments.

Acknowledgments

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